UNIVERSITY OF ALBERTA

UTILIZATION OF BARLEY β-GLUCAN IN DAIRY PRODUCTS

by

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Abstract

Beta-glucan is a soluble fiber component of barley grains that has been clinically shown to confer a number of health benefits. The present study investigated the potential of concentrated beta-glucan for incorporation into dairy food products. The effects of purified beta-glucan on the growth of yogurt starter cultures was initially investigated using a model yogurt system. The pH measurements indicated no effect on the growth, but viscosity measurements suggested that beta-glucan was depolymerized by starter cultures when lactose became a limiting nutrient during fermentation. Yogurt and ice cream were then formulated by incorporating beta-glucan at 0.375 and 0.75 g/serving and evaluated subjectively and objectively in relation to appropriate controls. The data indicated that incorporation of beta-glucan primarily influenced the textural attributes of dairy products. The study concluded that dairy products can be successfully formulated using a moderate level of beta-glucan

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Chapter 1
INTRODUCTION AND THESIS OBJECTIVES

The world production of barley grain was 141 million metric tonnes in 2003, and of this total Canada produced 8.7% while the United States produced 4.2% (FAOSTAT 2004). Alberta is the largest producer of barley in Canada with the bulk of this cereal crop going to animal feed or malting and brewing purposes, relatively lower-value uses. It is estimated that only 5% of all barley produced in Canada is used for human consumption (Bhatty 1986). Increased utilization of barley components in a variety of food products will add greater value to this crop and has the potential to enhance economic benefits to producers, processors, and retailers especially in Alberta, where approximately 50% of the Canadian total is being produced.

β-Glucan, a soluble dietary fiber component, is found in the greatest amounts in the endosperm cell walls of barley. β-Glucan has many functional properties that can aid in the formulation of food products. It is a hydrocolloid (binds water) with high aqueous viscosity, acts as a thickener, has gelation properties, is a stabilizer (prevention of settling, phase separation in emulsions, and foam collapse), prevents the formation of large ice crystals, which results in decreased syneresis, and in general, provides an improvement in organoleptic properties of various food products. As well, from a sensory perspective, it may potentially be a fat mimetic under proper conditions.

With the incidence of cardiovascular disease (CVD) rising and the "on the go" lifestyle increasing, it seems there is much room for improvement of one's health. The ability of soluble fiber from barley and oats, namely β-glucan, to decrease the risk of CVD by lowering cholesterol levels with healthy food choices and a diet high in fiber and low in fat has been scientifically proven. In addition to this, β-glucan has also been linked to improving blood glucose regulation and increased satiety (Howarth and others 2001; Yao and Roberts 2001).

The U.S. Food and Drug Administration (FDA) has allowed for a health claim to be placed on products made from oats that contain at least 0.75 g of soluble dietary fiber per serving. Since it is recognized that it is the soluble fiber component, β-glucan, which is responsible for the health benefits, it is postulated that β-glucan from other sources such as barley will also affect blood lipid levels in a similar manner. Based on mounting scientific evidence demonstrating the positive health effects of barley β-glucan, FDA is currently evaluating a petition to approve a similar health claim for barley β-glucan.

According to Alberta Milk, a non-profit organization, the dairy industry in Alberta contributed CDN$385 million in farm cash receipts in 2003. However, the dairy industry is currently showing little to no growth in the consumption of regular milk but the trend of innovative flavors and functional ingredients is resulting in rapid growth in other dairy segments. Yogurt consumption is on the rise as it is deemed a healthy choice and the beneficial effects of probiotics for health are being studied and advertised to the general public. Ice cream and frozen desserts are staple treats in the North American diets. Public attention has currently shifted from eating low- or non-fat products to products lower in fat. These products contribute lower amounts of fat to the diet but have comparable flavor and textural attributes to regular fat products.

As indicated above, the functionality of β-glucan is so broad that there are many products it could be added to, but the beneficial effect it exerts on human health is what makes it so attractive to the industry and consumers alike. Understanding of the influence of β-glucan addition on food texture and flavor as studied by trained and consumer panels as well as with instrumental methods will facilitate the successful use of this nutraceutical component in various food products, especially the dairy products targeted in this study since the literature lacks information on the use of β-glucan in dairy products. Therefore, the main objectives of this thesis were:

1) to determine the effect of high viscosity β-glucan gum on the ability of yogurt starter cultures to ferment and to determine whether or not bacteria from yogurt starter cultures can hydrolyze β-glucan polymers (Chapter 3);
2) to develop a yogurt product with β-glucan incorporation and characterize and evaluate the effects of β-glucan addition on color, flavor, and texture using instrumental and sensory techniques (Chapter 4); and
3) to develop a low-fat ice cream product with β-glucan incorporation and characterize and evaluate its effects on color, flavor, and texture using instrumental and sensory techniques (Chapter 5).

Chapter 2
LITERATURE REVIEW

2.1. BARLEY

The history of cultivated barley, *Hordeum vulgare*, spans centuries. It appears that this cereal crop was originally cultivated and domesticated as early as 8000 B.C. in the Middle East encompassing areas such as Lebanon, Iraq, and Turkey and was present at least 17,000 years ago near the Nile River (Wendorf and others 1979; Bothmer and Jacobsen 1985). Barley has since spread worldwide and is a source of nutrition for humans and animals alike. The use of barley was widespread and dominant as it is a hardy crop well adapted to growth in a wide range of environments (Nilan and Ullrich 1993). During the industrial age in the 19th century, improvements in harvesting, storage and processing conditions made the more desirable white flour, obtained from wheat, a more attractive commodity as it was now convenient, affordable, and available to the general population. Currently, the majority of the barley produced is used as animal feed for domesticated livestock and in the malting and brewing industry. There is only minimal usage in food production (e.g. pot and pearled barley grains for soups). Cultivated barley is a hardy crop grown worldwide. Its drought resistance, cold tolerance, and relatively short growing season make it an attractive crop to grow in temperate climates, such as in Canada (Nilan and Ullrich 1993). Increased interest has been generated for this ancient crop as studies are evaluating the health benefits of certain components, such as β-glucan and tocols that are found in elevated levels in barley. This interest is generating greater demand and the food industry will likely be one of the first to respond with increased application in novel products.

2.1.1. Production

According to the Food and Agriculture Organization (FAO) of the United Nations, world production of barley in 2003 was 141.5 million Mt (Table 2.1). Canada's barley production was only second to that of the Russian Federation (18 million Mt) with Canada contributing 8.71% (12.3 million Mt) of the world's supply in 2003 (FAOSTAT

Table 2.1. World barley production and top 6 producers in 2002-2003[1]

	Barley Production (Mt)	
	2002	2003
World	136,492,624	141,503,090
Russian Federation	18,738,890	17,967,900
Canada	7,489,400	12,327,600
Germany	10,927,970	10,665,700
France	10,987,714	9,818,000
Australia	3,713,000	8,525,000
United States of America	4,933,040	6,011,080

[1]Compiled from FAOSTAT 2004

2004). In contrast, the United States produced 6.0 million Mt. The prairie provinces of Canada produced a total of 12.1 million tonnes of barley for the 2004 growing season (Alberta, 5.8 million Mt; Saskatchewan, 4.8 million Mt; and Manitoba, 1.4 million Mt) (Statistics Canada 2004). Barley is currently the third largest cereal crop grown in Alberta with approximately half of all of the nation's production of this valuable crop coming from Alberta.

2.1.2. Composition

The composition of the barley grain can be affected by the location, climate, agronomic practices, and the variety of cultivar grown but the grain generally consists of starch, protein, lipid, fiber, and minerals. These components are found in varying degrees (Table 2.2) within the barley grain structure (Figure 2.1). The carbohydrate and protein fractions are generally found in the starchy endosperm; lipid component is found in the bran (aleurone) and embryo; and the fiber components, such as cellulose and β-glucan, are found in the bran and in the cell walls of the endosperm, respectively.

The rich composition of carbohydrates and proteins are what make barley an attractive feed crop to cattle, hog, and poultry producers. The high level of starch (63-65%) provides a readily available and highly digestible source of energy. Approximately 8-15% of the barley grain is made up of proteins, which can all be utilized by the developing seedling; these proteins are generally separated into two groups. These are the storage proteins, prolamines (hordeins) and glutelins, and the non-storage proteins, albumins and globulins, which serve as structural and metabolic proteins (Shewry 1996). From a nutritional standpoint, barley proteins are generally deficient in the essential amino acids of lysine and threonine, which has led to the breeding of high-lysine varieties.

The lipid fraction contains tocopherols and tocotrienols while the fiber components include soluble and insoluble fibers, the most notable soluble fiber component being β-glucan. There are many desirable and commercially valuable components in the barley grain, which make it so popular with feedlot operators and new health findings and methods of extraction make this grain highly appealing to those in the animal and food industries.

Table 2.2. Chemical composition of barley grain[1]

Component		Amount (%, w/w dry weight basis)
Carbohydrates		78-83
	Starch	63-65
	Sucrose	1-2
	Other sugars	1
	Water-soluble polysaccharides	1-1.5
	Alkali-soluble polysaccharides	8-10
	Cellulose	4-5
Lipid		2-3
Protein		10-12
	Albumins and globulins	3.5
	Hordeins	3-4
	Glutelins	3-4
Nucleic acids		0.2-0.3
Minerals		2
Other		5-6

[1] Adapted from MacGregor and Fincher (1993)

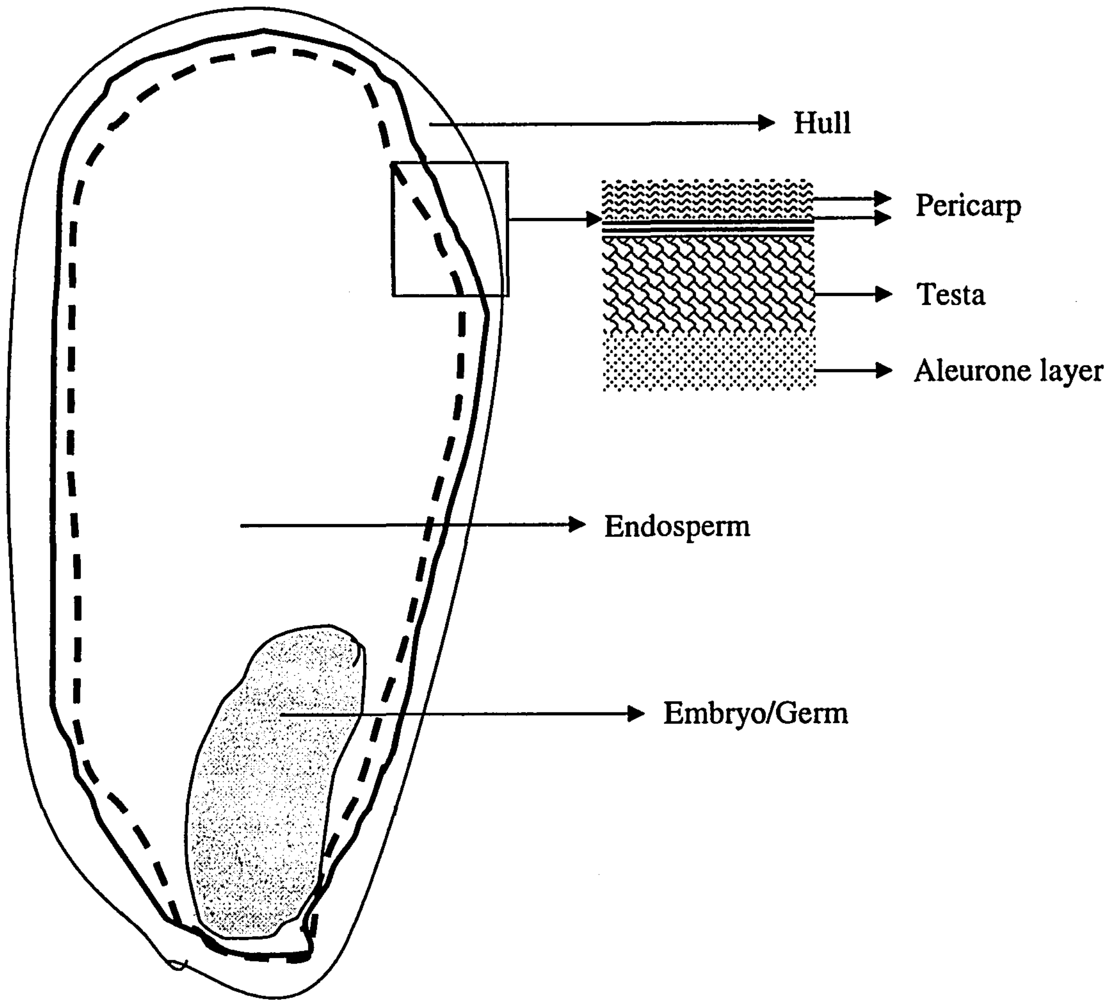

Figure 2.1. Diagram representing a longitudinal section of a barley grain

2.1.3. Utilization

Currently, the main use of barley grains is for animal feed (85%) or for malting and brewing purposes (10%) (Bhatty 1986; Bamforth and Barclay 1993). The use of barley as cattle, hog, and poultry feed remains a popular choice for the farmers due its relatively lower cost and ability to grow in climates not tolerable by other feed crops; and due to its high carbohydrate and protein contents. The malting industry primarily utilizes barley for the production of malt (steeped and germinated grain that has been kiln dried) for use in the brewing and distillation of beer or spirits (Bamforth and Barclay 1993). Malt is also utilized as a color and flavor enhancer in a variety of food formulations (Bamforth and Barclay 1993).

Very little barley is used for human consumption in developed countries; only 5% of barley produced in Canada is utilized for human consumption (Bhatty 1986, 1993b). Pearled and pot barley is widely used in soups and stews and flour has been utilized successfully in a variety of extruded products (Berglund and others 1994) and bakery products such as breads, muffins, cookies, and biscuits (Chaudhary and Weber 1990; Bergland and others 1992; Hudson and others 1992; Knuckles and others 1997; Klamczynski and Czuchajowska 1999). However, there is growing awareness of the potential benefits of using barley or barley components in human food products. The many healthful components found in barley, including tocols (vitamin E) and dietary fiber (insoluble and soluble) are being used in novel ways.

2.2. β-GLUCAN

Mixed linkage (1→3), (1→4)-β-D-glucan (β-glucan) is a soluble dietary fiber that is found in the cell walls of cereal grains with the largest quantities found in oats and barley at 2.5-6.6% and 2-10%, respectively (Lee and others 1997). The majority of β-glucan (BG) is found in the cell walls of the endosperm of the grain and is found uniformly distributed throughout the endosperm of barley. Oat β-glucan is mainly found in the cell walls of the aleurone layer. β-Glucan comprises 26% of the weight of the cell walls with the remainder of the wall composed of mainly arabinoxylan (76%), cellulose (2%), glucomannans (2%), and (1→3)-β-glucan (1%) (MacGregor and Fincher 1993).

The increased levels of β-glucan may have evolved in order to increase the ability of barley to survive stressful conditions (e.g. mild moisture stress and cold weather) as it has been postulated that it may provide protection from dehydration of tissues via its water-binding or gelation capability as well as imparting cold hardiness by impeding ice crystal growth (MacGregor and Fincher 1993).

There has been considerable interest in using β-glucan in food products as functional properties become well established and defined; nutritional and health benefits, including scientifically proven claims such as a reduction in cholesterol levels, become widely known and accepted by the general public; and as extraction methods become more cost effective and efficient. Companies such as Cevena Bioproducts Inc. (Edmonton, AB) and Cargill Inc. (Minneapolis, MN) currently have concentrated products and are promoting the use of β-glucan's in the food industry.

2.2.1. Occurrence

β-Glucan occurs in the cell walls of a variety of grains but is in greatest abundance in oats and barley. The β-glucan content can range from 2-11% in barley (Bhatty 1993a) and 2.2-4.2% in oats (Åman and Graham 1987). β-Glucan levels can also change with respect to location, climate, agronomic practices, and cultivar. Waxy hull-less barley cultivars, such as Wanubet or Prowashunupana, are found to consistently have higher levels of total β-glucan content (mean β-glucan level 6.9%) as compared to normal barley cultivars (4.8%) (Ullrich and others 1986). These varieties of grain are generally preferred when concentrating or isolating β-glucan in order to obtain the highest level of yield.

2.2.2. Structure

The structure of cereal β-glucans (BG) is of linear homopolysaccharides, which are composed of β-glycosyl residues linked by a mixture of β-(1→3) and β-(1→4) linkages (Figure 2.2). The (1→4)-β-linked glucose units (primarily cellotriosyl and cellotetraosyl) are separated by the β-(1→3) linkages. Linear (1→3) linkages occur singly and (1→4) are generally in sequences of 2 or 3 but sequences of 1 to 10 β-glycosyl

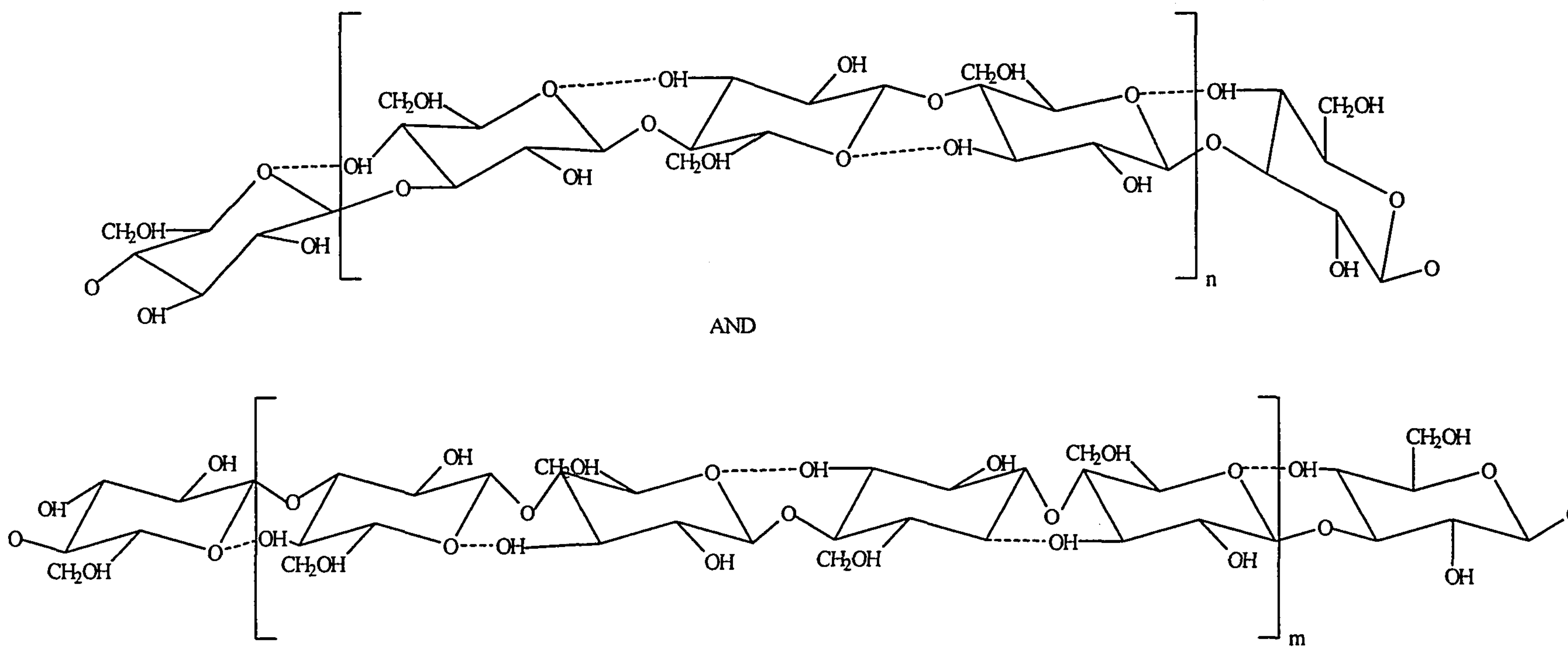

Figure 2.2. Cellotriosyl and cellotetraosyl units of β-glucan structure. Adapted from Wood (1984).

units have been reported in cereal β-glucans (Skendi and others 2003; Cui and others 2000). It is these β-(1→3) linkages that give β-glucan its solubility while remaining undigestable as the β-linkages cannot be hydrolyzed by the enzymes in the human digestive system. The β-(1→3) linkages allow for a "kink" in the structure thereby preventing β-glucan strands from completely packing into a totally insoluble form. As a result, water molecules are able to interact with β-glucan and form hydrogen bonds with the hydroxyl groups found extending from glucose subunits (MacGregor and Fincher 1993). A simplified depiction of the molecule presented in Figure 2.3 shows how the structure of β-glucan is formed by (1→3) and (1→4) linkages of β-glycosyl residues into cellotriosyl and cellotetraosyl units.

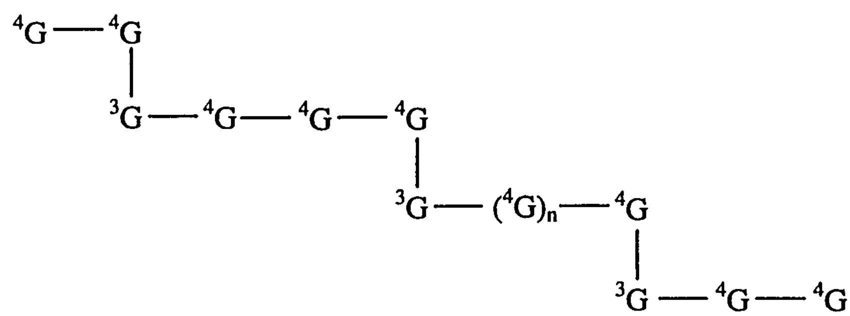

Figure 2.3. Simplified schematic of β-(1→3),(1→4)-D-glucan structure

2.2.3. Extraction

Barley and oat grains are rich sources of β-glucan with this important component occurring in the cell wall of the endosperm cells. The extraction and purification of these compounds is an area of great interest as the value of this nutraceutical product depends on extraction procedures that will optimize the yield, purity, and functional properties of β-glucan.

Extraction protocols of β-glucan include dry and wet techniques. Dry techniques include the physical separation by dry milling and sieving or air classification (Knuckles and others 1992; Sunberg and Aman 1994; Wu and others 1994). Physical separation by sieving generally produces a product of lower purity (approximately 7-8%) as it utilizes the differences in shape and size in order to separate the particles. Air classification can be optimized by adjusting parameters such as flour feed rate and the air flow rate in order to obtain products with approximately 20-22% purity. Although dry techniques are lower in cost, the low level of β-glucan in the concentrates obtained by dry separation techniques can result in challenges in the food formulation process.

The wet technique (solvent extraction) generally consists of 3 steps including: the inactivation of endogenous enzymes, extraction of the β-glucans, and precipitation of β-glucan (Brennan and Cleary 2005). Within these generalized steps is included the solubilization of β-glucan in water or aqueous alkali. Centrifugation is then utilized to separate solids from the aqueous β-glucan extract and proteins are precipitated (acid and/or heat precipitation) and removed via centrifugation. Finally, β-glucan is precipitated by alcohol and dried. The conditions of the extraction procedure are also important as it has been demonstrated that the type of enzymes used (thermostable α-amylase), increased temperature, pH conditions, and time of ethanol refluxing are important in yielding a product of high purity, stability and yield (Temelli 1997; Burkus and Temelli 1998; Symons and Brennan 2004). Solvent extraction can significantly increase the concentration of this valuable dietary fiber, in some cases up to 70%, thereby increasing the feasibility of β-glucan incorporation into food products. However, one disadvantage is the resultant shear fragmentation of the hydrated β-glucan molecule during centrifugation and mixing. Another drawback of the solvent extraction technique is its high cost of processing due to the use of large amounts of water and ethanol and the need for drying.

Highly purified β-glucan (>50% w/w purity) is generally not utilized in the food industry due to the enormous costs involved in producing a product of high purity; however, new techniques that allow for large-scale production at a lower cost are making it feasible to include β-glucan in products that have mass appeal.

2.2.4. Functionality

The potential uses of β-glucan are endless due to the variety of functional properties that it possesses. The β-glucan molecule is neutral and non-ionic and stable at a wide pH range (Dawkins and Nnanna 1995) and is also water soluble. Therefore, it does not impart an undesirable or unacceptable mouth feel such as grittiness or dryness as insoluble fibers often do. In fact, β-glucan aids in creating a smooth mouth feel, moistness and cohesiveness in food products. Morin and others (2002) produced low-fat breakfast sausage with β-glucan and found that a 0.3% (w/w) addition resulted in a similar degree of liking as the regular fat products. Sensory attributes are also affected by the addition of β-glucan. Lyly and others (2003) researched the effects of low- and high-molecular weight β-glucan in beverages and found a moderate correlation between perceived thickness and sliminess with instrumental viscosity. The addition of high-molecular weight product resulted in greater viscosity and perceived thickness.

Food products can benefit from the addition of β-glucan as it can impart many desirable functional traits. One of its main functions is as a viscosity enhancer. Viscosity is the measure of internal friction resulting from resistance to flow between adjacent layers of fluid. Viscosity can be related to organoleptic properties and acceptability of a food product (Glicksman 1982). In general, the viscosity of a hydrocolloid decreases as temperature increases and increases as temperatures decreases (Glicksman 1982). Studies on oat and barley β-glucan viscosity show that β-glucan responds in a similar manner (Dawkins and Nnanna 1995; Burkus and Temelli 2005). Shear-thinning or pseudoplasticity, a decrease in viscosity with an increase in rate of shear, is also a characteristic that is exhibited by high-viscosity β-glucan at concentration levels as low as 0.2% (Autio and others 1987).

β-Glucan also exhibits the ability to stabilize emulsions, primarily due to its high viscosity. Stabilization is necessary in a number of food products and allows for the prevention of settling, phase separation, and foam collapse. Temelli and others (2004a, b) formulated acceptable and stable orange flavored barley β-glucan beverages with or without whey protein isolate. They found no viscosity decrease over a 12 week storage period. However, there was some phase separation upon storage that was easily corrected by shaking.

2.2.5. Health effects and proposed mechanisms of β-glucan

The term dietary fiber was first coined in 1953 (Hipsley 1953) and since then, has been redefined a number of times by a number of individuals and agencies. In general, dietary fiber cannot be enzymatically digested and absorbed; therefore, it is considered to have low dietary energy density. The definition as determined by a scientific review committee of the American Association of Cereal Chemists (AACC) is as follows:

> "Dietary fiber is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fiber includes polysaccharides, oligosaccharides, lignin, and associated plant substances. Dietary fibers promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation." (AACC Report 2001)

As stated above, dietary fibers are not digestible by human enzymatic secretions and although there may be some fermentation by bacteria within the human gut, fiber remains intact. The physicochemical characteristics of soluble fibers such as β-glucan are believed to aid in the health benefits exhibited. Solubility of fibers resulting in attributes such as viscosity and gelling; binding properties; and potential for bacterial breakdown are believed to contribute to their beneficial health effects such as lowering blood cholesterol levels, glucose regulation and satiety. Satiety, which is "the state of inhibition over eating", may also be associated with the consumption of higher levels of fiber (Burley and Blundell 1990). This may be due to the ability of dietary fiber to alter gastric emptying rates, transit time within the gut, as well as hormonal influences on cholesystokinin. Cholesystokinin is a hormone, which stimulates pancreatic secretion of enzymes, the process of which eventually leads to slowing down of gastric emptying that has been hypothesized to reduce food intake.

2.2.5.1. Hypercholesterolemia

According to the Heart and Stroke Foundation of Canada and the American Stroke Association, the number one cause of hospitalization and 37% of all deaths in Canada in 2000 and 38% or 1 of every 2.6 deaths in the U.S. was due to cardiovascular disease (CVD). The economic impact of this disease in Canada was totaled at CDN$18.5 billion in 1998, greater than any other disease (Heart and Stroke Foundation 2003), while the U.S. estimated the direct and indirect cost to be $393.5 billion. (American Stroke Association 2005). CVD is the leading cause of death in both countries and it is estimated that 2005 will see 700,000 Americans suffering from new coronary attack and 500,000 suffering from a recurrent attack (American Stroke Association 2005). There are several factors that affect whether or not one will develop cardiovascular disease (CVD). Some factors are uncontrollable such as age, heredity and gender while others are controllable such as lifestyle (smoking, lack of physical activity, stress) and diet. For patients, oftentimes diet plays a significant part in controlling cholesterol levels but when these need to be further controlled, modern western medicine often turns to the use of drugs. However, a greater percentage of people with slightly elevated levels of cholesterol are now turning to diet and lifestyle changes in order to improve their health as the effect of dietary fiber is comparable to first-generation statin drugs (Anderson 2003; Jenkins and others 2002, 2005). It is this group of individuals that the addition of dietary fiber will likely benefit the most.

Health care practitioners encourage consumption of insoluble and soluble dietary fibers but it is the soluble fiber components, such as β-glucan, that have been proven to lower cholesterol levels in a variety of animal and human studies (McIntosh and Oakenfull 1990; McIntosh and others 1991; Lupton and others 1994; Wang and others 1997; Bourdon and others 1999; Rieckhoff and others 1999; Pomeroy and others 2001; Behall and others 2004; Jenkins and others 2005). There are a number of proposed mechanisms of action but none have been clearly identified as the reason for the observed hypocholesterolemic effect. Soluble fibers are thought to: increase viscosity within the lumen contents thereby decreasing the mobility of intestinal contents; decreasing the extent of the mixing of digesta (due to thickening) and inhibiting micelle formation that is necessary for nutrient absorption; and binding of bile acid resulting in increased bile acid excretion and decreasing availability of cholesterol in blood for lipoprotein synthetic pathways (Anderson 1995; Gallaher and Hassel 1995). In addition, short chain fatty acids (SCFA) such as propionic acid are produced by bacterial fermentation in the colon of soluble fibers. These SCFA's may lower cholesterol levels by reducing the production of HMG-CoA reductase, an enzyme required by the liver for cholesterol production (Anderson 1995).

Braaten and others (1994) performed a randomized crossover study with 19 mildly hypercholesterolemic patients instructed to consume a packet containing either 2.9

g of β-glucan agglomerated with maltodextrin or maltodextrin alone as a control twice a day for 4 weeks. This fiber packet was to be consumed with liquids with the 2 main meals for the day. The patients were also asked to record a three day diet diary and were monitored for weight changes. There was a 10% reduction in low density lipoproteins (LDL) at the end of the 4 week period for this test group. Behall and others (1997, 2003, 2004) also did extensive studies on the effect of β-glucan on blood lipids and found a decrease in total and LDL cholesterol in mildly hypercholesterolemic individuals. They reported in 1997 that the addition of oat β-glucan in low (2.1 g soluble BG/day) and high (8.7 g soluble BG/day) amounts in a randomized, crossover design resulted in significant differences in total and LDL cholesterol ($p<0.001$) in both the high- and low-BG diets as opposed to the maintenance diets but there was no significant difference between the high- and low-β-glucan diets. Behall and others (2003) researched the effect of barley β-glucan and its effect on blood cholesterol levels of moderately hypercholesterolemic men in a 5 week study at a dosage level of <0.4 g (diet 1), 3 g (diet 2) and 6 g (diet 3) added soluble fiber/2800 kcal in the form of brown rice/whole wheat, 1/2 barley and 1/2 brown rice/whole wheat or barley, respectively. Again, results indicated that compared to the study controls, LDL (17%, 17%, and 20%, respectively) and total cholesterol (14%, 17%, and 20%, respectively) decreased significantly ($p<0.0001$) for the diets from low- to high-solubility fiber. High density lipoprotein (HDL) cholesterol was again significantly higher ($p>0.001$) for all test diets. The reduction in LDL and total cholesterol of the patients consuming the high-soluble fiber diet was significantly greater than that in the other two experimental diets. Another study by Behall and others (2004) found that there is a significant decrease in total cholesterol of mildly cholesterolemic men and women when the diet included 3 or 6 g of β-glucan from barley as compared to the control which contained no β-glucan. This trend was more prominent in men and postmenopausal women.

It is believed that a combination of factors result in the decrease of cholesterol levels but it is hypothesized that the increased excretion of bile acids, increased LDL catabolism and reduced absorption of fat contribute to these positive effects (Mälkki and Virtanen 2001). Some of these effects are also attributed to the viscosity of the intestinal contents as increased viscosity can delay gastric emptying, nutrient absorption, and interfere with micelle formation (Mälkki and Virtanen 2001). The production of short chain fatty acids by the fermentation of the soluble fibers in the colon are also thought to be associated with inhibited cholesterol synthesis (Anderson and others 2002).

2.2.5.2. Glucose regulation

As previously stated, β-glucan is a soluble dietary fiber and as such, adds viscosity to a product once solubilized. The addition of soluble dietary fiber (and subsequent removal of more energy rich ingredients) decreases the caloric load as all fibers have low dietary energy density, that is available energy for metabolic processes per unit weight or volume of food (Yao and Roberts 2001) and affects insulin resistance by decreasing the glycemic response (postprandial blood sugars). This is possible as the highly viscous nature of β-glucan slows the transit time of digested materials, slows absorption rates, lowers blood concentrations of nutrients and alters hormonal responses to the absorbed nutrients causing a decrease in available energy (Wood and others 1994; Yokoyama and others 1997)

Wood and others (1994) and Wood (1994) reported that β-glucan addition from oat bran reduced the blood glucose peak proportionally to the viscosity of the oat β-glucan in healthy human subjects after an oral glucose load. Patients with non-insulin dependant diabetes mellitus (NIDDM) may benefit from taking high-levels of β-glucan as studies performed at the University of Alberta by Hawrysh and others (1995) showed that the effects of long term incorporation of barley β-glucan into bread products at approximately 5 g β-glucan/day for 24 weeks resulted in an improvement in glycemic, lipid and insulin responses. Some individuals in the study experienced extensive reductions, where a reduction in their dosage of oral hypoglycemic medication was required (Hawrysh and others 1995). Cavallero and others (2002) tested postprandial glucose response of eight non-diabetic subjects. These subjects were fed 50 g of available carbohydrate of bread containing 100% wheat flour, 50% barley flour, 50% barley flour and 50% β-glucan enriched sieved fractions, and 80% wheat flour and 20% water-extracted β-glucan enriched fraction. Results indicate that with increasing β-glucan content there was a linear decrease in glycemic index with an observed drop in glycemic index of 28% of the bread containing water-extracted β-glucan. In addition, researchers tested the sensory characteristics of the bread and panelists rated the water-extracted β-glucan bread as similar ($p>0.05$) to the control.

2.2.5.3. Weight loss and satiety

Obesity is attributed to increasing the risk of a number of health issues including coronary heart disease, type 2 diabetes, some cancers, and osteoarthritis. It is estimated that over 30% of U.S. adults 20 years of age and older are obese (National Centre for Health Statistics 2004). Even still more significant is the rate of increase, from 11% to 16% of the population, at which children and adolescents are becoming overweight, hence bearing a greater risk of becoming overweight adults. Weight loss would greatly benefit these populations therefore, studies on satiety are important.

Satiety, which is "the state of inhibition over eating", may be associated with the consumption of higher levels of fiber (Burley and Blundell 1990). Fiber is thought to increase satiety in a number of ways including: greater mastication resulting in greater effort and time to ingest food; gastric distention due to additional production of saliva and acid; increased water absorption; increased transit time within the gut; decreased rate of nutrient absorption; and increased gastrointestinal hormone secretion (Howarth and others 2001; Yao and Roberts 2001).

In theory, this decrease in the feeling of hunger resulting in longer periods of satiety can lead to a decrease in energy intake, potentially helping individuals control their weight. This was difficult to study in the past as methodology was varied and often unbalanced in study designs, there were often no controls or placebos, and knowledge of types and dosages of fiber was lacking. Rössner and others (1985) found that their controlled study did not result in any statistically significant effects but they postulated that this was due to the dosage of dietary fiber being too low (270 mg per tablet, 3 times daily for 6 months). Burley and Blundell (1990) also suggested that fiber-supplemented foods produce more consistent effects on hunger and satiety versus fiber isolates. Stevens and others (1987) monitored 12 overweight women who consumed 12 crackers per day for 2-week periods including a low fiber control and crackers containing variable amounts of fiber from wheat bran, psyllium gum, or a mixture of wheat bran and psyllium gum. Results of this study indicated that the crackers enriched with psyllium resulted in the greatest decrease in energy intake at 11%, an intermediate effect of the mixture, and no effect from the wheat bran. It was proposed that the soluble fiber increased the satiety due to hydration and swelling of the fiber resulting in increased viscosity of intestinal contents and a probable decrease in gastric emptying rates and transit time. Ludwig and others (1999) performed a multicenter population-based cohort study with 2909 healthy adults. They stated that increased levels of fiber consumption resulted in less weight gain for people over a 10-year period regardless of their level of fat intake. Additionally, an inverse association was made with fiber and a change in waist-to-hip ratio, but not with dietary fat. It was determined that decreased weight gain and reduced risk of obesity can be associated with increased fiber intake even after accounting statistically for the potentially confounding influence of dietary fat intake.

2.3. DAIRY PRODUCTS

Dairy products comprise a large portion of the average North American diet; therefore, it is by no surprise that in 2004, the retail value of dairy products for Canada and the U.S. was CDN$7.733 billion and US$50.655 billion, respectively (Euromonitor 2004). Although dairy products do contain saturated fats, which potentially contribute to increased cholesterol, they still play a vital role in the maintenance of human health. It is for that reason it is included in the healthy eating guide as one of the 4 essential food groups, which also includes: meat and meat alternatives, cereal and grain products, and fruits and vegetables. In general, fiber is absent from dairy products and any level of fiber incorporation into this broad category would further benefit healthy eating. The inclusion of insoluble or soluble fibers into dairy products would expand this market greatly as well as provide an additional source of fiber for the general population who fall well below the recommended daily intake of 25-30 g/day. Currently, the average level of fiber intake is 15.6 g/day (National Health and Nutrition Examination Survey (NHANES III) 1988-1994).

The health benefits of fiber and dairy products have been established but the effects of addition of fibers like β-glucan into dairy products and its impact on sensory parameters warrants further research.

2.3.1. Yogurt

Yogurt is a low-acid, fermented milk product with an approximate composition of 84-86% water and 14-16% total solids. Yogurt is low in lactose and high in bioavailable calcium thereby making it a desirable product for those who wish to increase calcium intake but may be limited due to lactose intolerance (Tamine and Robinson 1985; Ward and others 1999). There are a variety of yogurt and yogurt-like products ranging in flavor (strawberry, vanilla, to even prune) and consistency (set, stirred, drinkable, mousse, frozen) available in the market. The use of yogurt in the preparation of sweet and savory products also appeals to populations worldwide. Even spelling can be varied as it can also be spelled as yogourt, yoghurt, or as yogurt. The raw materials and product formulation do not generally change but the final product can be affected by the fortification of milk solids, thermal treatment, type of bacterial cultures used for fermentation, incubation time and temperature, cooling of coagulum, as well as the packaging and chilling of the final product (Afonso and Maia 1999).

2.3.1.1. History of yogurt

Documentation of the consumption of fermented foods can be traced back to the Old Testament (Genesis 18:8) in which it was stated that "Abraham owed his longevity to the consumption of sour milk". The history of yogurt likely goes back to the time of early domestication of milk producing animals such as cows, goats, sheep, camels, etc. It quickly became necessary to achieve a method of preservation for fresh milk as this important commodity and source of nourishment would only be produced seasonally. It has been proposed that the origins of yogurt are based in the nomadic cultures of the Middle East who instinctively fermented milks by heating it over an open fire and then allowing for fermentation in animal skins (Tamine and Robinson 1985). Across the globe, most cultures have a version of a yogurt product such as jugurt as is found in Turkey, tiaourti in Greece and shosim as found in Nepal (Tamine and Robinson 1985).

The perceived health benefits of yogurt were acknowledged and documented by the Nobel Prize winning scientist Elie Metchnikoff in 1908. He suggested that the health and longevity of Bulgarian peasants could be attributed to the consumption of yogurt, which contained *Lactobacillus* strains of bacteria (Teitelbaum and Walker 2002). This healthful perception of yogurt has dominated the market and the consumption of yogurt has been expanding worldwide ever since. The addition of fruits and new combinations of flavors will further help in maintaining the strong presence that yogurt holds in the dairy industry.

2.3.1.2 Consumption, production, and market trends

Yogurt is a very popular product in North America, Europe, and Asia with an estimated consumption level of yogurt at 4.6 kg per capita in the U.S. and 5.3 kg per capita in Canada according to industry and national statistics for 2002 (Euromonitor 2004) . The retail value of yogurt for the world was US$32.2 billion in 2004. As shown in Table 2.3, the retail value in Canada, U.S. and the world has been steadily growing.

According to a report by Euromonitor (2004) on Health and Wellness: Food in Canada, dairy products including those that are fortified and functional will likely see an increase in consumer base as people become more aware of their health and actively seek to improve their diets. It is estimated that there will be a 5.5% growth in yogurt products, including organic, reduced fat, functional/fortified products, throughout the 2004-2009 period. This growth can be translated to an increase of retail sales from CDN$879.8 million in 2004 to $1,152 million in 2009. New labeling regulations established by Health Canada on Natural Health Products will help consumers find products that are well-prepared, safe, and effective. Regulations will also help manufacturers by providing a regulation that will add prominence and legitimacy to their products and will allow them to further emphasize the health benefits thereby attracting new consumers into fortified or functional dairy products.

Production of yogurt has not changed a great deal since its discovery, but greater knowledge of starter cultures and milk proteins has led to the overall production methods in use today (Figure 2.4).

In general, production will begin with the pretreatment of milk, which includes the standardization of fat to 0.5-3.0%, fortification of milk solids to 14-16%, and the addition of sugars and/or stabilizers. Standardization is necessary as the composition of fresh milk will vary on a daily basis and will depend on factors such as the breed, age and health of the animal, climate and season, feed, etc. Fat content is normally standardized

Table 2.3. Retail volumes and values of yogurt[1]

	2002	2003	2004
World			
Retail volume ('000 tonnes)	11707.38	12340.03	12932.28
Retail value (US$ billion)	24.16	28.33	32.23
Canada			
Retail volume ('000 tonnes)	164.86	172.39	177.73
Retail value (CDN$ million)	768.55	824.02	879.77
U.S.			
Retail volume ('000 tonnes)	1301.95	1369.12	1442.78
Retail value (US$ million)	3554.71	3826.14	4121.25

[1]Euromonitor 2004

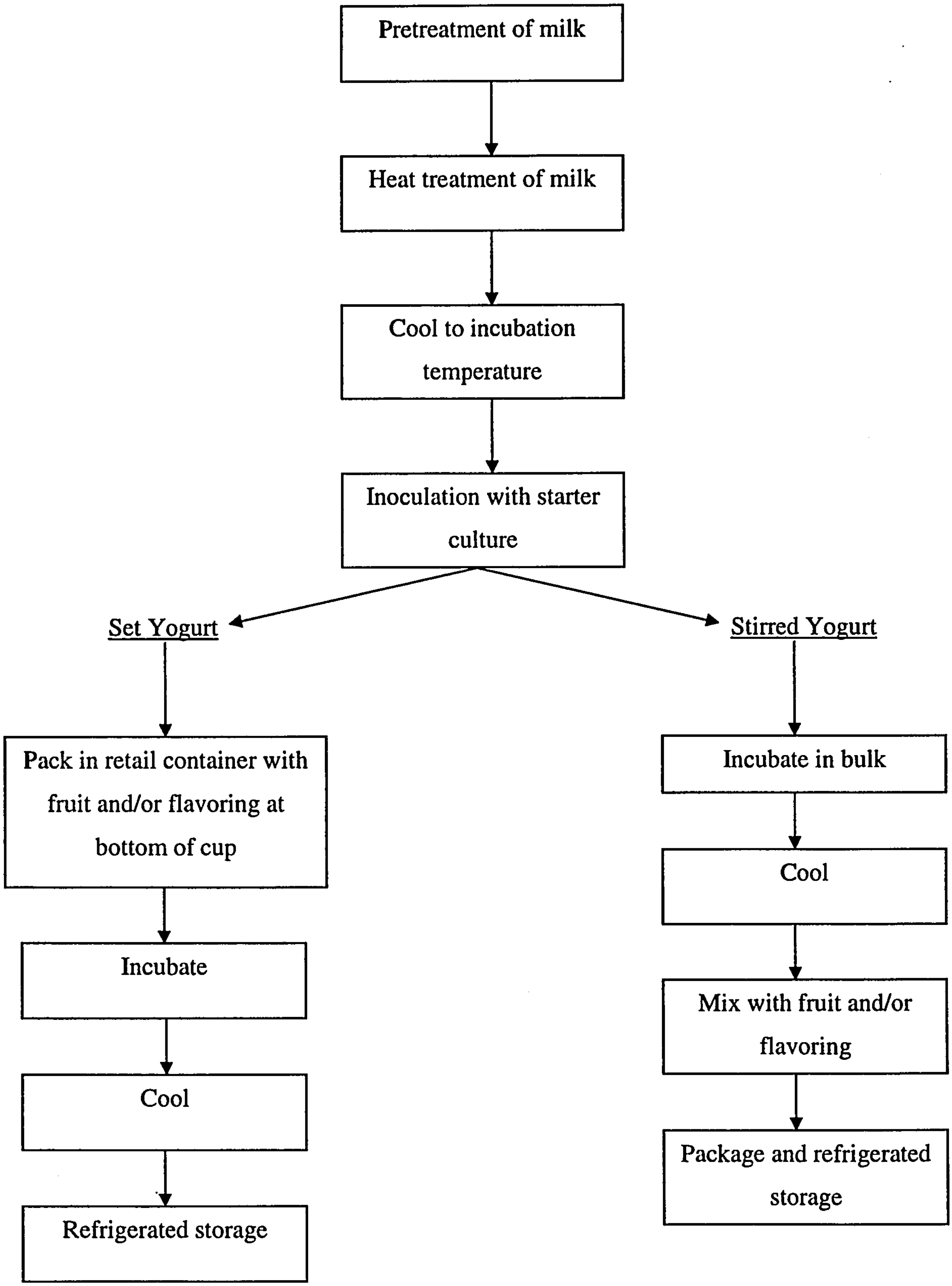

Figure 2.4. Flow diagram of yogurt production.

by removal of fat (cream) or by the addition of cream to skim or full fat milk. The minimum content of total solids in a finished yogurt product is comparable to that of liquid milk (8.2-8.6%); however, manufacturers generally increase this level using skim milk powder to 14-16% in order to improve the consistency of the end product. Sugars and stabilizers are often added to yogurt products that are flavored or contain fruit. Type and quantity of sugar or sweetener addition is often dependent on the type of fruit or flavoring introduced, consumer liking, effect on starter cultures, and economic and legal concerns. Stabilizers, also known as hydrocolloids, are generally added to stabilize the product thereby preventing syneresis in the product by binding water and by stabilizing the protein network. By standardizing the milk, the producer will be able to comply with legal standards and to produce a product that is consistent.

Next, a heating stage is introduced where the milk is heated to 85°C and held for 30 min, 90-95°C for 5-10 min or 120°C for 3-5 s. This is done in order to destroy the majority of microorganisms associated with milk, thereby ensuring that the starter culture will be able to grow with less competition. The heating stage is also important as it results in changes in the physicochemical properties of milk. Although the protein structure is not yet well-established, it has been postulated that heating denatures whey proteins and results in the formation of β-lactoglobulin and κ-casein complexes, which coat the fat globules. This results in an even distribution of protein within the network and increases the potential for coagulation (Tamine and Robinson 1985; Prentice 1992).

The milk is then cooled to incubation temperature, normally 42°C, and inoculated by a starter culture consisting of lactic acid bacteria (*Streptococcus thermophilus* and *Lactobacillus bulgaricus*). The starter culture utilizes the main carbohydrate, lactose, as a nutrient source and begins to produce lactic acid. As acidification increases, the casein micelles begin to disintegrate and reform into a network entrapping serum and fat globules into the structure. The acidity will decrease to a final pH of 4.6-4.8 at which point the coagulum will have created a final matrix and the viscosity of the yogurt will have increased and plateaued.

Finally, fruits or flavors are added if desired either in a set style yogurt where the fruit portion is placed at the bottom of the retail container and then milk inoculated with the starter cultures is added and allowed to ferment, or in a stirred style yogurt in which the fruit or flavors are added to the yogurt and stirred. In all cases, they are packaged and then placed under refrigerated storage until sold to the consumer and consumed.

2.3.1.3. Functional yogurts

With the variety of yogurt products on the shelves and the popularity of functional foods rising in the marketplace, it is only a matter of time before these two categories find a niche together. Functional foods are products, which provide a health benefit beyond basic nutrition. An example of a functional food currently on shelves are the wide variety of yogurt products boasting the presence of live microorganisms, known as probiotics. These products have been enjoying popularity in Europe, North America, and Asia. The openness people have towards products that are healthy with a preventative aspect can also be found in new products and as a result, a number of studies on the effects of functional yogurts have been reported.

There have been a number of studies focusing on the incorporation of health-promoting components such as iron and protein (Granata and Morr 1996; Hekmat and McMahon 1997); reduced or no fat products (Mistry and Hassan 1992; De Lorenzi and others 1995); fiber addition to non-traditional starting materials such as soymilk, oats, groundnut milk (Buono and others 1990; Mårtensson and others 2001; Mårtensson and others 2002; Sunny-Roberts and others 2004); and incorporation of fibers from a variety of sources including soy, gum Arabic, inulin, apple, wheat, bamboo, oat fiber, rice, corn, and sugar beet (Hoyda and others 1990; Fernández-García and McGregor 1997; Fernández-García and others 1998; Bekers and others 2001; Stafollo and others 2004).

Stafollo and others (2004) investigated the effects of storage time and addition (1.3%) of apple, wheat, bamboo, and inulin fiber on the sensory and rheological properties of plain yogurt. They found that the addition of these fibers had no significant effect on the levels of syneresis or pH. Rheological differences resulting from storage and type of fiber were determined using instrumental analysis and found to be significant; however, untrained consumer panelists found the enriched products to be acceptable for texture as well as color and flavor. Inulin, a soluble fiber, was found to have the best flavor attributes but did not differ significantly from the other insoluble fibers in any other way. Fernández-Garcia and McGregor (1997) also determined the effects of insoluble fiber addition (soy, rice, oat, corn, and sugar beet) to plain yogurt on the fermentation and sensory attributes. The results demonstrated that fiber addition of soy, sugar beet and rice resulted in increased fermentation rates, possibly caused by the presence of additional nutrients or growth stimulants available to the starter cultures in these particular fiber sources. There were no significant increases in apparent viscosity; however, some of the fibers caused an undesirable change in flavor, and texture as there was a pronounced grittiness when compared to the controls. Measurements of the organic acid production showed that yogurt with oat fiber produced the best product in terms of generating a similar organic acid profile with the least amount of differences compared to the control. Oat fiber addition also resulted in sensory values deemed to be commercially acceptable. In general, Fernández-Garcia and McGregor (1997) found fiber addition to be detrimental to the original characteristics of the yogurt product with oat fiber addition creating the least amount of differences.

2.3.2. Ice cream

Ice cream is a frozen dessert enjoyed worldwide for its smooth and creamy texture, ease of preparation, and delicious flavors. In reality, ice cream is a complicated three-phase system of air, liquid, and solids. In essence, ice cream is a frozen foam mixture consisting of air bubbles, fat globules, ice crystals, and serum; when added in appropriate levels and frozen properly, the result is the crystallization of the fat globules and water into a creamlike suspension of air and fat droplets coated with proteins and emulsifiers within an aqueous phase (Prentice 1992; Byars 2002). Ice cream generally consists of 10%-16% milkfat, 9-12% milk-solids not-fat (MSNF), 12-16% sweeteners, 0.2-0.5% stabilizers and emulsifiers, 55-64% water, and air (Table 2.4). The amount of milkfat in ice cream can vary as new innovations in ingredients and technology allow manufacturers to create premium (at least 12% milkfat), reduced fat (25% less total fat than referenced product), light (at least 50% less total fat or 33% fewer calories than referenced product), low-fat (contains a maximum of 3 g of total fat per ½ cup serving), and non-fat (less than 0.5 g of total fat per ½ cup serving) ice cream (Pszczola 2002).

Table 2.4. Ice cream ingredients and their functions[1]

Component	Function
Milk fat	Increases richness
	Produces smooth texture
	Contributes to body
MSNF[2]	Improves texture
	Contributes to body
	A higher overrun can be produced without sensory detriment
Sugar	Enhances flavor
	Improves texture
	Decreases freezing temperature
Stabilizers	Smoothes texture
	Adds body and melting resistance
Egg yolk solids	Improves smoothness of texture
Flavor	Increases acceptability
Air	Adds to texture and body

[1]Adapted from Arbuckle (1986)

[2]Milk solids not fat

The function of milkfat in ice cream is to impart a full, rich, and creamy flavor, as well as contributing to the body and melting properties through fat agglomeration. Fat particles concentrate towards the surface of the air cell during freezing resulting in the rich flavor associated with ice cream. It also tends to decrease the rate of whipping; therefore, high fat products are of higher cost, have a higher caloric value, and may limit consumption (Arbuckle 1986).

Proteins, milk sugars, and minerals make up the category known as MSNF. The presence of these compounds results in an increase in viscosity, resistance to melting as well as the lowering of freezing point. Proteins aid in the body and texture by making the ice cream more compact and smooth. The presence of lactose, the major carbohydrate found in milk, adds a slight sweetness but if there is a high concentration of lactose, undesirable crystallization can cause sandiness and coarse texture in the product.

Sweeteners are added to the product for their characteristic sweetness as well as enhancing other flavors, increasing the viscosity, and to decrease the freezing point of the aqueous phase thereby allowing for proper hardening.

Stabilizers, such as gelatin or carageenan, are added in order to prevent the formation of large ice crystals under temperature fluctuation, increase viscosity, and to provide resistance to melting due to their high water-holding capacity. The role of emulsifiers, traditionally egg yolk solids, is to produce air cells, which are small and evenly distributed resulting in a smooth texture as well as coating the fat cells thereby reducing the whipping time by stabilizing the product. Other commercially available emulsifiers include mono- and diglycerides and their use cannot exceed 0.2% by weight of the mix.

Water and air are both very important components of ice cream as the milkfat is distributed through a water-fat emulsion consisting of liquid water, ice crystals and solid globules of fat. The amount of air that is incorporated into the product is measured by overrun. Overrun is calculated as:

$$\text{Overrun \%} = \frac{\text{Volume of ice cream- Volume of mix}}{\text{Volume of mix}} \times 100$$

A uniform amount of air bubbles throughout the product influences quality and profits and as such, cannot exceed certain legal levels enforced in a given area, generally around 80-110%. Excessive amounts of air result in a fluffy, snowy and unpalatable product, while too little air makes a soggy and dense product.

Flavors, such as artificial vanilla and strawberry, are generally added just prior to freezing.

2.3.2.1. History of ice cream

The history of ice cream is highly debatable with its origins going back to the times of the great Roman Empire when Nero obtained mountain snow and covered it in wine and fruit juices to the time of the great explorer Marco Polo (1254-1324) who observed the making of an iced dessert on his trip to China and subsequently introduced it to Italy (Arbuckle 1986). Another popular story is that the chef of Charles I of England invented the dish and was paid a handsome salary in order to keep the recipe secret (International Association of Ice Cream Manufacturers (IAICM) 1978). Nevertheless, the combination of frozen milk (ice, fat and serum), fruit or flavors, emulsifiers, and air result in a delicious combination enjoyed worldwide. Like other dairy products, fiber is generally absent in ice cream unless present in the fruit portion.

2.3.2.2. Consumption and production of ice cream

Ice cream has an estimated consumption level of 13.7 kg per capita in the U.S. and 11.0 kg per capita in Canada according to industry and national statistics for 2002 and a world retail value of US$261.7 billion in 2004 (Table 2.5) (Euromonitor 2004). The popularity of this product is likely due to its sweet and creamy taste and texture as well as the convenience it affords for those with busy lifestyles.

Variation in mix production contributes to differences in quality, body, and texture of the final product. In addition, the cost of ice cream is determined by the type of starting ingredients, proportions of ingredients as well the type of machinery used in production.

Table 2.5. Retail values and volumes of ice cream[1]

	2002	2003	2004
World			
Retail volume (billion litres)	12.93	13.42	13.85
Retail value (US$ billion)	210.11	236.50	261.66
Canada			
Retail volume (million litres)	339.98	345.56	350.39
Retail value (CDN$ billion)	1.831	1.905	1.988
U.S.			
Retail volume (million litres)	3,889.73	3,935.95	3,928.81
Retail value (US$ billion)	13.53	13.80	14.01

[1]Euromonitor 2004

Ice cream production in a large scale generally consists of mix preparation, freezing, packaging, hardening and finally shipping or storage. Mix preparation includes the weighing or metering of the ingredients, mixing, pasteurization, homogenization, cooling, aging, and flavoring of the mix. Liquid ingredients are placed in a large vat and placed under agitation and heating. The dry ingredients are then added to the mixture as the mix is constantly being stirred. The ingredients are then pasteurized in order to destroy pathogenic bacteria, improve flavor and keeping quality in addition to it being a legal requirement (Arbuckle 1986). Pasteurization temperatures can vary either 30 min at temperatures of at least 69°C for batch pasteurization or 25 s at a minimum of 80°C using high temperature short time (HTST) heat exchangers. Other pasteurization times and temperatures can be used but must be approved. Large scale productions use heat exchangers in order to minimize holding times thereby improving efficiency. Homogenization of the mix is then performed in order to reduce the size of fat droplets to less than 1 μm thereby preventing a separation of cream from the rest of the mix. Homogenization suspends the small fat globules via shear forces as the mix travels through two close surfaces, then shattering as it comes into contact with an impact valve upon leaving the valve. This creates a permanent and uniform effect on the size of the fat globules resulting in a uniform ice cream with a smoother texture, and improved whipping ability as the fat globules decrease in size but increase in surface area. The mix is then cooled and aged for a minimum of 4 h. Aging is necessary as it results in protein and stabilizer hydration, protein and emulsifier interactions, fat crystallization and destabilization.

The freezing process is next and begins with the addition of flavorings or pureed fruits, and/or coloring. The mix is then very quickly frozen and agitated using a barrel-like heat exchanger consisting of a jacketed tubular barrel with rotating scraper blades and dashers, which remove the ice off the freezing surface as well as whipping and incorporating air into the mix, respectively. The partially frozen ice cream is then drawn from the freezer and checked for proper overrun, and placed into packages. At this stage, the ice cream is considered "soft-serve" and can also be consumed.

Hardening is the process of quickly cooling the ice cream to a point at which the remainder of the water is frozen. This is generally done using a blast freezer with forced air fans to increase freezing rate via convection and/or with plate freezers to increase freezing via conduction. Hardening must be done very rapidly in order to minimize the size of ice crystals. In addition, if stored below -25°C, ice cream remains stable indefinitely. Higher temperatures result in ice crystal growth, which may impart a coarse texture.

Shipping and storage are the final steps as the product is ready for retail immediately after hardening. Shipping is done under refrigerated conditions at the same temperature as it is maintained in the retailer's cabinets (Arbuckle 1986). Storage conditions must consist of low and constant temperatures, approximately -25°C, in order to maintain the quality of the ice cream.

2.3.2.3. Functional ice cream

Ice cream is a product generally thought of as an indulgent snack not a health product, so the majority of ice cream or frozen desserts are either high- or low-fat products with the variety coming from the availability of flavors and serving sizes. Flavors range from vanilla, which still currently holds its place as the most popular flavor, to unique flavors such as tiramisu and green tea. Klein (2004) states in his analysis of frozen dessert trends that in light of changes in household sizes a popular option with manufacturers is providing products with double-serving, individually wrapped portions.

With functional foods garnering greater attention from the public, it is possible that a functional ice cream produced with ingredients, such as fiber, that can also provide an extra health benefit in addition to its nutritional benefit could be successful if properly made. The function of hydrocolloids in ice cream systems is to add enhanced stability of the final product, prevent separation of the mix during standing, and to change textural attributes (Prentice 1992). The functionality and nutritional benefit of fibers can result in a product that is healthy and nutritionally beneficial.

With the discovery of ingredients that can be used as a functional ingredient in terms of their physicochemical properties in addition to the health benefits they may provide, it is likely that this popular food product will see enrichments in the near future. To date, functional ice creams have included addition of omega-3 fatty acids (Koert 2005); lactose reduced ice cream (Rossi and others 1999); dietetic ice cream (Banguela-Perez and Rodriguez-Herrera 1995); protein addition (whey, sodium caseinate, wheat and soy protein isolate) (Ahmedna and others 1999, Friedeck and others 2003); a number of low- or lower-fat varieties incorporating a number of starches and emulsifiers (Baer and others 1999); probiotics (Godward and Kailasapathy 2003; Taha and others 2005) and lower sugar levels (Güven and Karaca 2002).

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Chapter 3

CEREAL β-GLUCAN ENRICHED MODEL YOGURT SYSTEMS AS INFLUENCED BY STARTER CULTURES[1]

3.1. INTRODUCTION

Dietary fiber is known to confer important health promoting properties. Barley/oat mixed linkage (1→3),(1→4)-β-D-glucan (β-glucan) is a soluble fiber component of high viscosity. Incorporation of this form of fiber into food and beverages is garnering the attention of researchers and consumers alike as fiber consumption has been linked to a decrease in serum cholesterol (Behall and others 1997; Pomeroy and others 2001; Behall and others 2004), glycemic index (Braaten and others 1991; Wood 1994; Cavallero and others 2002), as well as potential immunostimulatory properties (Estrada and others 1997; Yokoyama and others 1997; Estrada and others 1999; Cheung and Modak, 2002). Recommended amounts for consumption of dietary fiber are currently set at levels of 25-30 g/day by Health Canada and the U.S. Food and Drug Administration (Canadian Food Inspection Agency 2003; Food and Drug Administration/Center for Food Safety and Applied Nutrition 2004). However, the average consumption level in North America is approximately 15.6 g/day (National Health and Nutrition Examination Survey (NHANES III) 1988-1994). The incorporation of β-glucan into a wide variety of products would allow for a general increase in fiber consumption and potentially for a beneficial change in health for the general population. With the approval by the Food and Drug Administration (FDA) of health claims concerning soluble dietary fiber, an increasing number of food and beverage products fortified with dietary fibers such as β-glucan and psyllium are being introduced to the market. Currently, the FDA has approved claims attributed to cardiovascular health for products produced from whole oats, psyllium fiber, and Oatrim (a soluble fraction of α-amylase hydrolyzed oat bran or whole oat flour) because these products have been clinically proven to reduce the risk of coronary heart disease (CHD) (Federal Register 2003). The FDA has acknowledged that it is primarily the soluble fiber component, β-

[1]A version of this chapter is to be submitted to the Journal of Food Science for consideration for publication.

glucan, in whole oats, which is responsible for the reduction of blood total- and low density lipoprotein (LDL)-cholesterol levels (Federal Register 2003). A barley petition is currently under review as β-glucan from sources other than whole oats, such as barley, has also been shown to affect blood lipid levels and thus lower the risk of CHD.

In general, the consumption of dairy products has been in decline, but yogurt consumption has been steadily increasing. Yogurt's reputation as probiotic, low-fat, as well as the general perception of being natural has most likely spurred its 65% growth in Canada since the mid-1980's (Byrne 1995; Chandan 1999; Euromonitor 2002). A variety of yogurt products has been formulated with the addition of fibers and/or non-traditional starting materials such as soymilk or oats, as well as the incorporation of other health-promoting components such as iron and protein (Buono and others 1990; Granata and Morr 1996; Fernández-García and McGregor 1997; Hekmat and McMahon 1997; Fernández-García and others 1998; Bekers and others 2001; Mårtensson and others 2001). Yogurt fortified with dietary fiber has the potential to appeal to the palate as well as being healthy for the body thereby leading to increased consumption of this valuable dietary component.

The addition of fiber to yogurt or fermented products has been reported previously (Fernández-Garcia and others 1997; Bekers and others 2001), but the literature is lacking information on the specific effects of starter cultures on barley β-glucan and vice versa. Fernández-Garcia and others (1998) studied the effect of adding oat fiber, sucrose and fructose with or without lactose-hydrolyzed milk on viscosity and showed that the addition of fiber increased viscosity. It was postulated that the viscosity increase was due to interactions between the dairy proteins and exogenous hydrocolloids in addition to the supplementation of fructose and lactose-hydrolyzed milk. Bekers and others (2001) studied lactic acid bacteria (LAB) fermentation of oat mash after the enzymatic hydrolysis of starch in the mash and evaluated the ability of LAB to survive and ferment in the final fermented product. Bekers and others (2001) determined that the addition of LAB to their formula of oligosaccharides produced typical fermentation products, namely lactic acid, acetic acid, formic acid and ethanol. They also found that fermentation did not significantly affect the concentration of β-glucan in the oat mash. Determining the extent of β-glucan breakdown by starter cultures warrants further investigation and viscosity can be used as an indirect means of ascertaining whether or not the high viscosity β-glucan polymer is being broken down. Lämbo and others (2005) studied the effects of LAB (*Lactobacillus delbrueckii* subsp. *bulgaricus* with *Streptococcus salivarius* subsp. *thermophilus* and *Lactobacillus acidophilus* or *Pediococcus damnosus* 2.6) on the content, viscosity and molecular weight of oat and barley β-glucan concentrates. They fermented oat and barley β-glucan concentrates with yogurt starter cultures and found via filtration and centrifugation-dialysis techniques that although molecular weights appeared to be unaffected, maximum viscosity values for oat fiber concentrates decreased whereas the viscosity of barley fiber concentrates was not significantly affected. Low molecular weights (<10,000) could not be detected by the Calcofluor method and it was speculated that some β-glucan was considerably degraded, resulting in a decreased β-glucan content.

Lämbo and others (2005) noted that viscosity may be a more relevant measurement when ascertaining the changes in physicochemical properties pertaining to physiological functionality. It is critical to minimize any degradation of β-glucan during processing since its health benefits have been attributed to its ability to impart high viscosity to intestinal contents (Jenkins and others 1978; Tietyen and others 1995; Wood and others 1994; Wood, 2004). β-Glucan increases the viscosity of intestinal contents thereby delaying digestion and absorption of lipids, inhibiting the reabsorption of bile acids, decreasing transit time and motility in the small intestine, and potentially modifying lipid absorption and metabolism (Anderson and others 1990; Mälkki and Virtanen, 2001).

The objectives of this study were to determine the effect of high viscosity barley β-glucan on the yogurt starter culture's ability to ferment and to determine whether or not bacteria from yogurt starter cultures can hydrolyze and depolymerize β-glucan, thereby causing a decrease in its viscosity.

3.2. MATERIALS AND METHODS

3.2.1. Materials

β-Glucan gum (83.4% w/w, as-is) was purified from barley **Visco*fiber*®** obtained from Cevena Bioproducts Inc. (Edmonton, AB). The purification process is illustrated in

Figure 3.1. β-Glucan (Mixed Linkage) Assay Kit, purchased from Megazyme International Ireland Ltd. (Wicklow, Ireland), was used to determine the purity of samples. Skim milk powder was obtained from Dairyworld Foods (Edmonton, AB) and bacteriological grade lactose was from Oxoid (Basingstoke, England).

Starter cultures (SC) used in this study were FD-DVS YC-380 and FD-DVS YC-X11 and will be referred to as YC-380 and YC-X11 (CHR Hansen, Milwaukee, WI, U.S.). Both starter cultures consisted of mixed strain freeze-dried yogurt cultures containing *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus.* According to manufacturer specifications, YC-380 is a starter culture for producing yogurt with a "medium body" and medium flavor whereas YC-X11 is a culture for producing yogurt with "high body", very firm gel, very mild flavor and minimal post acidification. All cultures were stored at -46°C until used.

The freeze-dried cultures were activated in reconstituted skim milk (RSM) with 12% solids that had been heat treated at 85°C for 30 min and agitated for 15 min in order to achieve a homogenous culture (according to manufacturer's recommendations).

3.2.2. Sample preparation

The control model yogurt mixture without β-glucan consisted of 110 g distilled water, 2% (w/w) skim milk powder (SMP), and 4.8% (w/w) lactose (L), which were weighed into a 150 mL beaker, stirred and heated at 85°C for 30 min followed by inoculation. In addition to the control, an aqueous solution of 0.5% (w/w) β-glucan (BG) was prepared by hydrating β-glucan in a 500 mL pasteurized beaker with magnetic stirring in a hot water bath at 85°C for 1 h. After hydration of β-glucan, 110 g of the solution was aseptically transferred into each of two smaller beakers (450 mL) with magnetic stirrers. SMP (2%, 2.2 g) was added to each beaker and 4.8% lactose was added to one of the two beakers. These solutions were further heat treated at 85°C for 30 min. After the additional heating process that mimics the pasteurization step required for yogurt production, 9 mL of the solution were transferred into each of 5 sterile tubes and sealed. Samples were inoculated with the starter cultures (SC) in 20 min intervals in order to maintain the same conditions for each run. All samples were heated in a water bath at 42°C for 12 h.

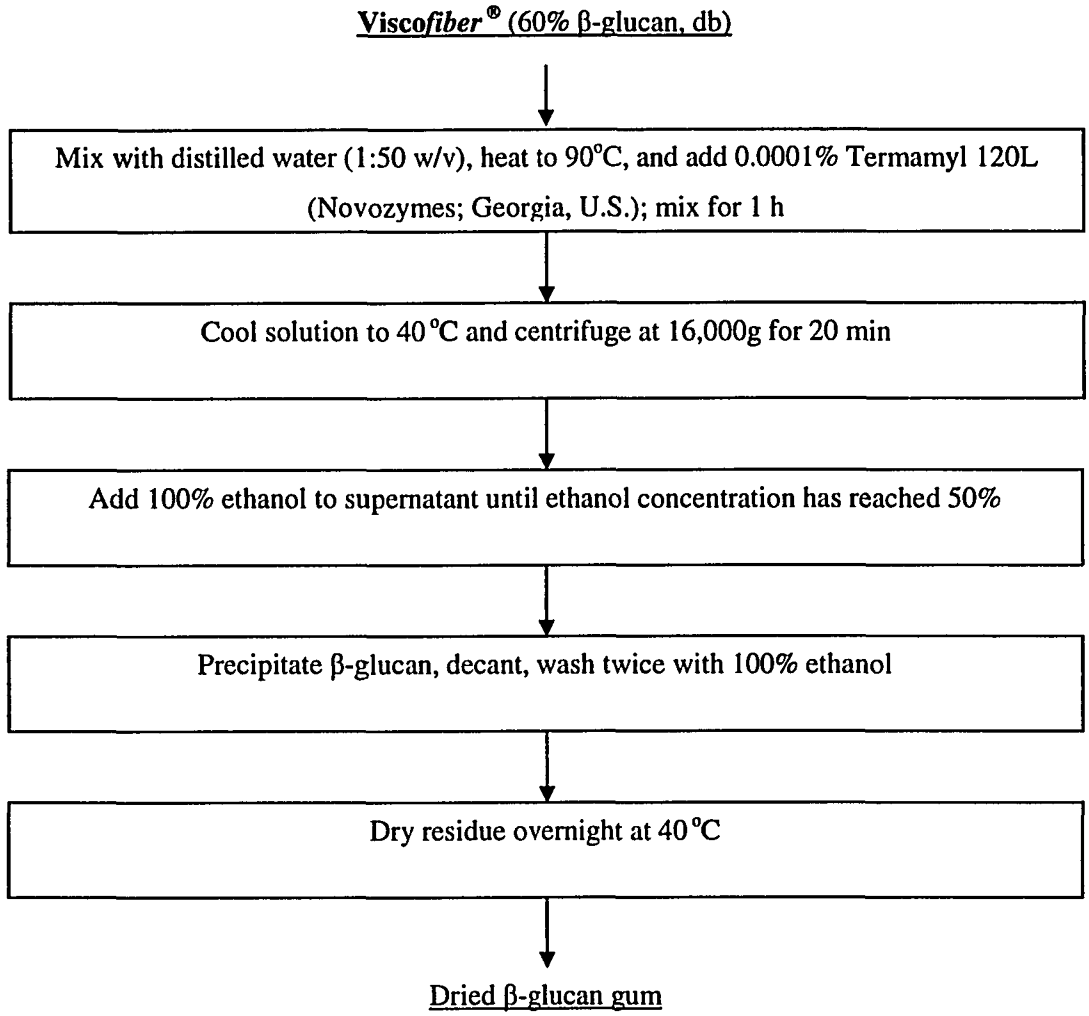

Figure 3.1. β-Glucan purification procedure.

Treatments used in this study were: (1) SMP + L + SC (pH measurements only), (2) BG + SMP, (3) BG + SMP + L, (4) BG + SMP + SC, and (5) BG + SMP + L + SC. All samples were prepared in sterilized containers in order to minimize any contamination of samples. Milk was inoculated with YC-380 or YC-X11 culture at an inoculation rate of 2% (w/w).

3.2.3. Viscosity

Model yogurt systems of each treatment were sampled (7.05 ± 0.01 g) in duplicate at 0, 2, 4, and 8 h. Viscosity was determined as a function of shear rate using a PAAR Physica UDS 200 rotational viscometer (Stuttgart, Germany) fitted with a DG 27 cup and bob with double gap geometry and Peltier heating system at a shear rate of 1-100 rpm (1.29-129 s^{-1}) and 20°C in the controlled shear rate mode.

3.2.4. Fermentation efficacy of yogurt starter cultures

After viscosity analyses, pH of the samples was recorded (pH meter Model 220, Corning, NY) over 8 h and the relative rate of acidity development was used as an indicator of the efficacy of starter cultures used in the presence of β-glucan.

3.2.5. Statistical analysis

Analysis of variance of results was performed using SAS Statistical Software, Version 8 (SAS Institute Inc., 2000). The model consisted of the main effects of culture, treatment, and time and their interaction effects. Means were compared using Schwarz's Bayesian Criterion using a Mixed Model analysis for repeated measures ($p \leq 0.05$) as this covariance structure gave the smallest value (Wang and Goonewardene 2004). All samples were prepared in duplicate and measurements on each sample were performed in duplicate.

3.3. RESULTS AND DISCUSSION

Formulations were prepared in order to observe the true effects of the starter culture on β-glucan. Skim milk powder (2%, w/w) was used in all samples in order to formulate the base that corresponds to the composition of regular skim milk and to provide a nitrogen source for bacteria. Addition of 4.8% (w/w) lactose to treatments 1, 3, and 5 was to provide the starter culture with the main source of fermentable carbohydrate and to mimic levels normally found in milk. Controls without added lactose were also prepared.

3.3.1. pH measurements

Development of acidity in yogurts (decrease in pH) is one method of determining the fermentation efficacy of a starter culture. Proper fermentation by a starter culture results in a decline in pH to approximately 4.4 in 4 h (Fernández-Garcia and others 1998). The pH of sample containing SMP + L + SC inoculated with YC-380 was 4.14 after 4 h as compared to the pH of 4.10 for the BG + SMP + L + SC sample (Table 3.1). The pH of sample containing SMP + L + SC inoculated with YC-X11 after 4 h was 4.20 while that of sample containing BG + SMP + L + SC had a value of 4.18. The data indicated that addition of β-glucan did not affect the fermentation efficacy of YC-380 or YC-X11 cultures. Values obtained in this study were slightly lower than the final fermentation pH level commonly practiced in the industry that ranges from 4.6-4.7, which is the isoelectric point at which the casein micelles aggregate and partially coalesce (Tamine and Robinson 1985). However, that could easily be remedied by halting fermentation prior to the acidity reaching that lower level. Furthermore, pH development was steady for all treatments containing starter cultures. It was evident that in the model systems used in this experiment, β-glucan had no significant effect on the ability of the starter cultures to ferment.

3.3.2. Viscosity measurements

Statistical analysis of viscosity at a shear rate of 12.9 s^{-1} (10 rpm), as seen in Table 3.2, showed that the main effects of culture, treatment, and time, as well as the interactions were highly significant except for the interaction of culture and treatment. The fact that this interaction is not significant indicates that the effect of culture was not treatment dependent. Therefore, the main interaction of time and treatment was of the greatest interest as well as the interactions within each culture group. Analysis at 12.9 s^{-1} was selected as it has been reported that the shear rate in the mouth to range from 10-50 s^{-1} depending on the viscosity of the product with a shear rate of 10 s^{-1} showing a better

Table 3.1. The effect of high-viscosity β-glucan gum on fermentation efficacy of yogurt starter cultures

Sample	pH[1]			
	0 h	2 h	4 h	8 h
			YC-380	
SMP + L + SC	6.86 (0.10)	5.36 (0.68)	4.14 (0.25)[a]	3.67 (0.13)
BG + SMP	7.00 (0.05)	7.03 (0.01)	7.00 (0.03)[b]	7.06 (0.04)
BG + SMP + L	6.96 (0.02)	6.97 (0.03)	6.99 (0.08)[b]	6.98 (0.08)
BG + SMP + SC	-	5.67 (0.33)	4.26 (0.02)[a]	3.88 (0.01)
BG + SMP + L + SC	-	5.45 (0.60)	4.10 (0.11)[a]	3.83 (0.16)
			YC-X11	
SMP + L + SC	6.86 (0.19)	5.17 (0.62)	4.20 (0.04)[a]	3.78 (0.15)
BG + SMP	6.90 (0.08)	6.90 (0.08)	6.97 (0.16)[b]	6.95 (0.14)
BG + SMP + L	6.92 (0.18)	6.93 (0.17)	6.97 (0.21)[b]	6.96 (0.18)
BG + SMP + SC	-	4.78 (1.09)	4.17 (0)[a]	3.87 (0.06)
BG + SMP + L + SC	-	4.25 (1.33)	4.18 (0.13)[a]	3.81 (0.16)

[1]Mean ± standard deviation (given in parenthesis); SMP: Skim milk powder; L: Lactose; SC: Starter culture; BG: β-glucan

[a,b] Means with the same letters in the same column are not significantly different (p>0.05)

Table 3.2. Type 3 tests of main effects and fixed interaction effects on viscosity and their significance as performed by SAS.

	Num DF	f-value	Pr > f	Significance
Culture[a]	1	10.72	0.0031	Significant
Treatment[b]	3	128.94	<0.0001	Significant
Culture * Treatment	3	1.52	0.2341	Not Significant
Time[c]	3	900.22	<0.0001	Significant
Culture * Time	3	11.99	<0.0001	Significant
Time * Treatment	9	230.98	<0.0001	Significant
Culture * Treatment * Time	9	6.66	<0.0001	Significant

[a]Culture: YC-380, YC-X11
[b]Treatment: SMP + L + SC, BG + SMP; BG + SMP + L; BG + SMP + SC; BG + SMP + L + SC
[c]Time: 0, 2, 4, 8 h

correlation with perceived thickness (Cutler and others 1983). Results from detailed statistical analysis of interactions effects can be found in Appendix A.

As shown in Figure 3.2 (A-D), there were no significant differences ($p>0.05$) in the viscosity of control samples containing BG + SMP and BG + SMP + L with increasing incubation time up to 8 h. BG + SMP for sample YC-380 and YC-X11 hadrespective average viscosities of 219 mPa·s and 216 mPa·s at a shear rate of 12.9 s^{-1} at time 0 h and 8 h.

Viscosity of the sample containing BG + SMP + SC and YC-380 decreased over the course of incubation (Figure 3.3A). During the first 2 h, there was no significant difference ($p>0.005$) in viscosity (222 mPa·s to 214 mPa·s) but at 4 h, viscosity significantly ($p<0.005$) dropped from 214 mPa·s to 118 mPa·s at 12.9 s^{-1}, a difference of 96 mPa·s. The same treatment with culture YC-X11 (Figure 3C) had a slight ($p>0.05$) initial drop from 218 mPa·s to 211 mPa·s at 12.9 s^{-1} in the first 2 h. However, between 2 h and 4 h period, there was a significant ($p\leq 0.005$) drop of 149 mPa·s in viscosity (211 mPa·s to 62 mPa·s). Starter culture YC-X11 appeared to hydrolyze β-glucan more vigorously as there was a greater drop in viscosity, which was evident in the significant ($p\leq 0.005$) effect of culture at 4 h.

As depicted in Figures 3.3B and 3.3D, both samples containing BG + SMP + L + SC show decreased viscosity breakdown when samples contained additional lactose. There was a decrease in viscosity of the sample containing BG + SMP + L + SC and YC-380 during the incubation period (Figure 3.3B). During the first 2 h, there was no significant ($p>0.005$) difference (230 mPa·s to 227 mPa·s) but at 4 h, viscosity dropped from 227 mPa·s to 182 mPa·s at 12.9 s^{-1}, a difference of 45 mPa·s. The same treatment with culture YC-X11 (Figure 3D) had a non-significant initial drop in viscosity from 224 mPa·s to 222 mPa·s at 12.9 s^{-1} in the first 2 h. Between the 2 h and 4 h period, there was a significant drop in viscosity. In general, the greater drop in viscosity for treatments not containing lactose may be attributed to starter cultures' preference to consume readily available lactose rather than use β-glucan as a source of nutrients. Hence, the addition of a fermentable sugar, lactose, reduces the degree of β-glucan breakdown by these starter cultures.

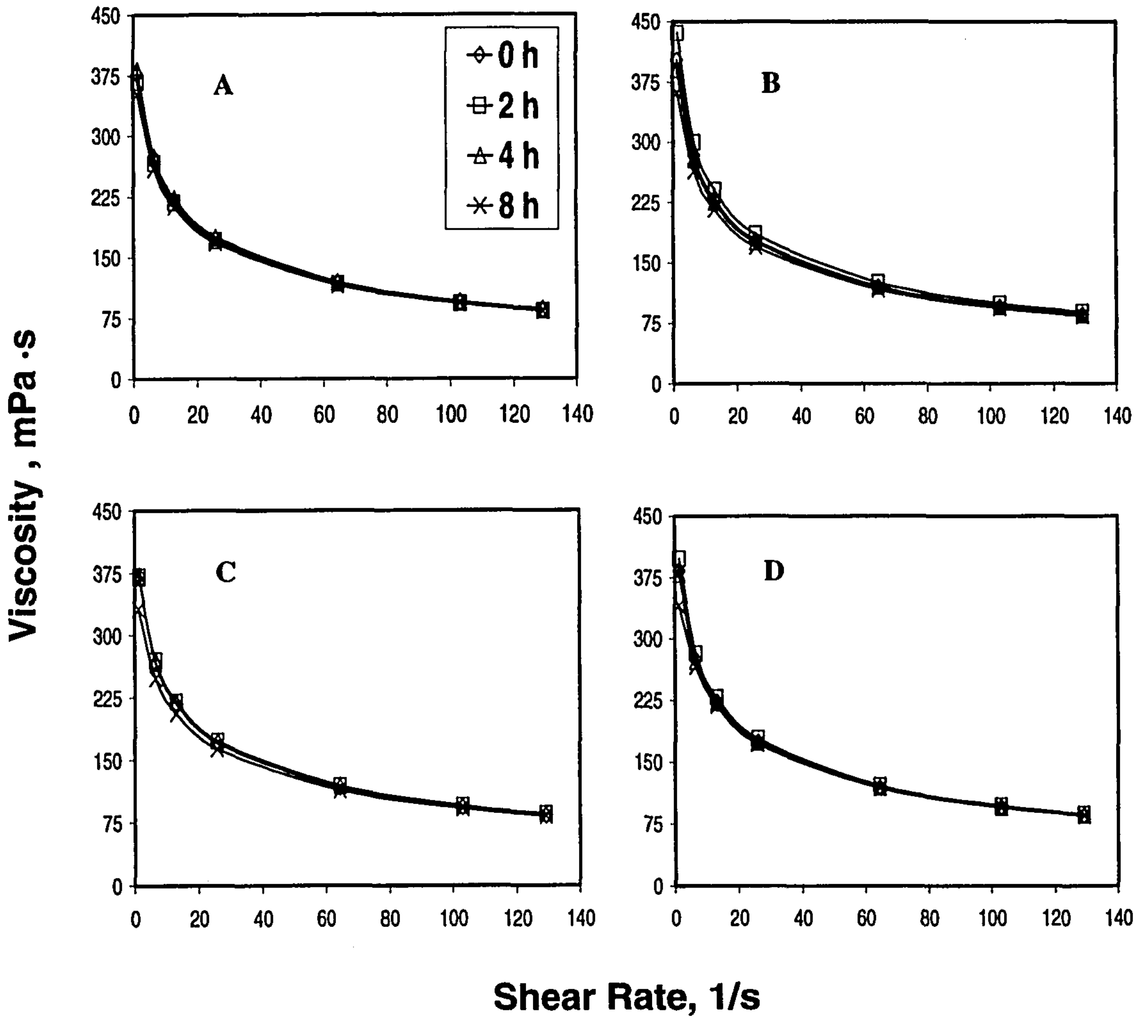

Figure 3.2. Viscosity of control (without inoculation) samples containing BG + SMP or BG + SMP + L for culture YC-380 or YC-X11, respectively. A: BG + SMP (control for YC-380); B: BG + SMP + L (control for YC-380); C: BG + SMP (control for YC-X11); D: BG + SMP + L (control for YC-X11)

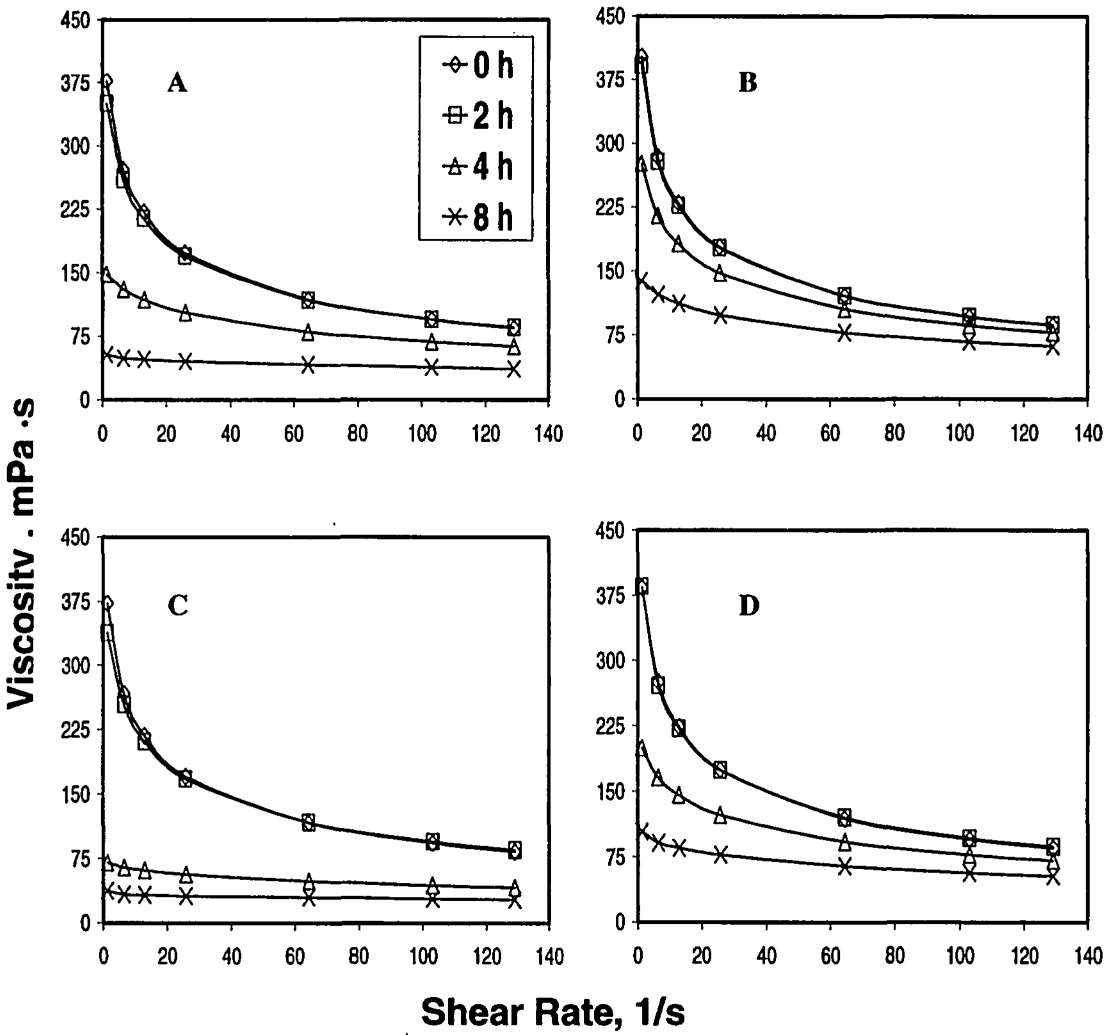

Figure 3.3. Viscosity measurements of inoculated samples containing BG + SMP + SC or BG + SMP + L + SC for cultures YC-380 and YC-X11. A: BG + SMP + SC (YC-380); B: BG + SMP + L + SC (YC-380); C: BG + SMP + SC (YC-X11); D: BG + SMP + L + SC (YC-X11)

Figure 3.4 shows a comparison of the different treatments and starter cultures after 4 h of incubation at 42°C. Viscosities of samples that had not been inoculated were similar. However, addition of the starter culture resulted in a significant ($p \leq 0.005$) decrease in the viscosity of samples, which was less pronounced in samples containing lactose, the main nutrient source for the starter culture. Evidently, the starter cultures were able to utilize β-glucan as a nutrient source, but their first preference was for lactose. Lämboand others (2005) added glucose or sucrose substrates to their fermented oat and barley fiber concentrates and found a decrease in viscosity that was postulated to be caused by a breakdown in dietary fiber polysaccharides. It was hypothesized that this was due to the ability of the cultures to hydrolyse and metabolise the cellulosic (1→4)-linkages on the β-glucan molecule. In this study, controls without the addition of lactose showed greater viscosity breakdown than their counterparts, which included lactose. It appeared that the addition of a substrate that is readily utilizable by the starter culture minimized the effect of β-glucan breakdown as observed through viscosity.

Culture YC-380 (Figure 3.4A) appeared to be better at maintaining the original viscosity of β-glucan as the viscosity of the sample at 4 h containing BG + SMP + L + SC was consistently higher at 181.81 mPa·s at 12.9 s^{-1} than YC-X11 inoculated BG + SMP + L + SC sample (Figure 3.4B) at 145.56 mPa·s at 12.9 s^{-1} and not significantly different from its inoculated control (BG + SMP + SC). The pH development in samples containing BG + SMP + L + SC after 4 h ranged from 4.02 to 4.46 (Table 3.1). Fermentation in yogurt is normally halted at pH 4.6 and therefore, the fermentation process could be ceased prior to 4 h by means of refrigerated storage.

Also apparent in Figures 3.2 and 3.3 are the changes to fluid flow behavior of the model yogurt systems. The Power Law model, which describes pseudoplastic behavior of gums, is as follows:

$$S=cR^n$$

where S is shear stress (N/m^2), c is the consistency coefficient, R is the shear rate (s^{-1}), and n is the flow behavior index. As the flow behavior index (n) approaches 1, the material becomes more Newtonian, that is, the viscosity of the material is independent of the shear force applied. As seen in Table 3.3, samples not inoculated with culture showed pseudoplasticity for controls for YC-380 and YC-X11 at averaged values of n =

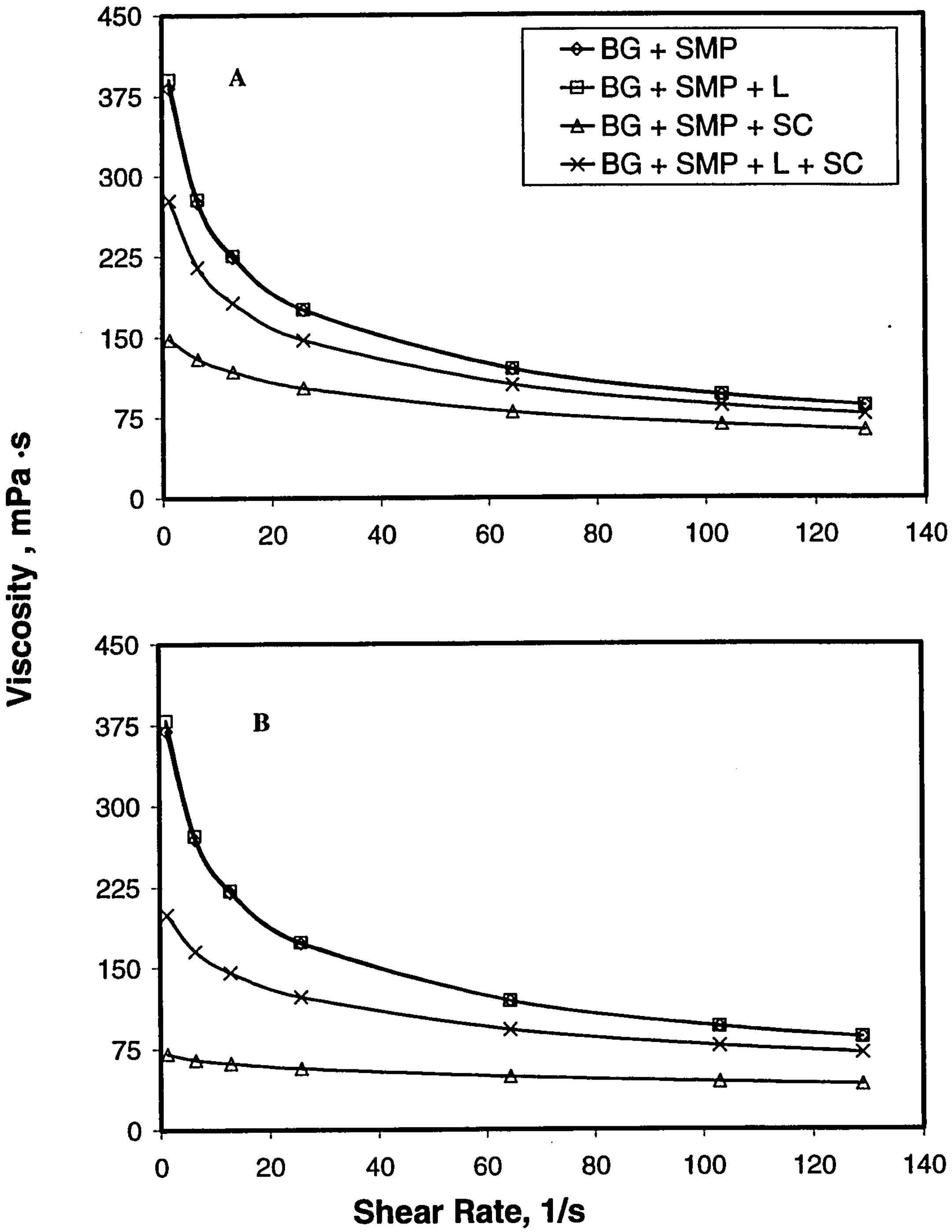

Figure 3.4. Rheological measurements for all treatments and cultures at 4 h; A:YC-380, B: YC-X11

Table 3.3. Flow behavior index and consistency index for model yogurt systems inoculated with culture YC-380 or YC-X11 at time 0 – 4 h.

Culture	Treatment	Time (h)	Flow Behavior Index (n)	Consistency Index (c)	R^2
YC-380	BG + SMP	0	0.6664	0.4697	0.9926
		2	0.6601	0.4754	0.9945
		4	0.6682	0.4731	0.9932
		8	0.6794	0.4363	0.993
	BG + SMP+L	0	0.6566	0.4999	0.9929
		2	0.648	0.5388	0.9935
		4	0.6634	0.483	0.9932
		8	0.6761	0.4473	0.9933
	BG + SMP + SC	0	0.6664	0.4697	0.9926
		2	0.7057	0.3883	0.9908
		4	0.8079	0.1751	0.9957
		8	0.9201	0.0563	0.9994
	BG + SMP + L + SC	0	0.6566	0.4999	0.9929
		2	0.6641	0.4842	0.9932
		4	0.7167	0.3387	0.9938
		8	0.8201	0.1619	0.9962
YC-X11	BG + SMP	0	0.6687	0.4596	0.9931
		2	0.6858	0.4225	0.9933
		4	0.6736	0.4586	0.9929
		8	0.6913	0.4091	0.9933
	BG + SMP+L	0	0.6655	0.4758	0.993
		2	0.6722	0.4545	0.9929
		4	0.6684	0.4692	0.9932
		8	0.676	0.453	0.9931
	BG + SMP + SC	0	0.6687	0.4596	0.9931
		2	0.6777	0.4514	0.9941
		4	0.8847	0.078	0.9985
		8	0.9365	0.0384	0.9999
	BG + SMP + L + SC	0	0.6655	0.4758	0.9300
		2	0.662	0.506	0.9945
		4	0.7699	0.2374	0.9958
		8	0.8546	0.1161	0.9982

0.66 and 0.68, respectively. The addition of inoculate and time, which allowed fermentation to occur, changed the viscosity profile of the model yogurt with n values approaching those of Newtonian fluids. Model yogurt systems inoculated with YC-380 at 8 h had n = 0.82 for samples containing lactose, while inoculated samples without lactose were less pseudoplastic or more Newtonian (n = 0.92). This general trend was also observed in culture YC-X11 where inoculated samples with and without lactose showed n values of 0.85 and 0.94, respectively. The above data clearly indicated that in the presence of lactose, the damage to β-glucan molecules was minimized thereby maintaining higher viscosity and higher pseudoplasticity.

3.4. CONCLUSIONS

β-Glucan does not affect the fermentation efficacy of starter cultures YC-380 and YC-X11, but it can be broken down and utilized by starter cultures when lactose becomes a limiting source of nutrient during the fermentation process. Data suggest that YC-380 culture is not as effective as YC-X11 in hydrolyzing and depolymerizing β-glucan; therefore the former is more suitable in the production of β-glucan fortified yogurts.

In general, there were no significant differences ($p>0.05$) in viscosity at 12.9 s^{-1} in non-inoculated treatments at time 0, 2, 4, or 8 h. Significant differences ($p\leq0.05$) were observed between inoculated treatments measured at 12.9 s^{-1} at 4 h and at 8 h. There was a greater decrease in viscosity in samples that did not contain lactose; hence viscosity breakdown can be minimized by lactose addition.

Since demonstrated health benefits of β-glucan are attributed to its high aqueous viscosity, the present study suggested that better strategies are required to incorporate β-glucan into yogurt systems. Perhaps simple blending of β-glucan at the end of yogurt production, as the activity of the culture is reduced due to high acidity and lower levels of nutrients, will minimize the damage to the molecule and preserve its healthful, native properties.

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Chapter 4

β-GLUCAN ENRICHED YOGURT: PHYSICAL AND SENSORY CHARACTERISTICS[1]

4.1. INTRODUCTION

The reduction of fat in one's diet has long been a suggestion by the World Health Organization as well as the consensus of medical practitioners worldwide. The Food and Drug Administration (FDA) of the United States has stated that a diet low in saturated fat and high in dietary fiber has the benefit of decreasing the incidence of coronary heart disease (CHD) (Federal Register 2003). The FDA also acknowledges that soluble dietary fiber (β-glucan) from whole oats and α-amylase hydrolyzed oat bran or whole oat flour (Oatrim) have been clinically proven to reduce the risk of CHD and has approved health claims for products containing 0.75 g/serving β-glucan (Federal Register 2003). It is proven and accepted by the FDA that the key component in whole oats causing a reduction in blood total- and low density lipoprotein (LDL)-cholesterol levels is (1→3),(1→4)-β-D-glucan (β-glucan) (Federal Register 2003). β-Glucan (BG) is a soluble dietary fiber found in grains, namely barley and oat, which have been found to result in a number of beneficial health effects. Proven and scientifically established effects include a decrease in serum cholesterol (Behall and others 1997; Pomeroy and others 2001; Delaney and others 2003; Kerckhoffs and others 2003; Behall and others 2004), glycemic index (Braaten and others 1994; Wood, 1994; Cavallero and others 2002; Jenkins and others 2002; Hallfrisch and others 2003; Li and others 2003) as well as potential immunostimulatory properties (Estrada and others 1997; Yokoyama and others 1997; Estrada and others 1999; Cheung and Modak 2002).

Yogurt is a dairy product with increasing gains in the marketplace. Yogurt is low in lactose and high in bioavailable calcium thereby making it a desirable product for those who wish to increase calcium intake but may be limited due to lactose intolerance (Tamine and Robinson 1985; Ward and others 1999). In addition, as the relationship

[1]A version of this chapter is to be submitted to the Journal of Food Science for consideration for publication.

between intestinal microorganisms and health garner more research and understanding, products such as yogurt receive greater positive media attention making it a more sought-after product. There has been a reported growth of yogurt sales in Canada by 65% since the mid-1980's while the worldwide market was worth US$18.3 billion in 1994 (Byrne 1995; Chandan 1999; Euromonitor 2002). The incorporation of new flavors (prune, mango, vanilla-peach, etc.), variations on products (yogurt drinks, addition of granola, addition of probiotic bacteria, etc.), as well as new methods of packaging (squeeze tubes, etc.) have likely aided in increasing sales worldwide. The potential for addition of a fiber ingredient to an already healthful product such as yogurt can aid the general public in obtaining the 25-30 g of total dietary fiber per day that is recommended by Health Canada and the FDA (Canadian Food Inspection Agency 2003; Food and Drug Administration 2003). The general population currently falls short of this target at 15.6 g/day (National Health and Nutrition Examination Survey (NHANES III) 1988-1994).

Developing a functional food that maintains its original sensory characteristics while incorporating a functional ingredient, which adds a health benefit to the consumer is quite challenging. There has been a flux in the market of products with added fiber but palatability is difficult to achieve as it often leaves a gritty or otherwise undesirable mouthcoat or flavor. Research has been performed on the formulation of fermented products including the addition of fibers and/or non-traditional starting materials such as soymilk or oats, as well as the incorporation of other health-promoting components such as iron and protein into yogurt (Buono and others 1990; Hoyda and others 1990; Granata and Morr 1996; Fernández-García and McGregor 1997; Hekmat and McMahon 1997; Fernández-García and others 1998; Bekers and others 2001; Mårtensson and others 2001). The effects of barley β-glucan on the sensory characteristics of yogurt have not been reported.

Therefore, the objectives of this study were to determine the effect of low- and high-solubility barley β-glucan addition at 0.375 g/175 g serving and 0.75 g/175 g serving after one day and one week storage on appearance, flavor and textural attributes of yogurt as determined by trained and consumer panels, as well as via objective analysis.

The use of low- and high-solubility β-glucan was evaluated as it has been demonstrated that one of the main mechanisms for the health benefits obtained is due to the high viscosity of intestinal contents upon consumption of soluble fibers (Jenkins and others 1978; Tietyen and others 1995; Wood 2002). Therefore, it can be hypothesized that the high-solubility β-glucan would solubilize more readily in the body and would likely create a greater health benefit whereas the low-solubility product would likely create a product closer to the control in regards to texture. However, the specific effects on texture and appearance of the low- and high-solubility β-glucan in a yogurt system are unknown.

4.2. MATERIALS AND METHODS

4.2.1. Materials

Plain 2% yogurt (Astro, Edmonton, AB), which contained no added stabilizers and seedless strawberry jam (J.M. Smuckers (Canada) Inc.) were purchased from local grocers (Edmonton, AB). Carageenan (SeaKem CM 2610) was obtained from FMC Biopolymer (Philadelphia, PN) and low- and high-solubility β-glucan barley **Visco*fiber*®** (60.7% and 67.7% β-glucan w/w, as-is; 13.5% and 78.3% β-glucan solubility after holding at 37°C for 1 h, respectively) were obtained from Cevena Bioproducts Inc. (Edmonton, AB) and used as-is. β-Glucan (Mixed Linkage) Assay Kit, purchased from Megazyme International Ireland Ltd. (Wicklow, Ireland), was used to determine the purity of samples.

4.2.2. Yogurt production

All yogurts were processed the day or week before they were to be tested by panels and stored at refrigeration temperature (4°C) until served. All yogurt treatments were produced following identical methods in order to maintain the same level of stirring (Figure 4.1). Five yogurt treatments were prepared (Table 4.1) including: 1) Control; 2) 0.375 g low-solubility BG/ 175 g serving (0.375 LSBG); 3) 0.75 g low-solubility BG/ 175 g serving (0.75 LSBG); 4) 0.375 g high-solubility BG/ 175 g serving (0.375 HSBG); and 5) 0.75 g high-solubility BG/ 175 g serving (0.75 HSBG). Carrageenan, a gum commonly used in the dairy industry, was added to all treatments to improve mouthcoat

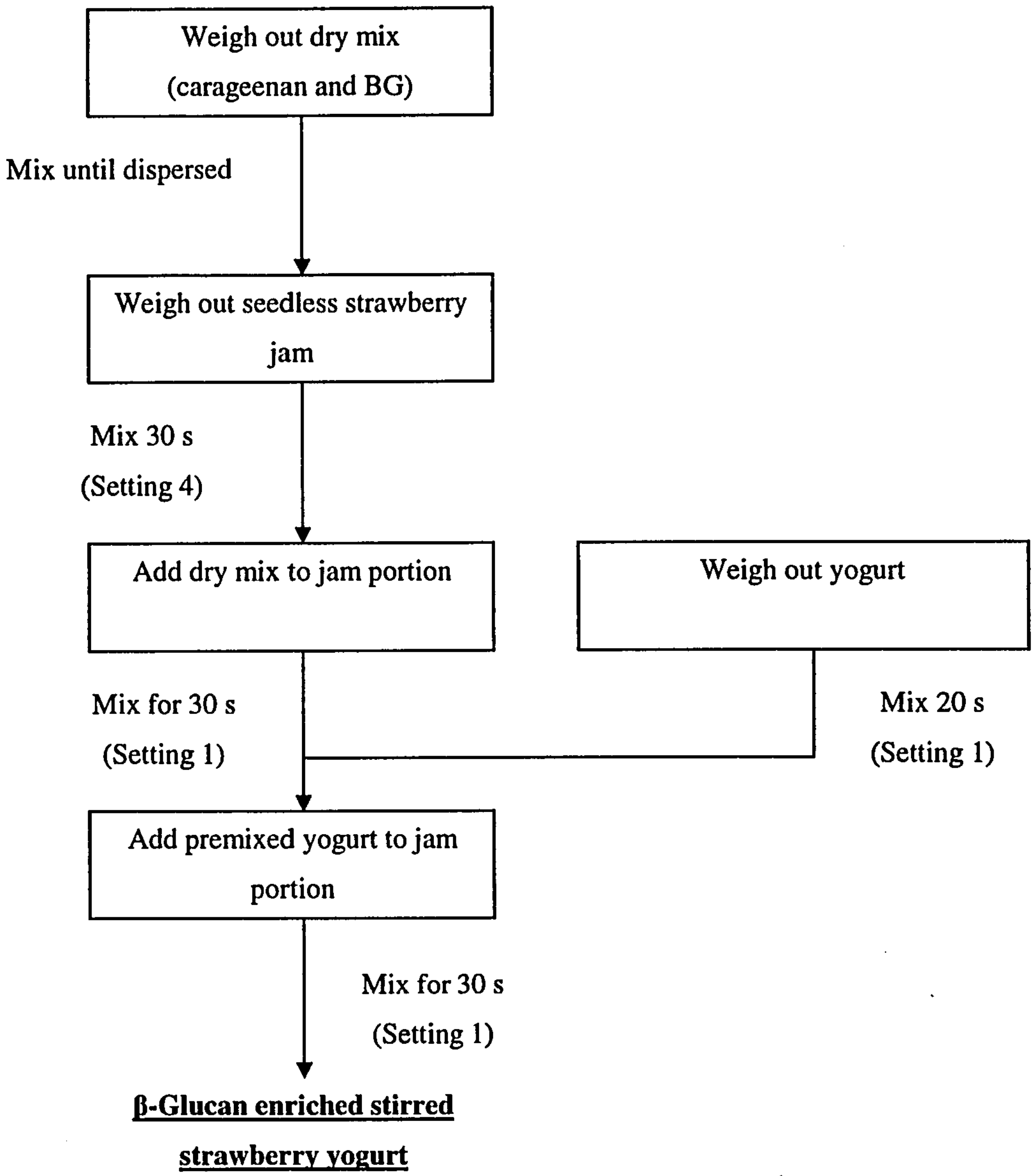

Figure 4.1. Procedure for yogurt production

Table 4.1. Yogurt control and treatment formulations (%, w/w)[1]

Ingredient	Control	Low-solubility β-glucan		High-solubility β-glucan	
		0.375 g BG (0.21% BG)	0.75 g BG (0.43% BG)	0.375 g BG (0.21% BG)	0.75 g BG (0.43% BG)
Strawberry Jam	22.84	22.76	22.68	22.77	22.69
Barley **Visco*fiber*®**	0.00	0.35	0.70	0.32	0.63
Carageenan	0.10	0.10	0.10	0.10	0.10
2% Yogurt	77.06	76.79	76.52	76.82	76.58

[1]Formulations based on a 175 g serving

and to decrease visible syneresis in the product as it reduces phase separation of proteins and polysaccharides that result from thermodynamic incompatibility. Preliminary laboratory scale formulations incorporating β-glucan at different stages in yogurt processing indicated that addition of β-glucan after completion of fermentation resulted in the most palatable yogurt product. Incorporation at the pasteurization stage, prior to starter culture addition and fermentation, yielded a yogurt product that was highly viscous, "ropy", lumpy, and generally unpleasant. The addition of β-glucan fiber after completion of fermentation yielded a product that was comparable to the original form. Therefore, it was decided that a locally purchased yogurt that did not contain any additional stabilizers would be used in order to maintain the same quality standards as well as for ease of use. Seedless strawberry jam was added to yogurt at approximately 23% in order to create a stirred strawberry yogurt. Several β-glucan levels were tested in the food lab in order to determine which dosage levels would allow products to remain palatable while delivering products with a high and low dosage level. The FDA has allowed health claims on soluble oat fiber products containing 0.75 g β-glucan per serving, hence that level was targeted. Levels up to 1.4 g β-glucan per serving were produced but these products became too viscous and had a very pronounced cereal flavor.

Dry ingredients consisting of carrageenan and low- or high-solubility β-glucan were initially weighed and mixed together prior to addition to yogurt. Yogurt was weighed out for the entire batch and mixed for 20 s in a KitchenAid Mixer using a whisk attachment (Model K45SS, KitchenAid Div., Hobart Corporation, Troy, OH) at setting 1 in order to achieve homogeneity for samples for that day. The strawberry jam portion for each treatment was also weighed out, mixed for 30 s at setting 4 in order to remove any lumps. The dry mixture was then added to the strawberry portion and mixed again for 30 s in order to disperse dry ingredients uniformly. Weighed out yogurt for the treatment was then added to the jam and dry mixture and a final mix of 30 s was performed to evenly distribute the jam and β-glucan throughout the yogurt in order to produce a stirred strawberry yogurt (Figure 4.1). Samples were then stored in airtight containers under refrigeration temperatures of 4°C for approximately 24 h prior to serving in order to allow for partial β-glucan solubilization. Samples for the 1 week storage study were produced in the same manner at the same time but stored separately at refrigeration temperatures until testing one week later.

4.2.3. Color

Samples of yogurt were analyzed for color using a Hunterlab (Labscan Spectrocolorimeter) LAB-XE Color Difference Meter (Hunter Associates Laboratory Inc., Reston, VA). Samples were weighed (10 g) into a petri dish with a diameter of 5 cm and triplicate readings were performed on each treatment as readings were taken with 2 subsequent rotations of 90°. Calibration of instrument was performed prior to measurements being taken using specially provided black and white calibration tiles (calibration values of 0 and 100, respectively). *L*-values correspond to lightness/darkness (100 = white, 0 = black); *a*-values to red/green (+ = redness, - = greenness); and *b*-values to yellow/blue (+ = yellowness, - = blueness).

4.2.4. Penetration tests

The force for penetration was determined on all treatments and their replicates using an Instron Universal Testing Machine (Model 4201, Instron Corp., Canton, MA) equipped with a 5 kg load cell. All samples were measured (30 g) into a container with a diameter of 6 cm and a height of 3 cm and then held at room temperature for 10 min prior to analysis. Samples were then penetrated once to 50% of the original height at a crosshead speed of 30 mm/min. Raw penetration force data were recorded as a measure of yogurt firmness for each day of sensory panel evaluation.

4.2.5. Viscosity

β-Glucan enriched yogurts of each treatment were sampled (7.05 g ± 0.01 g) in duplicate on the day of panelist evaluation. Viscosity was determined as a function of shear rate using a PAAR Physica UDS 200 rotational viscometer (Stuttgart, Germany) fitted with a DG 27 cup and bob with double gap geometry and Peltier heating system at a shear rate of 1-100 rpm (1.29-129 s^{-1}) and 10°C in the controlled shear rate mode.

4.2.6. Sensory analysis

4.2.6.1. Trained panel

For trained panels, the method of quantitative descriptive analysis (QDA) was utilized in order to train panelists in identifying and quantifying the intensity of sensory attributes via an anchored 15 cm line scale. This method ensured that the trained panelists themselves developed the terminology and tested the products repeatedly. Ten panelists were selected and trained from a group of 31 that were recruited and screened from the staff and students of the University of Alberta using standard sensory evaluation procedures (Meilgaard and others 1991). These procedures included a questionnaire and a taste test in order to determine sensory acuity. The questionnaire determined their availability, health status, food restrictions, comprehension of instructions, ability to generate descriptive terminology, and judgment of scaling. The taste test included the ability to identify dilute solutions of the 4 basic tastes (sweet, sour, bitter, salty) as well as a neutral sample, ability to identify increasing sucrose concentrations, and a dilute solution of 6-propylthiouracil (PROP), which was expectorated to determine if panelists had super tasting abilities. The selected panelists were trained for 4 weeks (4 one hour sessions per week) and evaluated the products in 6 evaluation sessions (30 min sessions). Panelists generated and agreed on terms and definitions (Table 4.2) for attributes describing appearance (smoothness), flavor (sweet, sour, strawberry, cereal), and texture (ropiness, viscosity, particle amount, mouthfeel) of the 5 stirred strawberry yogurt samples. Sample references representing different points on the line scale were also determined by the group and placed on the scale for panelist reference (Table 4.3).

Selected panelists who completed the training and product testing sessions were reimbursed for their time in gift certificates as well as with small treats at the end of each training or testing session in order to motivate and thank them for their continued participation.

Panelists, seated in individual booths, were presented with completely randomized trays with 30 mL each of the 5 yogurt treatments in 59.2 mL plastic cups (Solo Cup Company, Urbana, IL) placed in ice water baths created for each sample using styrofoam cups. This was done in order to maintain the temperature of all samples at

Table 4.2. Definition sheet and anchors of terms as generated by trained panel for evaluation on a 15 cm line scale

Attribute	Definition	Anchors
Appearance		
Smoothness	the absence of surface particles	None-extreme
Flavor		
Sweetness	the taste simulated by sucrose and other sugars	None-extreme
Sourness	the taste stimulated by acids	None-extreme
Strawberry	taste of a strawberry flavor	None-extreme
Cereal	flavor associated with various grains, character can be modified by specific grain and/or processing notes (e.g. toasted corn, raw rice, cooked wheat, etc.)	None-extreme
Texture		
Ropiness	the amount of stringiness perceived when the back of the spoon is brought to the surface of the yoghurt and pulled away	None-extreme
Viscosity	the thinness or thickness of a product	Not viscous-viscous
Particle amount	the relative number/amount of small particles in the mouth	None-extreme
Mouthcoat	amount of product that adheres to oral surfaces	None-extreme

Table 4.3. Reference samples and scores for yogurt trained panel

Sample	Attribute	Score [1]
2% (w/v) Sucrose solution	Sweetness	4.2
0.08% (w/v) Citric acid solution	Sourness	4.3
0.15% (w/v) Citric acid solution		12.2
25% (w/v) Smuckers strawberry jam solution	Strawberry	9.5
0.3% (w/v) LSBG heated solution	Cereal	10.0
1 cup Eagle brand condensed milk + 4 tsp cream	Viscosity	4.9
Jello vanilla pudding		10.8
¾ cup cream + 6.0 g Heinz Barley cereal + 2 tsp Eagle brand condensed milk, heated	Particle amount	7.4
Jello vanilla pudding	Mouthcoat	9.9

[1]Reference score on a 15 cm line scale

approximately 13°C. A complete randomized block design was used in all tests and samples were coded with random three-digit numbers. Panelists, who were seated in individual booths with fluorescent lighting, were also given unsalted crackers and a glass of distilled water with which to cleanse their palate. Panelists were not asked to expectorate samples. Data were entered using Compusense software, Version 3.6 (Compusense Inc., 1999) using a 15 cm line scale with the respective anchors. Instructions were given prior to each testing step and could be recalled by the panelists; in addition, panelists were made to wait 30 s between samples using a time delay function available in the Compusense program. Three replicates for fresh and storage study were performed with one replicate and evaluated on each day with a total of 6 days of sensory analysis (3 days for fresh samples, 3 days for 1 week stored samples).

4.2.6.2. Consumer panel

Consumer panelists were presented with 9-point hedonic scales in order to determine their opinions on appearance, flavor, texture, and overall liking. They were also asked to rank the order of their personal preference in addition to filling out a brief demographic survey.

Consumer panelists were recruited from the general population of the University of Alberta using posters and email as well as from an established database of previous panelists obtained from the sensory lab at the University of Alberta. Exclusion parameters included those under the age of consent and those with allergies or intolerances. The 5 strawberry yogurt treatments, with preparation and serving methods as described above, were presented to 82 panelists who were instructed to taste the product and mark their opinions on overall appearance, overall flavor, overall texture, and overall acceptability. Panelists were also asked to rank yogurts in the order of liking. Panelists were provided with unsalted crackers and distilled water with which they were instructed to cleanse their palates. There were also sections for them to make additional comments and a short demographic survey. They entered data via Compusense software, Version 3.6 (Compusense Inc., 1999) using a 9 point hedonic scale (scoring 9-1) with the following respective categories: like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much, and dislike extremely. Panelists were rewarded for their participation.

4.2.7. Statistical analysis

The study was replicated 3 times for fresh and stored samples for a total of 6 data sets. The analyses of variance for viscosity, color, and sensory panel data were performed using General Linear Model procedure of SPSS statistical software, Version 13.0 (SPSS Inc., 2004). Pearson's correlation analysis of trained panel data was also performed using SPSS software. Correlations were considered significant at $p \leq 0.05$. A completely randomized design was used to determine the main effects of treatment and a complete randomized block design was used to analyze results of the trained panel. Comparison of means was performed via Tukey's test at a significance level of $p \leq 0.05$. Box-plots of data were plotted and panelist data were eliminated if the data they provided were statistically determined to be an extreme case, that is, greater than 3 box lengths from upper or lower edge of the box-plot. No extreme cases were found in the following attributes: sweet, sour, strawberry, and viscosity. For the following attributes, the bracketed values represent the number of extreme cases that were removed from a possible total of 150 data points for each attribute: smoothness (4); cereal (3); ropiness (2); particle amount (1); and mouthcoat (6).

4.3. RESULTS AND DISCUSSION

4.3.1. Color evaluation

The Hunter Color Lab results (Table 4.4) showed no significant difference ($p>0.05$) in lightness (*L* value) between the 5 treatments in the fresh or the stored samples that had been kept under refrigeration conditions for 1 week. Degree of redness-greenness (*a* value) was affected by the amount and type of β-glucan addition. Control and 0.375 LSBG were significantly more red ($p \leq 0.05$) compared to the 0.75 LSBG, 0.375 HSBG, and 0.75 HSBG fresh samples. The stored samples were similar ($p>0.05$) in redness. There was a significant difference ($p \leq 0.05$) in the degree of yellowness-blueness (*b* value) between the control, 0.375 LSBG, 0.75 LSBG and compared to 0.375 HSBG and 0.75 HSBG of the fresh samples with the HSBG samples being more yellow.

Table 4.4. Hunter color values[1] for fresh and stored strawberry yogurt treatments

	Fresh[2]			Stored[3]		
Treatment	***L***	***a***	***b***	***L***	***a***	***b***
Control	55.69 [a]	10.81 [a]	8.95 [a]	55.91 [a]	10.23 [a]	8.77 [a]
0.375 LSBG	54.94 [a]	10.78 [a]	8.92 [a]	55.38 [a]	9.90 [b]	8.74 [a]
0.75 LSBG	54.99 [a]	10.48 [b]	8.92 [a]	55.08 [a]	9.63 [c]	8.32 [b]
0.375 HSBG	55.90 [a]	10.46 [b]	9.17 [b]	55.70 [a]	9.57 [c]	9.11 [c]
0.75 HSBG	55.50 [a]	10.43 [b]	9.27 [b]	55.34 [a]	9.67 [c]	9.24 [c]

[1]L = lightness/darkness (100 = white, 0 = black); a = red/green (+ = redness, - = greenness); b = yellow/blue (+ = yellowness, - = blueness)
[2]Samples stored overnight at refrigeration temperatures
[3]Samples stored for 1 week at refrigeration temperatures
[a, b, c]Means in the same column with the same letters are not significantly different at p>0.05

After 1 week storage, there were no significant differences ($p>0.05$) between the control and 0.375 LSBG sample; no significant differences between the 0.375 HSBG and 0.75 HSBG; while 0.75 LSBG was significantly different from all samples. In general, the *b* values declined with time resulting in less yellowness in the samples. However, there were no visible differences between the 5 treatment samples and the trained panelists did not feel that this was an attribute that needed to be evaluated in a panel setting.

4.3.2. Penetration force

Comparing the yogurt samples in terms of penetration force between the 3 testing days showed no significant differences between days, storage time, or treatments ($p\leq 0.05$). The yogurt gel was relatively soft for analysis by the Instron, hence raw data obtained were extracted and the maximum force required to penetrate the gel was tabulated (Table 4.5). The Instron readings were similar ($p>0.05$) despite the treatment, hence it was postulated that these were solely attributed to differences in the yogurt base used for each production day. Comparison of the 5 fresh treatments (Figure 4.2) showed that there was a decrease in measured force over the 3 days of yogurt production.

4.3.3. Viscosity analysis

The texture of a product is very important in consumer acceptance of a product. There were no significant differences in viscosity for treatments between evaluation days. Rheological variations can be attributed to the physical nature of yogurt (total solid content, milk composition, fat content, bacterial composition etc.) and processing conditions (homogenization, pre-treatment of milk, fermentation temperature, etc.) (De Lorenzi and others 1995; Skriver and others 1999). It was assumed that the viscosity of the yogurt purchased from the grocers would be consistent; however, any minor differences in viscosity within a sample (eg. control at day 1, day 2 or day 3) could be attributed to different production batches of purchased yogurt that had been used for each day's test production. As seen in Figure 4.2, there were definite differences between treatments with the samples with highest dosages and high-solubility treatments resulting in higher viscosity levels (0.75 HSBG> 0.375 HSBG> 0.75 LSBG> 0.375 LSBG> Control). There was a significant difference ($p\leq 0.05$) between control, 0.375 LSBG, and

Table 4.5. Penetration force at 50% penetration of original height

Treatment	Maximum penetration force (kgF)	
	Fresh	Stored
Control	0.001078[a]	0.000988[a]
0.375 LSBG	0.001078[a]	0.001080[a]
0.75 LSBG	0.001483[a]	0.001080[a]
0.375 HSBG	0.001045[a]	0.001305[a]
0.75 HSBG	0.001448[a]	0.001527[a]

Means with the same letter are not significantly different at p>0.05.

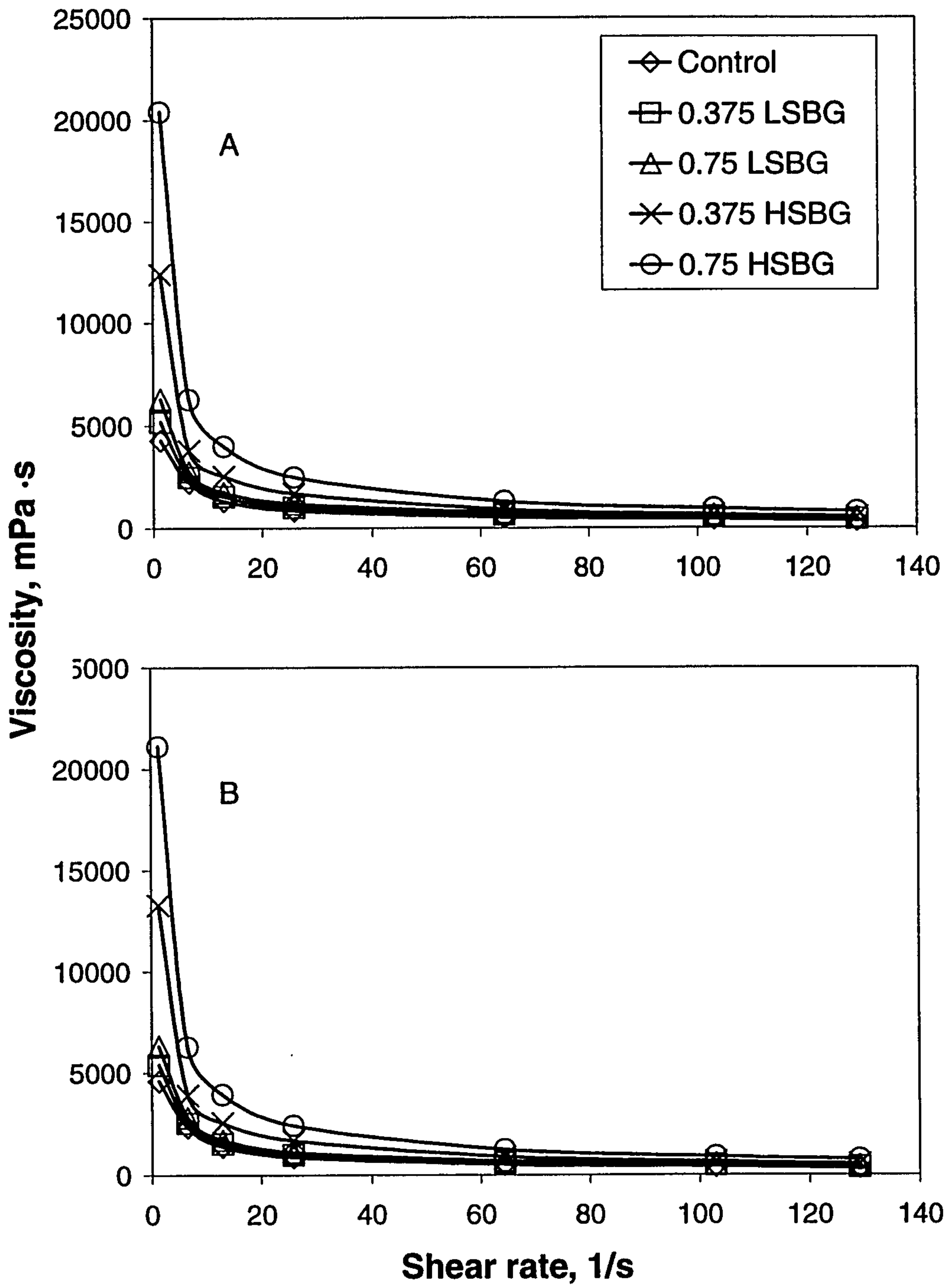

Figure 4.2. Viscosity of yogurt treatments one day (A) and one week (B) after production

0.75 LSBG from 0.375 HSBG and from 0.75 HSBG at a shear rate of 12.9 s^{-1} (Figure 4.2). Analysis at 12.9 s^{-1} was selected as it has been reported that the shear rate in the mouth to range from 10-50 s^{-1} depending on the viscosity of the product with a shear rate of 10 s^{-1} showing a better correlation with perceived thickness (Cutler and others 1983). Refrigerated storage of the stirred yogurt treatments showed no significant differences ($p>0.05$) between the viscosity of fresh and stored samples.

The Power Law model describes the pseudoplastic behavior of systems and can be shown mathematically as follows:

$$S=cR^n$$

where S is shear stress (N/m^2), c is the consistency coefficient, R is the shear rate (s^{-1}), and n is the flow behavior index. It appears that the yogurts were highly pseudoplastic with $n<<1$. The addition of increasing dosages of β-glucan (0.375 g to 0.75 g) and increased solubility of the product (low- to high-solubility) decreased the flow behavior index (n) (Table 4.6) indicating that the products were becoming more pseudoplastic. Hence, the viscosity was becoming more dependent on the level of shear force applied as the β-glucan was more soluble and increased in dosage. Also evident in Table 4.6 was the increasing consistency index (c) for the yogurt treatments, which clearly indicated that the viscosity was increasing with the aforementioned trend.

4.3.4. Trained panel

There were no significant differences in yogurt samples between evaluation days (i.e. replication effect); hence statistical analysis was run without including this factor as a block.

Data presented in Tables 4.7 and 4.8 revealed that control yogurt samples and 0.375 LSBG presented to panelists fresh and after 1 week refrigerated storage showed no significant differences ($p>0.05$) in appearance (smoothness), flavor (sweet, sour, strawberry), or in the textural attributes of ropiness and viscosity. However, the attributes of cereal flavor, particle amount, and mouth coat were significantly affected by the presence of low-solubility β-glucan.

Table 4.6. Flow behavior index and consistency index for yogurt systems with β-glucan addition.

Time	Treatment	Flow Behavior Index, (n)	Consistency Index, (c)	R^2
	Control	0.4298	5.6984	0.9938
	0.375 LSBG	0.4495	6.4424	0.9958
Fresh[1]	0.75 LSBG	0.4487	7.5478	0.9955
	0.375 HSBG	0.3296	14.4200	0.9925
	0.75 HSBG	0.2981	24.2650	0.9972
	Control	0.4116	6.1699	0.9931
	0.375 LSBG	0.4155	6.9443	0.9956
Stored[2]	0.75 LSBG	0.4134	8.0653	0.993
	0.375 HSBG	0.3130	15.328	0.9907
	0.75 HSBG	0.2801	25.073	0.9963

[1]Samples stored overnight at refrigeration temperatures
[2]Samples stored for 1 week at refrigeration temperatures

Table 4.7. Trained panel analysis results[1] of 5 fresh[2] yogurt samples

Attribute	Control	Low-solubility β-glucan		High-solubility β-glucan		SEM[3]
		0.375g BG	0.75g BG	0.375g BG	0.75g BG	
APPEARANCE						
Smoothness	1.92[a]	3.05[a]	5.00[b]	8.31[c]	12.07[d]	0.345
FLAVOR						
Sweet	7.56[a]	7.29[a]	7.10[a]	7.15[a]	7.34[a]	0.236
Sour	6.67[a]	6.22[a]	6.98[a]	5.87[a]	5.00[a]	0.231
Strawberry	5.81[a]	5.01[a]	5.49[a]	5.64[a]	5.04[a]	0.199
Cereal	1.01[a]	2.22[a]	4.02[b]	4.10[b]	5.44[c]	0.226
TEXTURE						
Ropiness	1.55[a]	2.23[a]	3.45[b]	10.10[c]	12.73[d]	0.392
Viscosity	2.14[a]	3.26[ab]	4.23[b]	7.70[c]	9.86[d]	0.270
Particle Amount	1.65[a]	3.14[b]	4.58[c]	4.99[c]	6.55[d]	0.236
Mouthcoat	2.02[a]	2.79[b]	4.14[c]	7.07[d]	9.19[e]	0.259

[1]15 cm line scale with anchor points at 0= none (smoothness, sweetness, sourness, strawberry, cereal, ropiness, particle amount, mouthcoat), not viscous; 15= extreme (smoothness, sweetness, sourness, strawberry, cereal, ropiness, particle amount, mouthcoat), viscous

[2]Samples stored overnight at refrigeration temperatures

[3]SEM = Standard error of the mean

[a-e] Means in the same row with the same letter are not significantly different at $p>0.05$

Table 4.8. Trained panel analysis results[1] of 5 yogurt samples stored for 1 week at refrigerated temperatures

Attribute	Control	Low-solubility β-glucan 0.375g BG	Low-solubility β-glucan 0.75g BG	High-solubility β-glucan 0.375g BG	High-solubility β-glucan 0.75g BG	SEM[2]
APPEARANCE						
Smoothness	1.91 [a]	2.83 [a]	4.49 [b]	7.26 [c]	11.18 [d]	0.321
FLAVOR						
Sweet	7.25 [a]	7.12 [a]	6.74 [a]	6.95 [a]	6.48 [a]	0.228
Sour	6.20 [a]	6.69 [a]	6.36 [a]	5.08 [a]	5.68 [a]	0.221
Strawberry	5.42 [a]	5.62 [a]	4.20 [a]	4.90 [a]	4.68 [a]	0.180
Cereal	1.40 [a]	2.14 [a]	3.90 [b]	4.32 [b]	5.61 [c]	0.236
TEXTURE						
Ropiness	1.62 [a]	2.03 [a]	2.66 [a]	8.70 [b]	12.15 [c]	0.372
Viscosity	2.15 [a]	2.83 [ab]	3.85 [b]	6.46 [c]	9.32 [d]	0.256
Particle Amount	1.54 [a]	3.00 [b]	4.51 [c]	4.69 [c]	6.57 [d]	0.244
Mouthcoat	1.69 [a]	2.68 [ab]	3.26 [b]	5.94 [c]	8.36 [d]	0.246

[1]15 cm line scale with anchor points at 0= none (smoothness, sweetness, sourness, strawberry, cereal, ropiness, particle amount, mouthcoat), not viscous; 15= extreme (smoothness, sweetness, sourness, strawberry, cereal, ropiness, particle amount, mouthcoat), viscous

[2]SEM= Standard error of the mean

[a-d] Means in the same row with the same letter are not significantly different at $p>0.05$

Appearance of smoothness was defined by the group as the absence of surface particles. The trained panel sensory scores indicated that increasing amounts and solubility of the β-glucan resulted in a greater appearance of round particles. The scores for the fresh samples ranged on a 15 cm scale from 1.92 for the control to 12.07 for the 0.75 HSBG sample. It can be postulated that an increase in solubility resulted in greater absorption of moisture by the fiber particles, thus these particles expanded to the point where they were visually detectable. An increase in fiber addition simply made this effect more obvious. The effect of β-glucan addition at low and high concentrations using the low- or high-solubility product, had no significant effect ($p>0.05$) on the flavor attributes of sweetness, sourness, or strawberry flavor. However, as expected, cereal flavor was significantly affected ($p\leq 0.05$) by increasing dosage and cereal flavor became increasingly higher for treatments containing high-solubility β-glucan (Control = 0.375 LSBG < 0.75 LSBG = 0.375 HSBG < 0.75 HSBG). The greater β-glucan dosage resulted in a more intense cereal flavor. In addition, the high-solubility product also produced higher cereal flavor intensity; this is likely due to the fact that the solubilization of β-glucan resulted in flavor compounds or volatiles present in the fiber ingredient being dissolved in the yogurt.

Textural attributes also followed this trend of increasing dosage and solubility of β-glucan resulting in greater intensities of ropiness, viscosity, particle amount, and mouthcoat. These results were confirmed via viscosity measurements. Fernández-Garcia and McGregor (1997) found that addition of a number of insoluble fibers, including corn, oat, soy, sugar beet and rice, resulted in a grainy and gritty texture. The increase in apparent viscosity was attributed to "interactions between exogenous hydrocolloids and dairy proteins". The long molecular strands of β-glucan may have resulted in a greater mouthfeel and ropiness as these chains would tend to interact in the long linear β-(1→4) sections of the β-glucan polymer. Additionally, β-glucan has the capability of forming gels and thus can form networks, which can trap and immobilize liquids as well as trapping the dairy proteins in order to create a more rigid structure (Burkus and Temelli 1999).

The storage time, one day after production (fresh) and after 1 week refrigerated storage, was determined to only significantly ($p\leq 0.05$) effect the appearance of smoothness, ropiness, viscosity, and mouthcoat. These attributes decreased upon storage, for example, 0.75 LSBG initially had a viscosity of 4.23 mPa·s. After 1 week of refrigerated storage, it had declined to 3.85 mPa·s. As shown in a separate study (Chapter 3), molecular weight of β-glucan can be broken down by yogurt starter cultures. It appears that with time, the cultures are utilizing β-glucan as a nutrient source and as a result, are hydrolyzing the β-glucan and decreasing the viscosity (Chapter 3). This data can be supported by the viscosity measurements performed, which showed a decrease in viscosity after 1 week refrigerated storage. The effects of β-glucan hydrolysis also resulted in a change in the ropiness and mouthcoat as it can be hypothesized that a change in molecular weight changes the way in which the molecules slide across a surface such as the tongue.

Correlation analysis as seen in Table 4.9 showed that the appearance of smoothness in the yogurt was significantly ($p \leq 0.05$) affected positively by increasing cereal flavor, ropiness, viscosity, particle amount and mouthcoat. Sweetness was affected by strawberry and cereal flavors while increasing sweetness resulted in a significant decrease in sourness. Increased sourness also resulted in a decrease in strawberry flavor and viscosity, and a greater strawberry flavor in the yogurts was correlated with a decrease in cereal flavor. Sourness has generally been linked to flavor with a preference of lower acid products (Ott and others 2000). Although there were no significant differences in sourness as detected by the trained panel, there was a decrease in sourness of the high-solubility product and a correlating decrease in strawberry flavor. An increase in cereal flavor was positively correlated with an increase in ropiness, viscosity, particle amount, and viscosity. Although trained panelists did not find significant differences between sweetness, sourness, and strawberry flavors, correlation data prove that there was an effect on the flavor profile of the yogurts. For example, as the sourness increased, viscosity apparently decreased. As observed, a change in viscosity is caused by the addition of the β-glucan; hence, the greater the β-glucan addition, the greater the viscosity. Therefore, it can be concluded from this data that greater addition of β-glucan resulted in a decrease in sourness, which in turn can be correlated to an increase in sweetness and strawberry flavor. All the textural attributes were positively correlated at a significance level of $p \leq 0.05$ with each other. This correlation shows that increasing

Table 4.9. Correlation analysis of yogurt attributes as determined by trained panel sensory analysis

Pearson Correlation	Smoothness	Sweet	Sour	Strawberry	Cereal	Ropiness	Viscosity	Particle Amount	Mouthcoat
Smoothness	1	0.033	-0.068	-0.055	0.543**	0.898**	0.800**	0.597**	0.783**
Sweet	0.033	1	0.431**	0.436**	0.138**	0.020	0.083	0.033	0.038
Sour	-0.068	-0.431**	1	-0.241**	-0.020	-0.101	-0.118*	0.093	-0.032
Strawberry	-0.055	0.436**	-0.241**	1	-0.162**	-0.038	-0.033	-0.037	-0.086
Cereal	0.543**	0.138**	-0.020	-0.162**	1	0.526**	0.553**	0.423**	0.518
Ropiness	0.898**	0.020	-0.101	-0.038	0.526**	1	0.835**	0.542**	0.848**
Viscosity	0.800**	0.083	-0.118*	-0.033	0.553**	0.835**	1	0.600**	0.821**
Particle Amount	0.597**	0.033	-0.093	-0.037	0.423**	0.542**	0.600**	1	0.481**
Mouthcoat	0.783**	0.038	-0.032	-0.086	0.518	0.848**	0.821**	0.481**	1

* Correlation is significant at the $p \leq 0.05$ level (2-tailed)

** Correlation is significant at the $p \leq 0.01$ level (2-tailed) presence of β-glucan led to a greater cereal flavor and a greater change in textural attributes.

In general, significant effects (smoothness, cereal flavor, ropiness, particle amount, viscosity, and mouthcoat) as determined by the trained panel were more pronounced for samples containing elevated concentrations of high-solubility β-glucan.

4.3.5. Consumer panel

The 82 panelists, consisted of University of Alberta staff and students, were representative of a wide range of ages and included a greater percentage of females (Table 4.10). Although price point analysis was not performed, of the 82 panelists, 66.7% indicated on the demographic survey that they consumed yogurt daily or at least once a week and 86.4% would purchase a fiber enriched yogurt if available in the marketplace.

Results generated by the consumer panel (Table 4.11, Figure 4.3) suggested that there were no significant differences ($p>0.05$) in appearance between yogurt treatments. No significant differences in flavor were detected in the control, 0.375 LSBG, or 0.75 LSBG and these placed into the hedonic scale at "like moderately" to "like slightly" (Figure 4.4). However, flavor of the treatments containing the 0.375 g or 0.75 g per serving of high-solubility β-glucan was rated significantly lower than that of the control at 5.8 and 4.8, respectively (Table 4.11, Figure 4.4). These results correspond to "neither like nor dislike" (5) and "like slightly" (6). The addition of high-solubility β-glucan with increasing concentrations appeared to cause a detriment to flavor. Texture (Figure 4.5) was also affected negatively by increasing concentrations of β-glucan with higher concentrations of high-solubility product leading to the most deleterious effects. Overall acceptability scores (Figure 4.6) indicated that the addition of a low-solubility β-glucan concentrate had no significant effect ($p>0.05$) on overall liking as compared to the control product. However, addition of high-solubility β-glucan at increasing levels decreased the degree of liking significantly ($p\leq0.05$). Panelists were asked to rank products (Figure 4.7) from like most to like least (1-5) with the results demonstrating that the increase in dosage and solubility decreased liking. Comments from consumer panelists can be found in Appendix B.

Table 4.10. Consumer panel demographic information

Gender	%
Male	32.1
Female	67.9
Age range	**%**
18-24	50.6
25-30	25.9
31-40	9.9
41-50	3.7
51+	9.9
Frequency of consumption	**%**
At least once a day	28.4
At least once a week	38.3
At least once a month	24.7
At least once every 3 months	8.6
I never consume this product	0
Would you purchase a fiber enriched yogurt if available in market?	**%**
Yes	86.4
No	13.6

Table 4.11. Consumer panel sensory results[1] on 5 fresh yogurt treatments (n= 82)

	Appearance	Flavor	Texture	Overall Acceptability
Control	6.7[a]	7.1[a]	7.3[a]	7.0[a]
0.375 LSBG	6.5[a]	7.1[a]	6.9[ab]	6.9[a]
0.75 LSBG	6.4[a]	6.8[a]	6.4[b]	6.6[a]
0.375 HSBG	6.4[a]	5.8[b]	5.5[c]	5.6[b]
0.75 HSBG	6.4[a]	4.8[c]	4.4[d]	4.5[c]
SEM[2]	0.116	0.156	0.155	0.151

[1]Numbers ranked on an anchored 9-point hedonic scale (1= dislike extremely, 9= like extremely)
[2]SEM = Standard error of the mean
[a-c] Means in the same column with the same letter are not significantly different at p>0.05

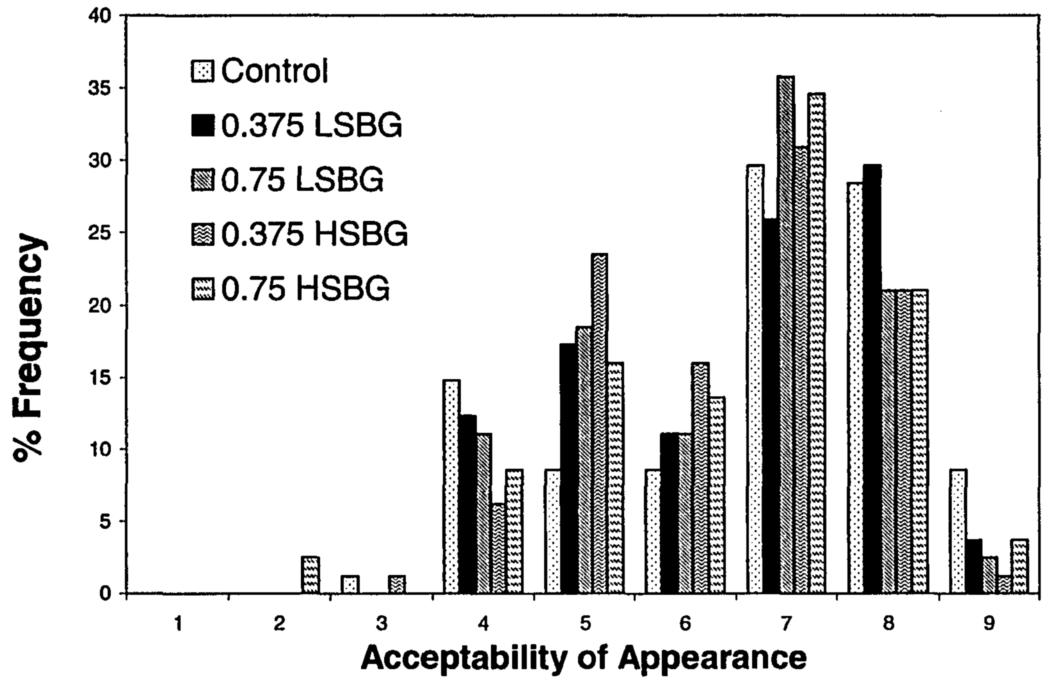

Figure 4.3. Frequency distribution of acceptability of yogurt appearance by a consumer panel, 1=dislike extremely, 9= like extremely

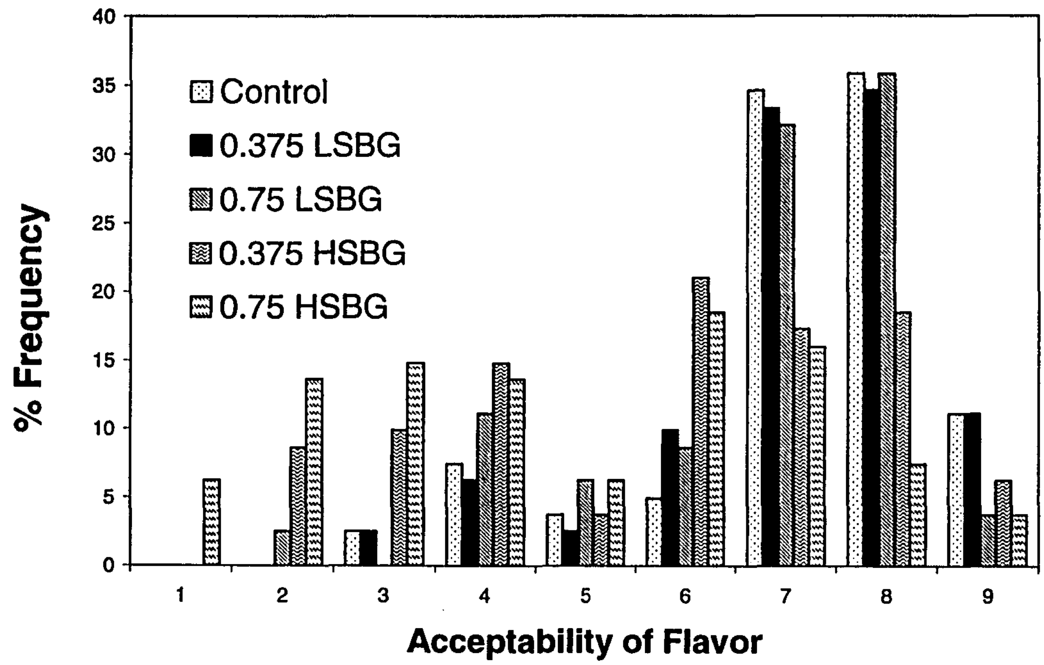

Figure 4.4. Frequency distribution of acceptability of yogurt flavor by a consumer panel, 1=dislike extremely, 9= like extremely

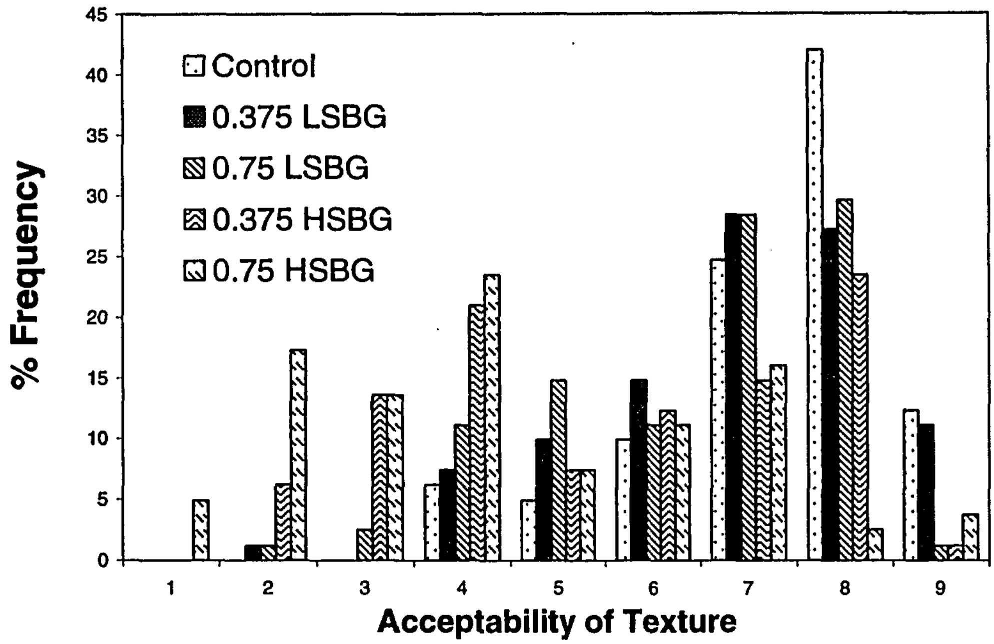

Figure 4.5. Frequency distribution of acceptability of yogurt texture by a consumer panel, 1=dislike extremely, 9= like extremely

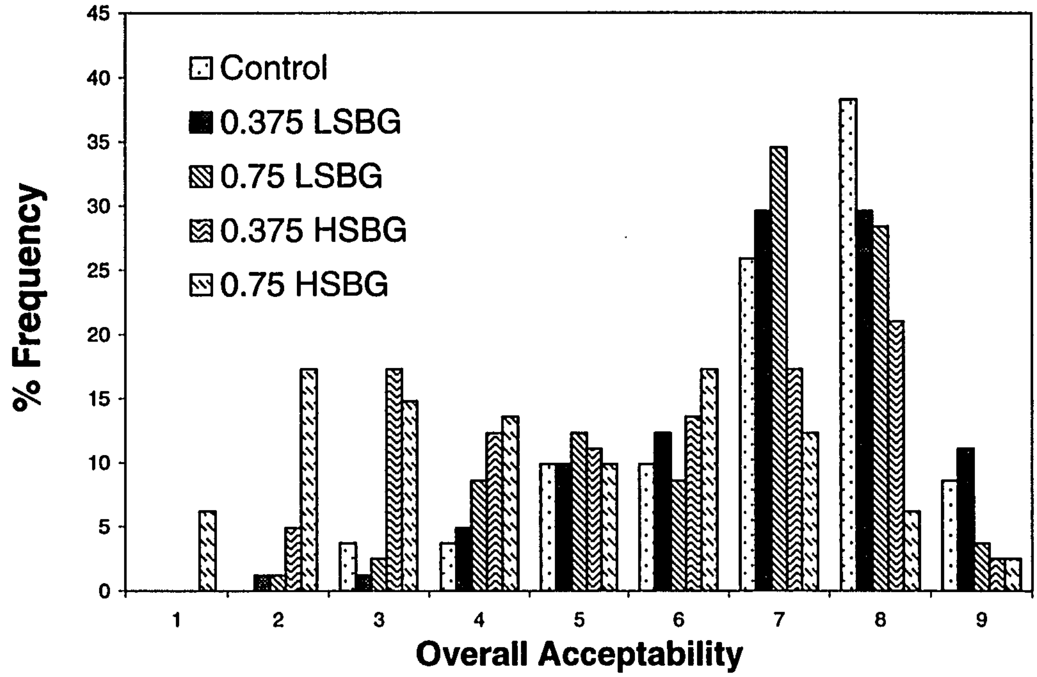

Figure 4.6. Frequency distribution of overall acceptability of yogurt by a consumer panel, 1=dislike extremely, 9= like extremely

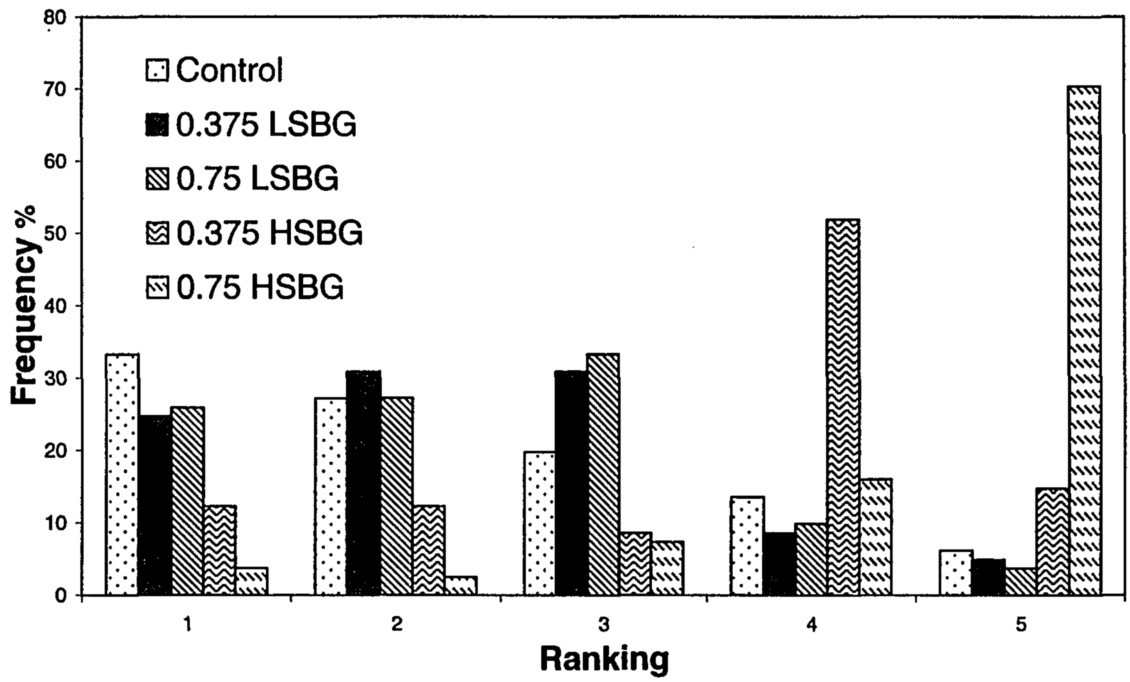

Figure 4.7. Frequency distribution of ranking of yogurt by a consumer panel, 1= like most, 5= like least

Panelists consistently found that increasing dosages and solubility of the β-glucan product resulted in undesirable changes in textural characteristics as well as in the degree of liking.

4.4. CONCLUSIONS

The greater the addition of a high-solubility β-glucan gum the greater was the increase in viscosity as detected by viscosity measurements as well as a trained panel. In addition, a trained panel found that the β-glucan addition caused a significant change in the flavor (cereal flavor) and texture profile (viscosity, mouthcoat, ropiness) of a stirred strawberry yogurt. In general, the greater change in the flavor/texture profile resulted in a greater decrease in the liking of that attribute by the consumer panel. The low-solubility β-glucan did not result in as great a difference in attributes and trained panelists found little to no differences between the 0.375 g/175 g serving product as compared to the control. Consumer panel found the overall acceptability of the low-solubility β-glucan products to be similar to that of the control and ranked these products at "like moderately". Further formulation and price point analysis of this product would greatly fill a niche in the marketplace as consumers have indicated that they would consider purchasing a fiber-enriched yogurt product should there be one in the marketplace.

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Chapter 5

β-GLUCAN ENRICHED ICE CREAM: PHYSICAL AND SENSORY CHARACTERISTICS[1]

5.1. INTRODUCTION

The level of total dietary fiber consumption in the average U.S. diet is currently at 15.6 g/day (National Health and Nutrition Examination Survey (NHANES III) 1988-1994). This level falls significantly below the recommended levels of 25-30 g as suggested by Health Canada and the Food and Drug Administration (Canadian Food Inspection Agency 2003; Food and Drug Administration/Center for Food Safety and Applied Nutrition 2004). Currently, the majority of chronic illnesses and issues of health affecting North Americans can be partially or wholly related to the effect of diet (Cordain and others 2005). Dairy products generally contain little or no fiber but constitute a major portion of ones diet, hence the addition of fiber to a category otherwise devoid of such a component would be highly desirable.

Ice cream can be described as a frozen foam system consisting of fat globules, protein, sugar, frozen and liquid water, emulsifier and air bubbles (Prentice 1992; Aime and others 2001). Any change in the composition of this mixture can influence the appearance, texture and/or flavor of the product, which in turn can influence sales. For example, fat will affect texture as well as flavor by interacting with sugars and proteins (Stampanoni-Koeferli and others 1996; Byars 2002). This very scientific definition of ice cream results in a very delicious and highly desirable product consumed worldwide. In 2004, ice cream had an economic impact in Canada of CDN$2.0 billion and in the U.S. of US$14.0 billion (Euromonitor 2002).

Reduced-fat frozen desserts including ice cream and frozen yogurts have been studied by various researchers. Aime and others (2001) concluded that low fat vanilla ice creams, utilizing modified pea starch as a fat replacer, resulted in lower perceived viscosity, smoothness and mouth coat. More recent studies investigated the development of ice cream or frozen desserts that contain components, which may result in additional

[1]A version of this chapter is to be submitted to the Journal of Food Science for consideration for publication.

health benefits. Salem and others (2003) developed a low fat and low sugar ice cream by the addition of Jerusalem artichoke, a vegetable rich in inulin. These researchers assessed the organoleptic properties and found that the addition of Jerusalem artichoke improved the body and texture of the ice cream with little effect on flavor.

β-Glucan ((1→3),(1→4)-β-D-glucan) is a soluble fiber found in grains, namely barley and oat that has been linked to a variety of beneficial health effects. It seems likely that the combination of these two categories can produce an appealing product, which can be beneficial to ones health as well as feasible in the growing functional foods marketplace. However, the literature lacks information on the incorporation of β-glucan to ice cream products.

Therefore, the objectives of this study were to determine the effect of β-glucan (BG) addition at 0.375 g/125 g serving and 0.75 g/125 g serving on appearance, flavor and textural attributes of ice cream as determined by trained and consumer panels, as well as via objective analysis.

5.2. MATERIALS AND METHODS

5.2.1. Materials

Barley **Visco*fiber*®** (60.7% β-glucan w/w as-is basis; 13.5% β-glucan solubility after holding at 37°C for 1 h), a concentrate of β-glucan obtained from Cevena Bioproducts Inc., was used as-is (Edmonton, AB). A low-solubility product was used as the ice cream mix would be pasteurized thereby allowing for greater solubilizaion of β-glucan. β-Glucan content was determined according to the β-Glucan (Mixed Linkage) Assay Kit, purchased from Megazyme International Ireland Ltd. (Wicklow, Ireland). Pasteurized and homogenized milk (2% fat), skim milk powder, granulated white sugar, whole eggs, and artificial vanilla flavoring were purchased from a local supermarket (Edmonton, AB). Carageenan (SeaKem CM 2610) was obtained from FMC Biopolymer (Philadelphia, PA).

5.2.2. Ice cream production

All ice creams were processed in a Gilson, Taylor ice cream machine (Patent Design, Model 6F, Rockton, IL) 8 days prior to being tested by panelists as shown in

Figure 5.1. Samples were then stored at -20°C until just prior to serving at which point they were tempered in a -4°C freezer for 10 min. Three ice cream treatments were prepared using the recipes given in Table 5.1 and they were: 1) Control 2) 0.375 g BG/125 g serving (0.375 BG); and 3) 0.75 g BG/125 g serving (0.75 BG). Carrageenan, a gum commonly used in the dairy industry, was added to all treatments to improve mouthcoat and to decrease visible syneresis in the product as it reduces phase separation of proteins and polysaccharides that result from thermodynamic incompatibility.

5.2.3. Color

Samples of ice cream were analyzed for color using a Hunterlab (Labscan Spectrocolorimeter) LAB-XE Color Difference Meter (Hunter Associates Laboratory Inc., Reston, VA). Samples were melted at room temperature then weighed (10 g) into a petri dish with a diameter of 5 cm. Triplicate readings were recorded for each treatment as readings were taken with 2 subsequent rotations of 90°. Calibration of the instrument was performed prior to sample measurements using specially provided black and white calibration tiles (calibration values of 0 and 100, respectively). *L*-values correspond to lightness/darkness (100 = white, 0 = black); *a*-values to red/green (+ = redness, - = greenness); and *b*-values to yellow/blue (+ = yellowness, - = blueness).

5.2.4. Compression force

The force for compression was determined in duplicate on 2.5 cm x 2.5 cm (1 in x 1 in) cubes using the Instron Universal Testing Machine (Model 4201, Instron Corp., Canton, MA) equipped with a 5 kg load cell. All samples were held at room temperature for 10 min prior to analysis and compressed once to 50% of the original height at a crosshead speed of 30 mm/min.

5.2.5. Viscosity

β-Glucan enriched ice creams (7.05 g ± 0.01 g) were sampled in duplicate after allowing the samples to melt at room temperature. Viscosity was determined as a function of shear rate using a PAAR Physica UDS 200 rotational viscometer (Stuttgart, Germany) fitted with a DG 27 cup and bob with double gap geometry and Peltier heating system at a shear rate of 1-100 rpm (1.29-129 s^{-1}) at 15°C in the controlled shear rate

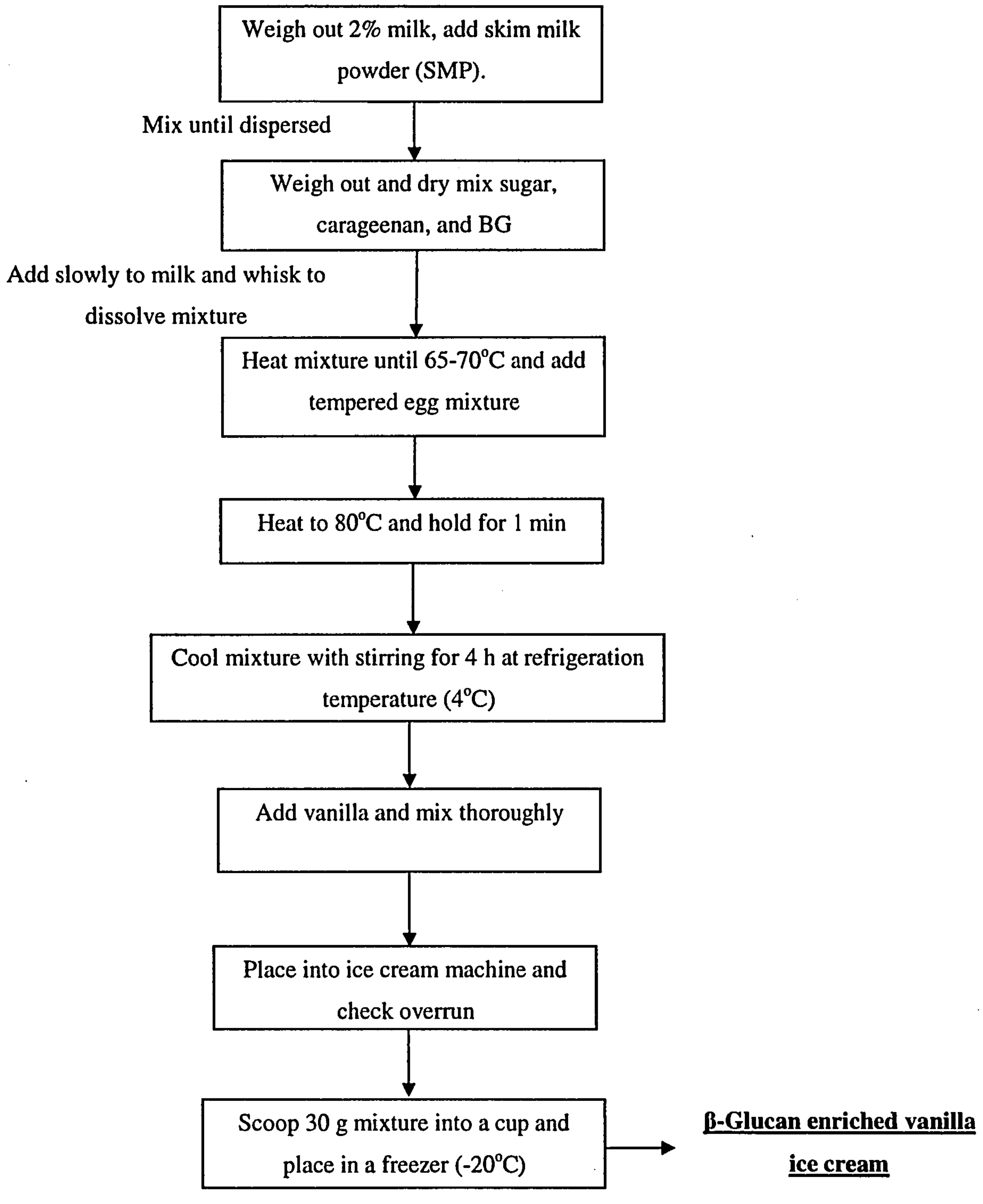

Figure 5.1. Procedure for ice cream production

Table 5.1. Ice cream control and treatment formulations (%, w/w)[1]

Ingredient (g)	Control	0.375 BG (0.3% BG)	0.75 BG (0.6% BG)
2% milk	80.84	80.51	80.19
Skim milk powder	4.94	4.92	4.90
Sugar	11.55	11.50	11.46
Carrageenan	0.08	0.08	0.08
Barley Visco*fiber*®	0.00	0.40	0.80
Egg	1.97	1.96	1.95
Vanilla	0.63	0.63	0.62

[1]Formulation based on a 125 g serving size

mode.

5.2.6. Rate of melt

Methodology for the determination of rate of melt was adapted from Abd El-Rahman and others (1997). Samples of each treatment condition were uniformly cut into 2.5 cm x 1.3 cm (1 in x 0.5 in) cubes, and then returned to a -4°C freezer for 10 min to simulate panelist conditions. A Standard Series No. 10 mesh sieve with an opening of 2.00 mm (0.0787 in) (W.S. Tyler Company of Canada, St. Catharine's, ON, Canada) was placed above a funnel and a pre-weighed cup was placed under the apparatus. The samples were then placed onto the mesh sieve and allowed to melt at ambient temperature (21°C) and the weight of samples that dripped into the cup was recorded at 5, 10, 15, 20 and 30 min.

5.2.7. Sensory analysis

5.2.7.1. Trained panel

Quantitative descriptive analysis (QDA) was used for the trained panel evaluations. Panelists were trained to identify and quantify sensory attributes using terminology that they developed. Trained panelists tested the products in three replications and quantified their responses on an anchored 15 cm line scale.

Trained panelists were recruited and screened from the general population at the University of Alberta using standard sensory evaluation procedures (Meilgaard and others 1991) and 10 panelists were selected from a group of 31. However, only 9 panelists were able to complete the training and evaluation sessions due to unforeseen circumstances.

The standard selection procedures for the trained panel included a questionnaire section as well as a taste test in order to determine the sensory acuity of the panelists. The questionnaire determined panelist availability, ability to follow instructions, current health status, medications that may affect tasting ability, food restrictions, ability to generate descriptive terminology, and judgment of scaling. The taste test asked panelists to identify dilute solutions of the 4 basic tastes (sweet, sour, bitter, salty) as well as a neutral sample, and to identify increasing sucrose concentrations. Panelists were also given a dilute solution of 6-propylthiouracil (PROP), which was then expectorated in order to determine if panelists had "super tasting" abilities. The selected panelists were trained for 3 weeks (4 one hour sessions per week) and evaluated the products in 3 evaluation sessions (30 min each). Panelists generated and agreed on terms and definitions (Table 5.2) for attributes describing appearance (degree of whiteness, brown particles), flavor (milky, wooden/popsicle stick flavor), and texture (firmness, degree of smoothness, rate of melt, mouthcoat) of the 3 vanilla ice cream samples. The group also determined and placed sample references on the 15 cm line scale (Table 5.3).

Trained panelists were reimbursed for their time and participation at the completion of the study with gift certificates. Small treats were also provided at the end of each training or testing session to express gratitude for their continued participation and for motivational purposes.

Panelists were presented with completely randomized trays with 30 g each of the 3 ice cream treatments in 120 mL styrofoam cups (Dart Container Corp., Mason, MI), a spoon, distilled water, and unsalted crackers. Each sample was coded with random three-digit numbers. Samples were brought out at timed intervals to ensure the same level of freezing for each ice cream sample. Each ice cream sample was tempered in a -4°C freezer for 10 min prior to serving and brought out individually to panelists.

Panelists were individually seated in booths with fluorescent lighting and entered data via Compusense software, Version 3.6 (Compusense Inc., 1999) using a 15 cm line scale with the respective anchors. Instructions were presented to panelists at each testing step and could be recalled by panelists at all times. The time-delay function in the Compusense program was used in order to force a waiting period on panelists between samples and attributes. Three replicates of the control and ice cream samples enriched with barley β-glucan were evaluated over 3 days of sensory analysis.

5.2.7.2. Consumer panel

Consumer panelists were instructed to use a 9-point hedonic scale in order to input their opinions on appearance, flavor, texture, and overall liking. The consumer panelists were also asked to enter comments, rank the ice creams in order of personal preference, and respond to a series of questions in a brief questionnaire.

Table 5.2. Definitions and anchors of terms as generated by trained panel for evaluation of ice cream on a 15 cm line scale

Attribute	Definition	Anchors
APPEARANCE		
Degree of whiteness	change in color from white to pale yellow	White-Pale yellow
Brown particles	amount of brown particles visually present in ice cream sample	None-extreme
FLAVOR		
Milky	the flavor of cooked cow's milk	None-extreme
Wooden/Popsicle stick flavor	the flavor of a popsicle stick	None-extreme
TEXTURE		
Firmness	the amount of force required to flatten the ice cream in the mouth using the tongue and palate	None-extreme
Degree of smoothness	the amount of smoothness found in a sample; no detection of coarse or rough particles/texture	None-extreme
Rate of melting	speed of melting, the faster the sample becomes liquid, the higher the rate of melting	Slow-fast
Mouthcoat	ease of complete removal of the sample from the oral cavity after swallowing (i.e. the amount of film remaining in the mouth after swallowing)	None-extreme

Table 5.3. Reference samples and scores for ice cream trained panel

Sample	Attribute	Score [1]
2% UHT milk	Milky	8.57
Popsicle stick	Wooden/Popsicle stick flavor	10.88
Cream cheese cube (1 cm x 1 cm) (Philadelphia, Kraft)	Firmness	9.99
Condensed milk (250 mL) + Whipping cream (80 mL)	Mouthcoat	9.34

[1]Reference score on a 15 cm line scale

All consumer panelists were recruited from the general population of staff and students from the University of Alberta via posters, email, as well as the use of the database of panelists who had asked to be contacted for additional panels. Exclusion parameters included those under the age of consent and those with allergies or intolerances. The 3 vanilla ice cream treatments were prepared and served to panelists seated in individual booths in a completely randomized order. The 98 panelists were instructed to taste the product in the order provided and asked to mark their degree of liking using a 9-point hedonic scale on overall appearance, overall flavor, overall texture, and overall acceptability. The participants were provided with unsalted crackers and distilled water to cleanse their palates after each evaluation and encouraged to write comments in the sections available. Panelists were also asked to rank the ice creams in the order of liking and to fill in a short demographic survey. Data were entered via Compusense software, Version 3.6 (Compusense Inc., 1999) using a 9-point hedonic scale (scoring 9-1) with the following respective categories: like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much, and dislike extremely. Panelists were rewarded for their participation.

5.2.8. Statistical analysis

The whole study was replicated 3 times and data from viscosity, color and sensory analysis were subjected to analysis of variance (ANOVA) using the General Linear Model procedure of SPSS statistical software, Version 13.0 (SPSS Inc., 2004). A complete randomized block design was used to analyze results of the trained panel. Pearson's correlation analysis of trained panel data was also performed using SPSS software. Correlations were considered significant at $p \leq 0.05$. A completely randomized design was used to determine the effect of the treatments and was used to analyze the results of the trained panel. Comparison of means was performed using Tukey's test at a significance level of $p \leq 0.05$. SPSS software was also used to generate box-plots of panelist data in order to determine if there were statistically determined extreme cases, that is, greater than 3 box lengths from upper or lower edge of the box-plot. No extreme cases were found in the following attributes: degree of whiteness, cooked milk flavor, rate of melt, or firmness. The attributes of brown particles, wooden/popsicle stick flavor, and smoothness had one data point removed from each while the attribute of mouthcoat had two extreme data points removed.

5.3. RESULTS AND DISCUSSION

5.3.1. Color

Appearance is generally the first sensory attribute to be evaluated when examining a product. Oftentimes, this attribute can influence the perception of a product and whether or not it is "liked" before it is even sampled or if the product will even be sampled. According to consumer panelist comments, vanilla ice cream should appear "smooth" or "creamy", white, and should be homogenous with no ice crystals and/or specks. The Hunter Color Lab results for the control, 0.375 BG, and 0.75 BG vanilla ice creams highlight these attributes that the panelists were expecting. Results obtained (Table 5.4) demonstrate that the control was significantly ($p \leq 0.05$) whiter in appearance with an L value of 75.74 than ice creams containing 0.375 BG and 0.75 BG whose L values were 69.97 and 70.12, respectively. The a (degree of redness-greenness) and b (degree of yellowness-blueness) values were not affected ($p>0.05$) by β-glucan addition.

5.3.2. Compression force

Representative compression curves of treatments are shown in Figure 5.2. The average maximum peak forces were similar ($p>0.05$) and calculated to be 1.09 ± 0.17 N, 1.51 ± 0.45 N, and 1.23 ± 0.32 N for the control, 0.375 BG, and 0.75 BG, respectively. The force/displacement plot shows that more force was required in order to deform samples containing greater amounts of β-glucan. The peak of the control reached the maximum force and then dropped sharply, whereas the 0.375 BG sample reached the maximum force at a similar distance but maintained a higher force over a longer distance before starting to drop. The treatment with 0.75 g β-glucan addition also showed a high maximum force that was maintained over a greater distance of penetration. The ability of the sample to illicit a greater applied force indicates increased elasticity of the product. Patmore and others (2003) studied the effect of adding locust bean gum and guar gum, long chain polysaccharides, to model ice cream systems and found that elastic structures were created with temperature cycling. Yield stress and frequency data showed that

Table 5.4. Hunter color values[1] for ice cream treatments

Treatment	*L*	*a*	*b*
Control	75.74[a]	-3.04[a]	8.12[a]
0.375 BG	69.97[b]	-2.98[a]	7.84[a]
0.75 BG	70.12[b]	-2.71[a]	8.77[a]

[1]*L* = lightness/darkness (100 = white, 0 = black); *a* = red/green (+ = redness, - = greenness); *b* = yellow/blue (+ = yellowness, - = blueness)

[a, b, c] Means in the same column with the same letter are not significantly ($p>0.05$) different.

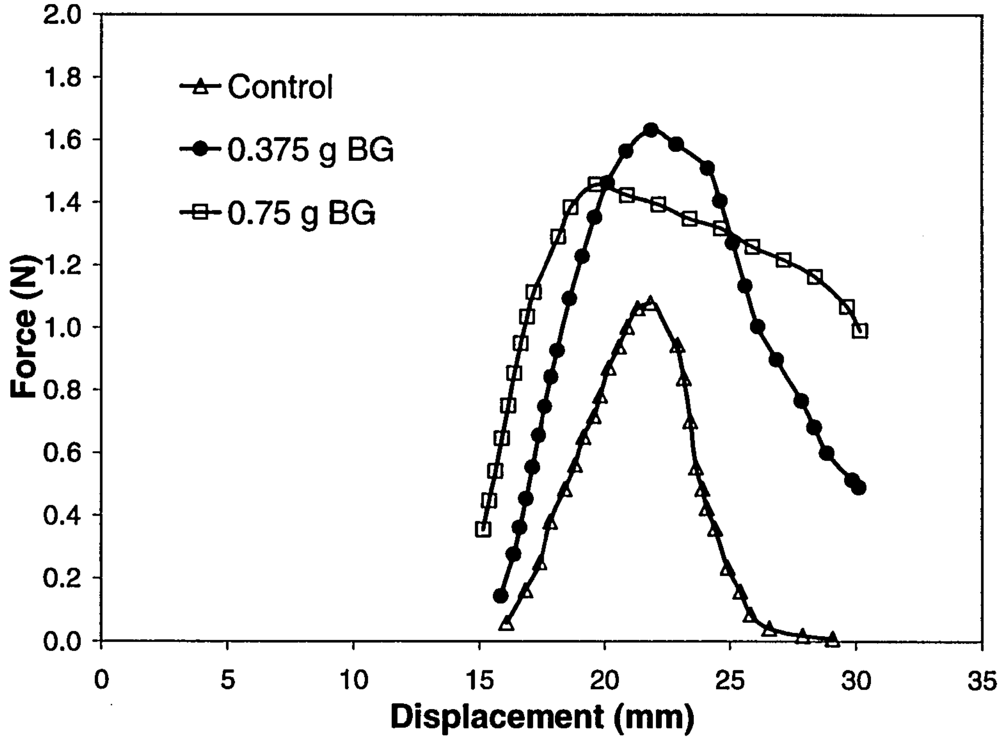

Figure 5.2. Compression force as a function of displacement for ice cream samples

locust bean gum, but not guar gum, formed systems demonstrating characteristics of weak gels as a result of freeze concentration and greater protein/stabilizer incompatibilities. Patmore and others (2003) determined that some long chain polysaccharides have polysaccharide/protein incompatibilities and the ability to gel result in elastic structures in the unfrozen aqueous phase of model ice cream systems. β-Glucan, also a long chain polysaccharide, appears to exhibit similar characteristics.

5.3.3. Viscosity

The acceptability of a product is notably affected by texture and a major textural attribute of ice cream is the viscosity it imparts in the mouth upon melting and the size of the frozen water crystals during recrystallization. In general, hydrocolloids work by forming viscous gels, which interact with components in the mix, like sugars and proteins, thereby hindering motion (Decker 2002). Viscosity influences the rate of migration of free water to ice crystal surfaces and high viscosity results in a slow rate of diffusion (Adapa 2000). The viscosities of the different treatments are presented in Figure 5.3. Measurements were performed on melted mix in order to mimic the mix as panelists would experience, that is, after it had melted in their mouths. The effect of BG addition at 0.75 g β-glucan per serving resulted in a significant ($p \leq 0.05$) increase in viscosity to 1777 mPa·s at 12.9 s^{-1} when compared to 272 mPa·s generated by the control at the same shear rate. Analysis at 12.9 s^{-1} was selected as it has been reported that the shear rate in the mouth to range from 10-50 s^{-1} depending on the viscosity of the product with a shear rate of 10 s^{-1} showing a better correlation with perceived thickness (Cutler and others 1983). Addition of β-glucan at 0.375 g per serving also demonstrated an increase of viscosity to 515 mPa·s at 12.9 s^{-1} as compared to the control; however, this increase was not statistically significant ($p > 0.05$). β-Glucan is a hydrocolloid with the ability to bind water thereby resulting in an increase in viscosity (Burkus and Temelli 1999). In addition, it is postulated that the long and kinked β-glucan molecules tend to interact and become tangled at low shear rates and disentangle at high shear thus exhibiting pseudoplastic behavior. The high β-glucan concentrations result in greater interaction and entanglement, hence greater viscosity, whereas the low concentrations allow for space between the molecules leading to greater freedom of movement of the molecules (Oakenfull 2001). Furthermore, freezing and thawing of the mix results in further freeze

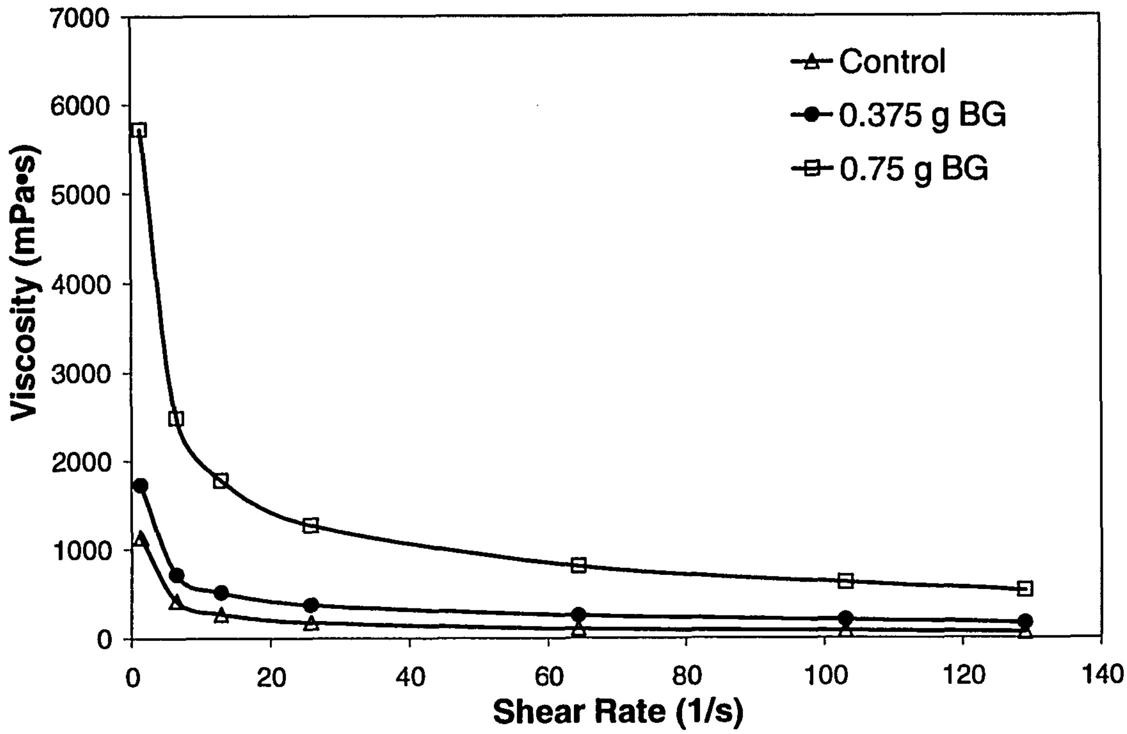

Figure 5.3. Viscosity of ice cream mixes as a function of shear rate

concentration, which may result in the formation of cryo-gels, that is, networks of entangled polysaccharides (Regand and Goff 2003). The control sample contained no β-glucan and demonstrated a viscosity reading of 272 mPa·s. Addition of 0.375 g β-glucan increased the viscosity to 515 mPa·s while a doubling of this enrichment resulted in an increase in viscosity that was greater than 3.45 times the previous level at 1777 mPa·s. Inulin, another soluble dietary fiber, has been added to a "yogurt-ice cream" product by El-Nagar and others (2002) while Salem and others (2003) used Jerusalem artichoke, a vegetable high in inulin content, in ice cream. These researchers also demonstrated that the increase in viscosity they observed was due to the hygroscopic property of inulin and its ability to create a highly viscous product. The molecular network of β-glucan and its ability to interact with water and other long chain polysaccharides resulted in a substantial increase in viscosity.

Ice cream is a complex mixture of air bubbles, ice crystals, serum, fat globules, proteins, sugars, and emulsifiers. These particular treatments also included β-glucan, which demonstrated the importance of the stabilizing effect of viscosity as imparted by β-glucan. The high viscosity prevented the separation between the aqueous and fat phases in the mixture. The high viscosity was attributed to the long β-glucan polysaccharide molecules which physically formed a barrier to movement of fat globules. The high viscosity also made it more difficult for the fat to diffuse through and separate from the aqueous phase. Freezing of the mixture also created greater viscosity due to the freezing of the previously free liquid water. This resulted in a concentration effect of the remaining components including sugars, β-glucan, and fat, hence an increased apparent viscosity. Viscosity is often related to ice crystal growth but different stabilizers have different effectiveness at the same levels of viscosity and cannot necessarily be correlated (Cottrell and others 1979; Miller-Liveney and Hartel 1997; Wang and others 1998). Wang and others (1998) studied the effect of carboxymethylcellulose (CMC) and guar gum on the propagation of ice crystals in a sucrose-lactose solution. Researchers found that CMC's had no effect on ice crystal growth while guar gums greatly retarded ice crystal formation, even though CMC's had twice the viscosity. The slowing of ice crystal growth in the presence of 0.4% guar gum was hypothesized to be the result of entanglement of guar gum in and around sites for ice crystal propagation. These sites on the crystal surface are where free water molecules will attach and propagate.

Addition of β-glucan to ice cream results in changes to its fluid flow behavior. The pseudoplastic behavior of gums is described by the Power Law model, which is:

$$S=cR^n$$

where S is the shear stress (N/m^2), c is the consistency coefficient, R is the shear rate (s^{-1}), and n is the flow behavior index. As previously stated, increases in concentration of water-soluble polysaccharides such as β-glucan results in increased viscosity due to entanglement of the molecules. It can be postulated that the 0.375 g and 0.75 g addition of β-glucan to a 125 g serving of ice cream resulted in a large amount of entanglement and interaction, resulting in an increase in viscosity and an increase in flow behavior index (n) as compared to the control (Table 5.5). Critical concentration (c*) is the concentration at which significant interactions, interpenetrations, and overlap of the molecules begin (Bolliger and others 2000). Burkus and Temelli (2003) reported the critical concentration (c*) of barley β-glucan to be approximately 1.49% and 0.51% for material with a molecular weight of 198,000 and 598,000, respectively. The entanglement in the ice cream containing 0.375 g and 0.75 g β-glucan per serving, that is 0.3% and 0.6% β-glucan, respectively, in addition to the interactions between other gums, proteins, and sugars may have approached or surpassed the critical concentration (c*) since the molecular weight of β-glucan used in this study was substantially higher than that used by Burkus and Temelli (2003). Flow behavior index values (n) for the enriched ice creams were not significantly different ($p>0.05$) at 0. 5103 and 0.4919. At critical concentration, the molecules interact more closely and may form fringed micelles. These micelles may interact but as they had become more compact, this ice cream mix was not as affected by shear hence the expected increase in flow behavior index was not observed. The consistency index also shows that although there is an increase in the level of viscosity with a lower level of β-glucan addition, the change in consistency index is prominent at higher dosages of 0.75 g per serving.

5.3.4. Rate of melt

Ice creams with higher total milk solids melt faster than those with lower total

Table 5.5 Flow behavior index and consistency index of ice cream with β-glucan addition.

Treatment	Flow behavior Index, (n)	Consistency Index, (c)	R^2
Control	0.387[a]	1.3144	0.9978
0.375 BG	0.5103[b]	1.8685	0.9974
0.75 BG	0.4919[b]	6.5181	0.9992

[a, b] Means in the same column with the same letter are not significantly different ($p>0.05$)

solids (Arbuckle 1986; Li and others 1997). This can be attributed to the effect of dissolved solids on freezing point depression. However, El-Nagar and others (2002) observed reduced melting rates in their "yogurt-ice cream" and attributed this to the fact that inulin may act as a stabilizer thereby reducing the freedom of movement of molecules and immobilization of water. Güven and others (2003) researched the effects of stabilizers (locust bean gum, CMC, guar gum, and sodium alginates) as compared to salep extract, an expensive stabilizer derived from orchids used in the production of a type of Turkish ice cream. Güven and others (2003) found that locust bean gum combined with other stabilizers produced the best results in physical, chemical, and sensory properties including higher viscosity and increased resistance to melting over a storage time of 6-months.

In this study, the order in which melting occurred from fastest to slowest was 0.375 BG, control and then 0.75 BG (Figure 5.4). The 0.375 BG contained the most total solids at 27.43% while the control contained the least amount of total solids at 26.09% as there was no added fiber, while the 0.75 BG sample contained a higher level of added fiber with total solids at 26.74%. It can be hypothesized that although the 0.75 BG sample did not have the largest amount of total solids, the nature of the β-glucan resulted in the least amount of melting due to its high apparent viscosity and its ability to bind water, thereby delaying the rate of melt. With this reasoning, it would follow that 0.375 BG would also retard product melting through the functional properties imparted by the β-glucan when in reality it melted more quickly. This may be due to the effect of increased amount of total solids resulting in a greater effect than the effect brought about by the functional properties of the hydrocolloid. It can be postulated that the lower level of β-glucan addition did not create enough binding capacity or a gel-like network that was capable of immobilizing the movement of the water molecules. This increase in dissolved solids in the 0.375 BG sample may have affected the freezing point depression, which resulted in a more rapid rate of melting as compared to the control. In addition, throughout the freezing process free liquid water is converted to solid ice crystals, resulting in the concentration of the sugars and proteins in the remaining liquid portion, thereby depressing the freezing point further.

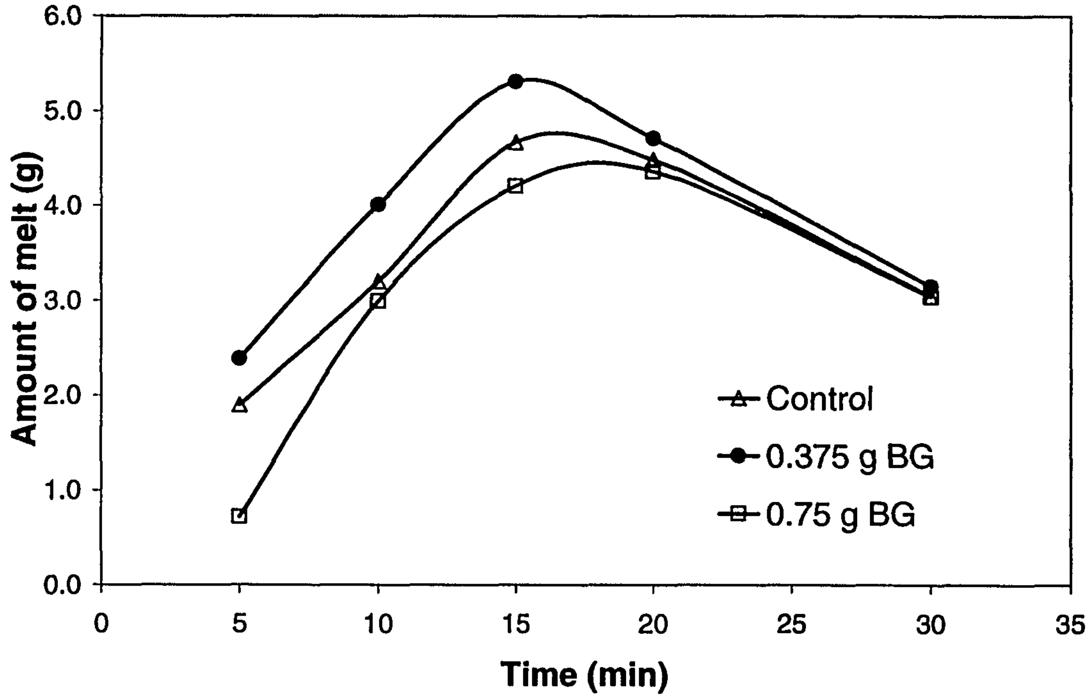

Figure 5.4. Effect of β-glucan on the rate of melting of ice cream samples

Research into the effects of other long chain polysaccharides such as carrageenan, carboxymethyl cellulose (CMC), xanthan gum, sodium alginate, locust bean gum (LBG), guar gum, and gelatin on ice cream model systems have been performed in order to study the effect of these hydrocolloid stabilizers on structure and recrystallization (Sutton and Wilcox 1998; Baer and others 1999; Güven and others 2003; Regand and Goff 2002, 2003; Patmore and others 2003). The addition of these long chain stabilizers aid in the maintenance of desirable textural attributes by minimizing the effect of inevitable freeze/thaw cycles. Stabilizers slow the migration of water by increasing serum viscosity thereby decreasing diffusion rates and by decreasing the amount of available water during frozen storage (Adapa and others 2000; Decker 2002). The addition of β-glucan also performed this function as the long chain molecule created a physical barrier to movement of melted water as well as being a highly viscous material, which slows water migration. It can be anticipated that upon freeze/thaw stability testing, β-glucan would act similar to other stabilizers and be an effective agent against ice recrystallization.

5.3.5. Trained panel

Panelists were trained to identify and quantify the traits they felt exhibited differences. Panelists determined which attributes were to be evaluated. Interestingly, the addition of β-glucan fiber did not cause any detectable changes in texture in terms of perception of fiber particles or any coarseness in the product. Textural defects are highly detrimental to the quality of a product. Evaluation took place over a period of 3 days and data (Table 5.6) indicated that there were significant differences ($p \leq 0.05$) among samples for all attributes but not between replications. The degree of whiteness and firmness between the 0.375 BG and 0.75 BG samples were similar and determined to be significantly less white and firmer than the control. All treatments were found to be significantly different ($p \leq 0.05$) in all other attributes.

In general, addition of β-glucan resulted in greater intensity of the attribute being tested. Degree of whiteness of the ice cream decreased with increasing β-glucan content, that is, fiber enriched samples appeared significantly ($p \leq 0.05$) more yellow to the panelists. Panelists rated the appearance of brown particles in the enriched ice creams at a higher level. This can easily be attributed to the fact that the greater the β-glucan

Table 5.6. Trained panel analysis results[1] of β-glucan enriched ice cream samples

Attribute	Control	0.375 BG	0.75 BG	SEM[2]
APPEARANCE				
Degree of whiteness	3.57[a]	8.75[b]	9.91[b]	0.366
Brown particles	0.18[a]	6.22[b]	9.13[c]	0.490
FLAVOR				
Milky	4.12[a]	4.84[b]	5.46[c]	0.416
Wooden/Popsicle stick flavor	0.96[a]	5.50[b]	7.76[c]	0.269
TEXTURE				
Degree of smoothness	4.60[a]	8.05[b]	10.78[c]	0.331
Rate of melt	3.77[a]	6.58[b]	9.98[c]	0.350
Firmness	6.24[a]	9.02[b]	10.57[b]	0.337
Mouthcoat	4.60[a]	8.05[b]	10.78[c]	0.288

[1]15 cm line scale with anchor points at 0= none (milky, wooden/ popsicle stick flavor, firmness, mouthcoat), white (degree of whiteness), fast (rate of melt); 15= extreme (milky, wooden/popsicle stick flavor, firmness, mouthcoat), pale yellow (degree of whiteness), slow (rate of melt)

[2]SEM = Standard error of the mean

[a, b, c] Means in the same row with the same letter are not significantly different (p>0.05)

addition, the greater the addition of other insoluble components, namely bran, found in the fiber.

Milky flavor significantly ($p \leq 0.05$) increased in intensity with greater β-glucan addition. In the present study, the control contained no β-glucan and the panelists indicated that they did not detect the presence of a wooden flavor that is associated with the β-glucan. This can also be attributed to the low-fat content (2%) of the ice cream along with the increased β-glucan concentration resulting in a greater perceived intensity of a wooden/popsicle stick flavor.

The level of smoothness can be associated with creaminess. Hyvönven and others (2003) reported that in order for a product to be perceived as creamy, there must be a smooth but viscous fluid layer between the tongue and the palate. β-Glucan creates a high level of viscosity as it binds moisture within the structure and thus provides a smooth mouthfeel. In this study, panelists used the definition of smoothness as "the amount of smoothness found in a sample; no detection of coarse or rough particles/texture". The addition of β-glucan fiber did not create any difficulties with the texture in terms of perception of particles or sandiness, normally associated with the presence of large lactose crystals, within the ice cream product. The increase in β-glucan content resulted in a significant ($p \leq 0.05$) increase in the perceived smoothness of ice cream. Hyvönven and others (2003) determined that the release in flavor, perceived fattiness and creaminess were significantly affected by the addition of polydextrose and maltodextrins and that the intensity and sharpness of flavor were greatest in fat-free samples and lowest in high-fat (18%) ice cream. Therefore, the increased intensity of perceived smoothness was a result of the increasing levels of β-glucan.

Although the effect of added fiber on the rate of melting has not been studied extensively, it has been suggested that there is no relationship between the perceived sensory melting rate and objective analysis due to differences in experimental conditions such as drip weight at ambient temperature versus temperature conditions and shear found in a panelist's mouth (Guinard and others 1997; Li and others 1997; Hyvönven and others 2003). Trained panelists found that the rate of melt decreased significantly with fiber addition slightly differing from the data generated objectively (Figure 5.4). Mouth coat was significantly different ($p \leq 0.05$) and increased with increasing fiber addition and this may be due to the fact that the high β-glucan concentration leads to greater interaction and entanglement of molecules resulting in a greater perceived amount of film in the mouth after swallowing.

The correlation between attributes was also analysed and the data are compiled in Table 5.7. The addition of increasing amounts of β-glucan resulted in significant correlations as seen in the appearance of the enriched ice cream product. Both the attributes of degree of whiteness and the amount of visible brown particles were correlated to an increase in wooden flavor, rate of melt, degree of smoothness, firmness and mouthcoat. An increase in the presence of brown particles was also correlated to a decrease in cooked milk flavor. Wooden flavor was increased with increasing changes in the textural attributes of degree of smoothness, firmness, and mouthcoat, but a decrease in rate of melt. The change in cooked milk flavor was not correlated to any flavor or textural attributes. The rate of melt was correlated negatively to the other textural attributes.

Panelist results and correlation data clearly show that with the increased addition of β-glucan there was a significant change in the perception of the appearance, the degree of whiteness, brown particles, wooden flavor, rate of melt, degree of smoothness, firmness, and mouthcoat.

5.3.6. Consumer panel

The consumer panel, recruited from the population of staff and students at the University of Alberta, consisted of a wide range of ages with the majority of participants being females between the ages of 18-24 and with a frequency of consumption of ice cream products of at least once a month (Table 5.8). Although price point analysis was not performed, of the 98 panelists participating in the study, 80.2% indicated on the demographic survey that they would purchase a fiber enriched ice cream if available. This value is somewhat lower than the 86.4% who stated they may potentially purchase fiber enriched yogurt (Chapter 4). This was likely due to the fact that yogurt is already perceived as a healthy product whereas ice cream is generally considered as a treat that is not healthy.

Consumer panelists evaluated the fiber-enriched vanilla ice creams and found no significant difference in appearance between the control and 0.375 BG and no significant

Table 5.7. Correlation of attributes of ice cream

Pearson Correlation	Degree of Whiteness	Brown Particles	Wooden Flavor	Cooked Milk Flavor	Rate of Melt	Degree of Smoothness	Firmness	Mouthcoat
Degree of Whiteness	1	0.866**	0.735**	-0.107	-0.772**	0.743**	0.572**	0.646**
Brown Particles	0.866**	1	0.820**	-0.239*	0.811**	0.747**	0.592**	0.695**
Wooden Flavor	0.735**	0.820**	1	-0.118	-0.689**	0.757**	0.509**	0.809**
Cooked Milk Flavor	-0.107	-0.239*	-0.118	1	0.147	-0.73	-.046	-0.53
Rate of Melt	-0.772**	-0.811**	-0.689**	0.147	1	-0.756**	-0.754**	-0.704**
Degree of Smoothness	0.743**	0.747**	0.757**	-0.073	-0.756**	1	0.580**	0.802**
Firmness	0.572**	0.592**	0.509**	-0.046	-0.754**	0.580**	1	0.564**
Mouthcoat	0.646**	0.695**	0.809**	-0.053	-0.704**	0.802**	0.564**	1

* Correlation is significant at the $p \leq 0.05$ level (2-tailed)
** Correlation is significant at the $p \leq 0.01$ level (2-tailed

Table 5.8. Demographic information gathered from the consumer panel

Gender	%
Male	38.5
Female	61.5
Age range	**%**
18-24	50
25-30	26
31-40	10.4
41-50	5.2
51+	8.3
Frequency of consumption	**%**
At least per week	20.8
At least per month	56.2
At least once every 3 months	16.7
At least once every 6 months	6.2
I never consume this product	0
Would you purchase a fiber enriched ice cream if available in the market?	**%**
Yes	80.2
No	19.8

difference ($p>0.05$) between 0.375 BG and 0.75 BG as rated on a 9-point hedonic scale (Table 5.9). The panelists rated the appearance of the control at 6.0 ("like slightly") while the enriched treatments were rated slightly lower with the 0.75 BG being ratedsignificantly lower ($p\leq0.05$) than the control. Frequency distribution chart (Figure 5.5) on acceptability of appearance indicated that the median rating of the control and the 0.375 BG product was "like moderately" (7). There was an equal split in the median rating for 0.75 BG at "like moderately" (7) and "dislike slightly" (4). The average values for the liking of flavor and texture showed no significant ($p>0.05$) differences among the 3 treatments; however, frequency distribution (Figures 5.6 and 5.7) showed that median values of control were higher at "like very much", "like moderately" for 0.375 BG, and "like moderately" and "like very much" for 0.75 BG. Comments from panelists on texture (Appendix C) indicate that the addition of β-glucan created a smoother and "creamy" mouthfeel, a desirable trait for low-fat products. The frequency chart showed a similar rating for control with median rating for the texture of the control at "like moderately", "like very much" for 0.375 BG, and "like moderately" for 0.75 BG. Overall acceptability was similar ($p>0.05$) between treatments but its frequency distribution (Figure 5.8) indicate that in general, the control was rated as the most acceptable with 58.3% rating it at 7 ("like moderately") or greater; the 0.375 BG treatment had 53.2% rating it at 7 or greater; while 49.0% of the panelists rated the 0.75 BG at 7 or greater. Panelists were also asked to rank the products from "like most" to "like least" with 36.5% of panelists ranked 0.375 BG as the product they liked the most and 42.7% ranked 0.75g as the product they liked the least (Figure 5.9). Additional comments from the consumer panel can be found in Appendix C.

Consumer panelists indicated in the demographic survey that there is market potential for a fiber-enriched ice cream product. The use of barley β-glucan in a low-fat ice cream product can help to deliver this important component while still maintaining the sensory attributes that are generally attributed to ice cream or frozen dessert products.

5.4. CONCLUSIONS

Considering the absence of fiber in dairy products, any type of fiber enrichment is considered substantial. Soluble barley β-glucan can be utilized in the production of a

Table 5.9. Consumer panel sensory results[1] on 3 ice cream treatments (n= 98)

	Appearance	Flavor	Texture	Overall acceptability
Control	6.0[a]	6.2[a]	6.7[a]	6.5[a]
0.375 BG	5.6[ab]	6.3[a]	6.6[a]	6.5[a]
0.75 BG	5.3[b]	6.5[a]	6.1[a]	6.1[a]
SEM[2]	0.112	0.107	0.104	0.099

[1]Numbers ranked on an anchored 9-point hedonic scale (1= dislike extremely, 9= like extremely)
[2]SEM = Standard error of the mean
[a, b, c]Means in the same column with the same letter are not significantly different ($p>0.05$)

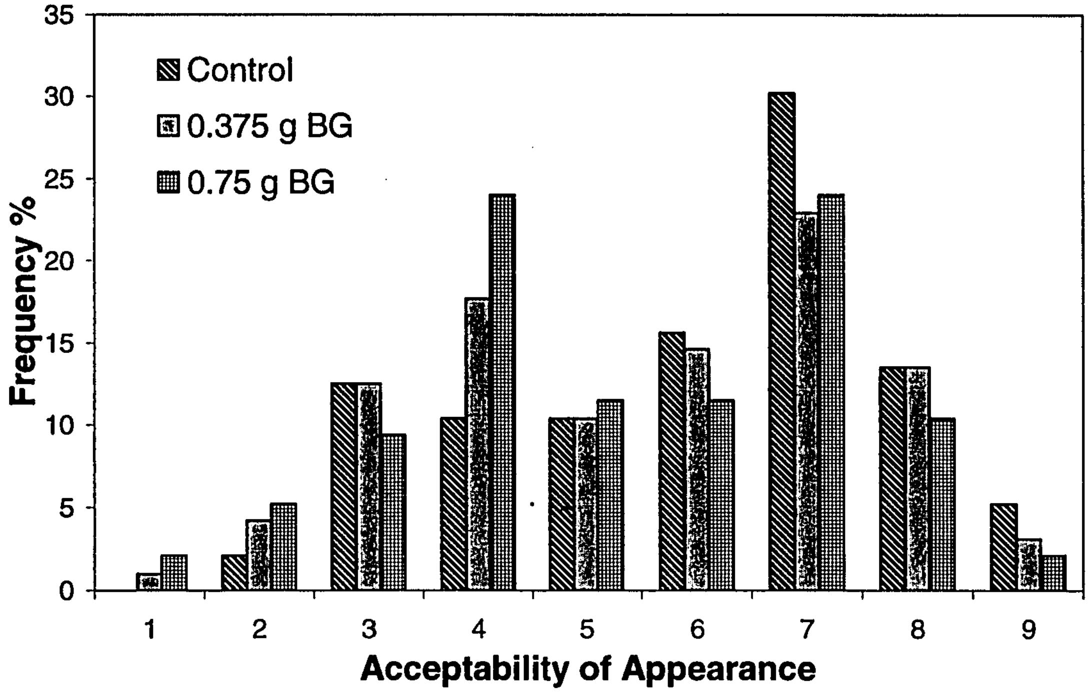

Figure 5.5. Frequency distribution of acceptability of appearance of ice cream as determined by the consumer panel, 1= dislike extremely, 9= like extremely

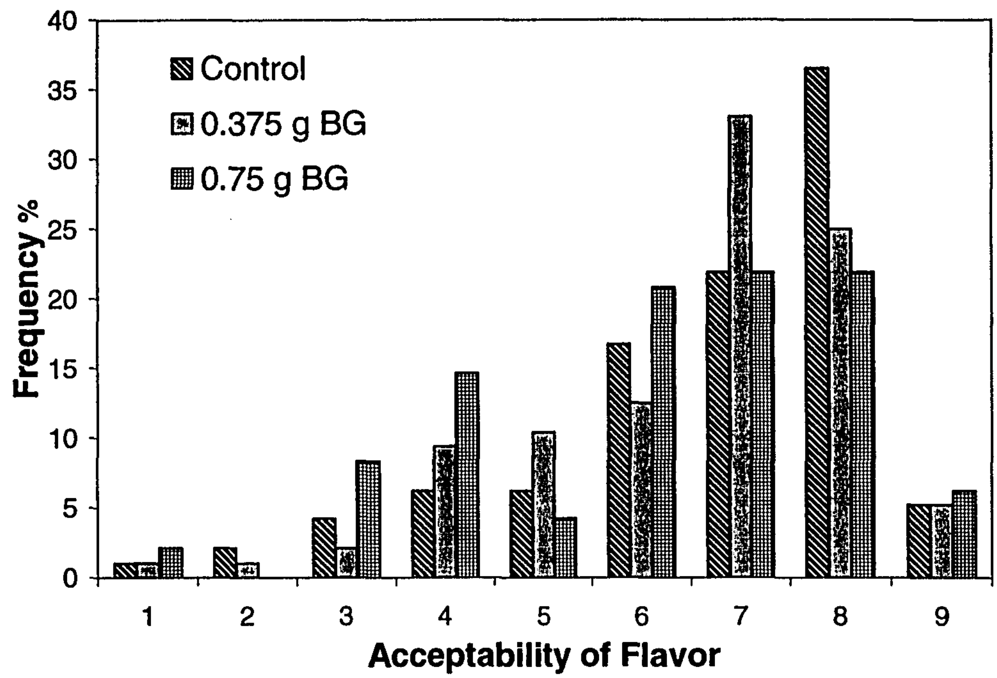

Figure 5.6. Frequency distribution of acceptability of flavor of ice cream as determined by the consumer panel, 1=dislike extremely, 9= like extremely

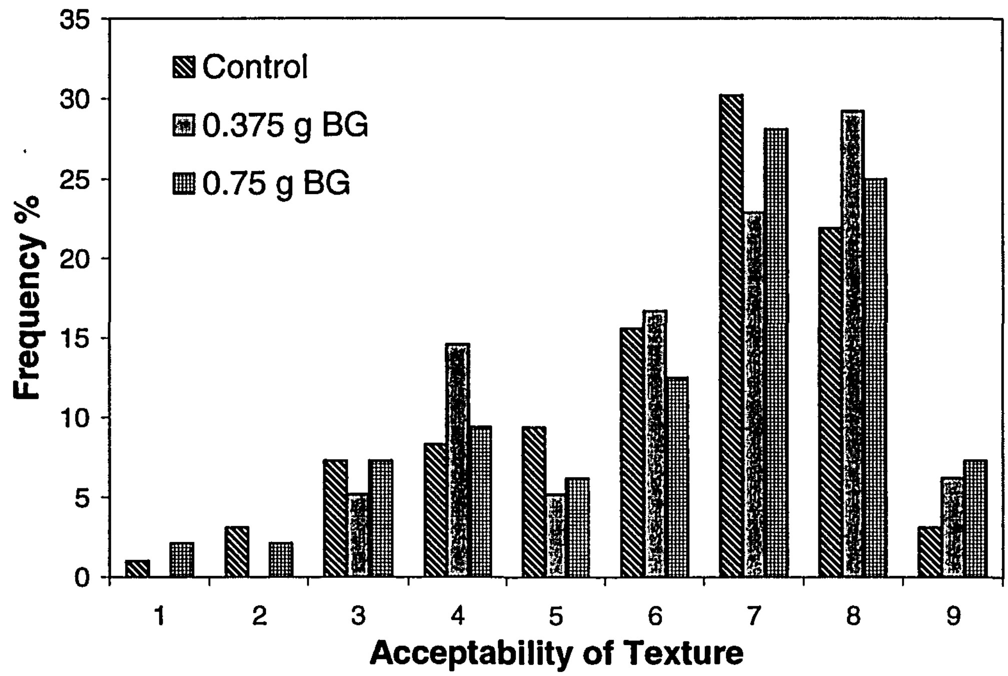

Figure 5.7. Frequency distribution of acceptability of texture of ice cream by the consumer panel, 1=dislike extremely, 9= like extremely

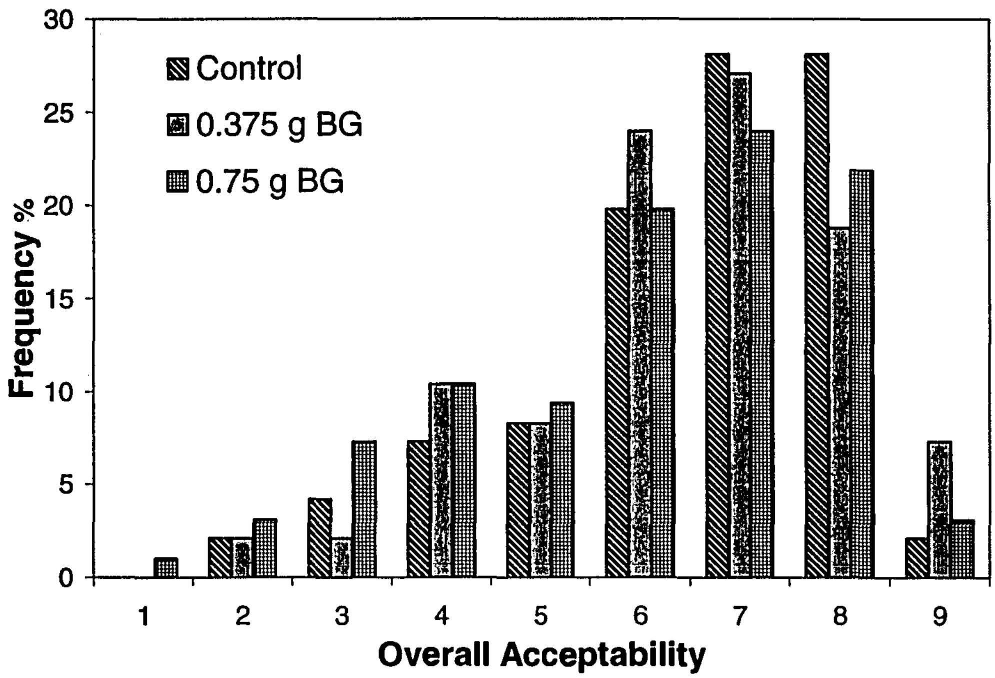

Figure 5.8. Frequency distribution of overall acceptability of ice cream by the consumer panel, 1=dislike extremely, 9= like extremely

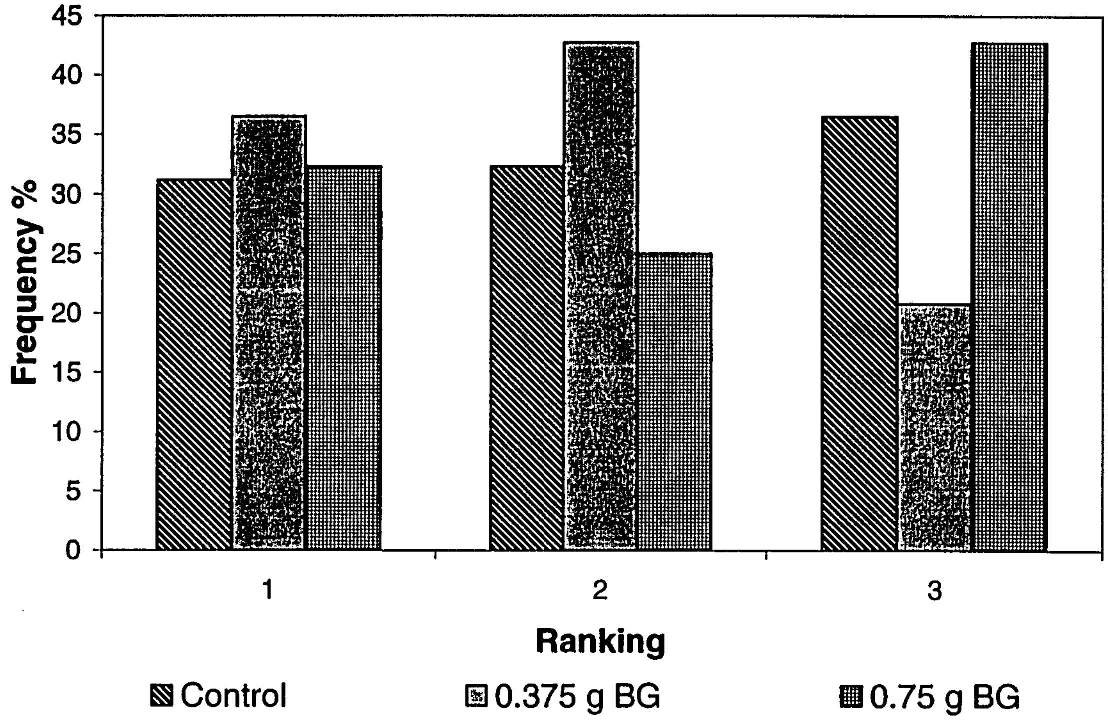

Figure 5.9. Frequency distribution of ranking of ice cream by a consumer panel, 1= like most, 3= like least

functional ice cream product. The addition of β-glucan at a level of 0.75 g/125 g serving can significantly reduce the whiteness of the product with no effect on Hunter *a* and *b* values. Increasing the level of β-glucan addition generally resulted in a similar ($p>0.05$) level of liking as compared to the control sample, but a moderate addition of 0.375 g β-glucan was ranked by panelists as the most liked product. Further fine-tuning of formulations and analysis of the price point consumers are willing to pay in order to improve and refine the product would make it feasible to bring a product such as this to market successfully.

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Chapter 6
CONCLUSIONS AND RECOMMENDATIONS

The variety of nutraceutical products available in the marketplace is growing rapidly. A greater number of individuals are approaching their health and wellbeing proactively and are using their diet in order to maintain or improve their health. The FDA has allowed a claim on heart health (e.g. "may reduce the risk of heart disease") to be placed on products that contain at least 0.75 g of soluble fiber (β-glucan) from oats per serving (Federal Register 2003). Soluble dietary fibers, mainly β-glucan, were acknowledged as playing a major role in imparting proven health benefits such as the ability to lower serum cholesterol and regulation of glycemic response. β-Glucan also possesses functional properties that would make it a desirable replacement for a number of stabilizers and/or thickeners found in dairy products. This thesis research targeted the incorporation of barley β-glucan into strawberry yogurt and vanilla ice cream not only for its potential health benefits but also because these products would benefit from the functional properties of β-glucan.

The effect of β-glucan on the ability of two starter cultures (YC-380 and YC-X11) to grow and their effect on β-glucan, namely their ability to hydrolyze β-glucan polymers, were first ascertained in this study. β-Glucan addition to a model yogurt system did not significantly affect the growth of starter cultures. However, β-glucan can be broken down and utilized by starter cultures when lactose becomes a limiting source of nutrient during the fermentation process. The concern was that with a viscosity decrease the potential health benefits, which are mainly attributed to viscosity, of the soluble fiber would also be diminished. However, conditions were established in which viscosity would be preserved. Hydrolysis of β-glucan was minimized with the addition of lactose, a more desirable substrate for the cultures. It was also suggested that minimization of β-glucan hydrolysis could be achieved by adding β-glucan at the end of yogurt fermentation. Following fermentation, cool refrigeration temperatures and low pH ensured that the lactic acid bacteria were in a decreased metabolic stage, thus minimizing β-glucan hydrolysis. Addition of β-glucan, provided in a separate pouch, prior to consumption is also an option. As β-glucan is a potential prebiotic, further research into the effects and interaction of starter cultures, probiotic bacteria, and β-glucan would yield interesting and useful data that could later be used in the formulation of new yogurt products.

With the knowledge that β-glucan can be hydrolyzed by starter cultures, strawberry yogurt incorporating high- and low-solubility barley β-glucan containing 0.375 g or 0.75 g β-glucan/175 g serving (0.21% or 0.43%, w/w) was successfully produced by adding β-glucan into yogurt after fermentation is completed. This study maintained certain parameters in order to observe the effects of dose and degree of solubility. No significant differences ($p>0.05$) were found between samples as determined by trained panels and instrumental analysis that were tested 1 day after production or after 1 week of refrigerated storage. The addition of high-solubility β-glucan gum resulted in a proportional increase in product viscosity as detected by viscosity measurements and trained panel. Although panelists did not perceive color variations in products, differences were found through objective measurements. Trained panelists assessed the appearance of smoothness and found that it decreased significantly with increasing levels of β-glucan and solubility. In addition, a trained panel found that β-glucan addition caused a significant change ($p\leq0.05$) to the flavor (cereal flavor) and texture profile (viscosity, mouthcoat, ropiness) of a stirred strawberry yogurt. In general, the greater the change in flavor/texture profile as compared to the control resulted in a greater decrease in the degree of liking of that attribute by the consumer panel. The addition of low-solubility β-glucan did not result in as great a difference in attributes and trained panelists found the control and 0.375 g per serving samples to be similar ($p>0.05$). Significant changes in viscosity, ropiness, mouthcoat, and cereal flavor were detected when β-glucan was incorporated at 0.75 g/serving with the effect being more pronounced for samples containing high-solubility β-glucan.

Consumer panel found that overall acceptability of the low-solubility β-glucan strawberry yogurt was similar to that of the control and ranked these products at "like moderately". In general, degree of liking and overall acceptability of the strawberry yogurt decreased with increasing dosage levels and solubility of β-glucan; however, overall acceptability of the control, 0.375 g and 0.75 g/serving of low-solubility β-glucan were similar ($p>0.05$) and ranked as "like moderately". Strawberry yogurts with high-solubility β-glucan (0.375 g or 0.75 g/serving) added were ranked as "neither like nor dislike" or "dislike slightly", respectively. Findings from this study suggest that the addition of low-solubility β-glucan was acceptable and the formulation could be further refined in order to achieve a widely acceptable/liked product. High-solubility products also have potential utility in yogurt products but further formulation and acceptability testing at lower doses are necessary to determine the maximum level of addition. Further formulation of a fiber-enriched yogurt would fill a niche in the marketplace as 86.4% of consumers indicated that they would purchase a fiber-enriched yogurt product should there be one in the marketplace. The successful incorporation of β-glucan into a healthful product such as yogurt may result in increased consumption of this valuable dietary fiber component and may also generate interest for novel product development.

A low-fat ice cream containing 0.375 g or 0.75 g barley β-glucan/125 g serving (0.3% or 0.6%, w/w) was successfully formulated and tested via objective and sensory analyses. There were no significant differences in color according to panelist observations and objective analysis (Hunter *a*- and *b*-values); however the control was significantly whiter than samples containing added β-glucan.

Compression force data showed that ice creams containing increasing concentrations of β-glucan required greater force in order to deform the samples. Deformation curves showed greater elasticity of the product, which related to higher β-glucan levels. Objective physical tests showed a slower rate of melt for ice cream enriched with 0.375 g β-glucan per serving; trained panel also indicated that increasing levels of gum decreased the rate of melt. Ice cream with β-glucan resulted in greater apparent viscosity and exhibited pseudoplastic behavior. It was hypothesized that the apparent viscosity of enriched ice creams was higher than the control due to hydration of β-glucan.

Trained panelists indicated significant differences for all attributes including: appearance (degree of whiteness, brown particles); flavor (milky flavor, wooden/popsicle stick flavor); and textural attributes (degree of smoothness, rate of melt, firmness, and moutcoat). In general, increased β-glucan addition resulted in greater intensity of these attributes.

Consumer panelists rated all three ice creams similarly ($p>0.05$) for flavor and texture but found the appearance of the high dosage ice cream to be significantly different from the control. Increased levels of β-glucan addition did not cause a change ($p>0.05$) in overall acceptability as compared to the control sample. Over half of the panelists (53.2%) rated the ice cream enriched with 0.375 g β-glucan per serving as "like moderately" to "like extremely"; it was also ranked by panelists as the product that was "liked most". Comments also indicated that β-glucan addition resulted in greater smoothness and creaminess, both highly desirable traits in low-fat ice cream. Further formulations in order to improve and refine the product would most likely make it feasible to bring a product such as this to market successfully.

Ice cream is a complicated system. It is a specific combination of air bubbles, fat globules, ice crystals, serum, proteins and emulsifiers which, upon proper freezing, becomes the frozen foam mixture known as ice cream. Further characterization of the effects of freezing and thawing cycles on water migration would clarify interdynamic interactions between β-glucan, proteins, and other emulsifiers. Research into these fundamental interactions will further elucidate β-glucan's ability to replace conventional gums in ice cream products or other products that require stabilization. Clinical studies and research to better understand the mechanisms of action would serve to promote the rational use of β-glucan as a nutraceutical ingredient.

Although β-glucan has been added to yogurt by other researchers, this is the first study to characterize the physical impact on viscosity by starter cultures. Furthermore, the effect on sensory perception and level of acceptability of products enriched with low- and high-solubility β-glucan at varying dosages was determined. Currently, there are no studies in the literature that report on enrichment of low-fat ice cream, a complex food system, with β-glucan. This study demonstrated that β-glucan can be utilized in order to change physical and sensory qualities, including viscosity and mimicking smoothness associated with higher fat levels.

β-Glucan has been proven to impart health benefits as well as exhibit important functional properties (e.g. viscosity, stabilization, and mouthfeel), thereby making it an appealing alternative to gums currently used in the industry. New methods of extraction and purification are making it more feasible from an economic standpoint to incorporate β-glucan gum into a variety of products. With consumers indicating that they are ready to purchase products that promote wellbeing, β-glucan is an ideal food ingredient for the changes ongoing in the food industry. The functional foods category is the fastest growing segment in the food industry and β-glucan has the opportunity to represent the best in this category as it has a multiplicity of uses.

6.1. REFERENCES

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Appendix A

Table 1: Statistical analysis of treatment and time interaction via SAS using a p-value of 0.05 for viscosity values at a shear rate of 12.9 s^{-1}

	Trt	a	a	a	a	b	b	b	b	c	c	c	c	d	d	d	d
Trt[a]	Time[b]	0	2	4	8	0	2	4	8	0	2	4	8	0	2	4	8
a	0	-	0.8635	0.7607	0.0672	0.3895	0.0422	0.606	0.7497	0.6199	0.4542	<0.0001	<0.0001	0.5971	0.5341	<0.0001	<0.0001
a	2	0.8635	-	0.4619	0.0043	0.2842	0.0168	0.4879	0.8071	0.4979	0.4562	<0.0001	<0.0001	0.4906	0.4027	<0.0001	<0.0001
a	4	0.7607	0.4619	-	0.0045	0.5421	0.0675	0.8207	0.4692	0.8356	0.2591	<0.0001	<0.0001	0.7901	0.749	<0.0001	<0.0001
a	8	0.0672	0.0043	0.0045	-	0.0095	<0.0001	0.021	0.0546	0.0195	0.3215	<0.0001	<0.0001	0.0327	0.0078	<0.0001	<0.0001
b	0	0.3895	0.2842	0.5421	0.0095	-	0.078	0.689	0.1103	0.6775	0.0882	<0.0001	<0.0001	0.7586	0.7256	<0.0001	<0.0001
b	2	0.0422	0.0168	0.0675	<0.0001	0.078	-	0.0124	<0.0001	0.1009	0.0024	<0.0001	<0.0001	0.1625	0.0985	<0.0001	<0.0001
b	4	0.606	0.4879	0.8207	0.021	0.689	0.0124	-	0.1519	0.982	0.1708	<0.0001	<0.0001	0.9545	0.9408	<0.0001	<0.0001
b	8	0.7497	0.8071	0.4692	0.0546	0.1103	<0.0001	0.1519	-	0.3231	0.5269	<0.0001	<0.0001	0.3231	0.5269	<0.0001	<0.0001
c	0	0.6199	0.4979	0.8356	0.0195	0.6775	0.1009	0.982	0.3231	-	0.039	<0.0001	<0.0001	0.9379	0.9207	<0.0001	<0.0001
c	2	0.4542	0.4562	0.2591	0.3215	0.0882	0.0024	0.1708	0.5269	0.039	-	<0.0001	<0.0001	0.1927	0.1166	<0.0001	<0.0001
c	4	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001	0.4733
c	8	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001
d	0	0.5971	0.4906	0.7901	0.0327	0.7586	0.1625	0.9545	0.3231	0.9379	0.1927	<0.0001	<0.0001	-	0.9921	<0.0001	<0.0001
d	2	0.5341	0.4027	0.749	0.0078	0.7256	0.0985	0.9408	0.5269	0.9207	0.1166	<0.0001	<0.0001	0.9921	-	<0.0001	<0.0001
d	4	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001
d	8	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.4733	<0.0001	<0.0001	<0.0001	<0.0001	-

[a]Trt a- BG + SMP, b- BG + SMP + L, c- BG + SMP + SC, d- BG + SMP + L + SC; [b]Time, h.

Values in tables show significance for treatments if p-values are < 0.05

Table 2: Statistical analysis of treatment and time interaction of starter culture YC-380 via SAS using a p-value of 0.05 for viscosity values at a shear rate of 12.9 s^{-1}

	Trt	a	a	a	a	b	b	b	b	c	c	c	c	d	d	d	d
Trt[a]	Time[b]	0	2	4	8	0	2	4	8	0	2	4	8	0	2	4	8
a	0	-	0.5317	0.8594	0.2603	0.4886	0.0656	0.7456	0.5558	0.8605	0.4941	<0.0001	<0.0001	0.5353	0.6288	0.0005	<0.0001
a	2	0.5317	-	0.3259	0.2634	0.2477	0.0138	0.4406	0.8464	0.5414	0.7314	<0.0001	<0.0001	0.2918	0.3198	0.0005	<0.0001
a	4	0.8594	0.3259	-	0.0732	0.5784	0.0789	0.875	0.3944	0.999	0.3574	<0.0001	<0.0001	0.6292	0.7529	0.0004	<0.0001
a	8	0.2603	0.2634	0.0732	-	0.0699	0.0007	0.1491	0.5545	0.1999	0.7815	<0.0001	<0.0001	0.0957	0.0725	0.0007	<0.0001
b	0	0.4886	0.2477	0.5784	0.0699	-	0.0817	0.6799	0.0976	0.5782	0.1449	<0.0001	<0.0001	0.9601	0.7658	<0.0001	<0.0001
b	2	0.0656	0.0138	0.0789	0.0007	0.0817	-	0.0124	<0.0001	0.0755	0.0053	<0.0001	<0.0001	0.2691	0.114	<0.0001	<0.0001
b	4	0.7456	0.4406	0.875	0.1491	0.6799	0.0124	-	0.1354	0.8741	0.2758	<0.0001	<0.0001	0.7353	0.8852	0.0003	<0.0001
b	8	0.5558	0.8464	0.3944	0.5545	0.0976	<0.0001	0.1354	-	0.3855	0.836	<0.0001	<0.0001	0.1893	0.1762	0.0002	<0.0001
c	0	0.8605	0.5414	0.999	0.1999	0.5782	0.0755	0.8741	0.3855	-	0.1511	<0.0001	<0.0001	0.629	0.7511	0.0001	<0.0001
c	2	0.4941	0.7314	0.3574	0.7815	0.1449	0.0053	0.2758	0.836	0.1511	-	<0.0001	<0.0001	0.1793	0.179	0.0011	<0.0001
c	4	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001	0.4733
c	8	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001
d	0	0.5353	0.2918	0.6292	0.0957	0.9601	0.2691	0.7353	0.1893	0.629	0.1793	<0.0001	<0.0001	-	0.726	0.0002	<0.0001
d	2	0.6288	0.3198	0.7529	0.0725	0.7658	0.114	0.8852	0.1762	0.7511	0.179	<0.0001	<0.0001	0.726	-	<0.0001	<0.0001
d	4	0.0005	0.0005	0.0004	0.0007	<0.0001	<0.0001	0.0003	0.0002	0.0001	0.0011	<0.0001	<0.0001	0.0002	<0.0001	-	<0.0001
d	8	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.4733	<0.0001	<0.0001	<0.0001	<0.0001	-

[a]Trt a- BG + SMP, b- BG + SMP + L, c- BG + SMP + SC, d- BG + SMP + L + SC; [b]Time, h.

Values in tables show significance for treatments if p-values are < 0.05

Table 3: Statistical analysis of treatment and time interaction of starter culture YC-X11 via SAS using a p-value of 0.05 for viscosity values at a shear rate of 12.9 s^{-1}

	Trt	a	a	a	a	b	b	b	b	c	c	c	c	d	d	d	d
Trt[a]	Time[b]	0	2	4	8	0	2	4	8	0	2	4	8	0	2	4	8
a	0	-	0.7007	0.7997	0.1317	0.597	0.2867	0.6851	0.8895	0.5989	0.7068	<0.0001	<0.0001	0.8987	0.6914	<0.0001	<0.0001
a	2	0.7007	-	0.957	0.0029	0.719	0.337	0.8337	0.8795	0.7271	0.4762	<0.0001	<0.0001	0.933	0.8519	<0.0001	<0.0001
a	4	0.7997	0.957	-	0.017	0.7587	0.396	0.8703	0.864	0.7701	0.4947	<0.0001	<0.0001	0.9149	0.8904	<0.0001	<0.0001
a	8	0.1317	0.0029	0.017	-	0.0522	0.0042	0.059	0.0333	0.0383	0.2609	<0.0001	<0.0001	0.1624	0.0382	<0.0001	<0.0001
b	0	0.597	0.719	0.7587	0.0522	-	0.4385	0.878	0.54	0.9749	0.3297	<0.0001	<0.0001	0.7007	0.8425	<0.0001	<0.0001
b	2	0.2867	0.337	0.396	0.0042	0.4385	-	0.2726	0.0363	0.585	0.0974	<0.0001	<0.0001	0.3776	0.4367	<0.0001	<0.0001
b	4	0.6851	0.8337	0.8703	0.059	0.878	0.2726	-	0.5888	0.8993	0.3895	<0.0001	<0.0001	0.7968	0.9686	<0.0001	<0.0001
b	8	0.8895	0.8795	0.864	0.0333	0.54	0.0363	0.5888	-	0.5937	0.4915	<0.0001	<0.0001	0.9798	0.7111	<0.0001	<0.0001
c	0	0.5989	0.7271	0.7701	0.0383	0.9749	0.585	0.8993	0.5937	-	0.122	<0.0001	<0.0001	0.7088	0.8598	<0.0001	<0.0001
c	2	0.7068	0.4762	0.4947	0.2609	0.3297	0.0974	0.3895	0.4915	0.122	-	<0.0001	<0.0001	0.6149	0.3686	<0.0001	<0.0001
c	4	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001	0.0088
c	8	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001
d	0	0.8987	0.933	0.9149	0.1624	0.7007	0.3776	0.7968	0.9798	0.7088	0.6149	<0.0001	<0.0001	-	0.7156	<0.0001	<0.0001
d	2	0.6914	0.8519	0.8904	0.0382	0.8425	0.4367	0.9686	0.7111	0.8598	0.3686	<0.0001	<0.0001	0.7156	-	<0.0001	<0.0001
d	4	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001
d	8	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0088	<0.0001	<0.0001	<0.0001	<0.0001	-

[a]Trt a- BG + SMP, b- BG + SMP + L, c- BG + SMP + SC, d- BG + SMP + L + SC; [b]Time, h.

Values in tables show significance for treatments if p-values are < 0.05

Appendix B

Codes for yogurt treatments
Control- 521
0.375 LSBG- 988
0.75 LSBG- 828
0.375 HSBG- 339
0.75 HSBG- 763

Consumer panel comments on appearance
Control

- Looks normal - can't see any bran specks.
- smooth and nice color
- consistent colour (no particles as in 763)
- Looks very good, best looking_
- has white chunky things in it
- Good
- looks like normal yogurt but really shiny
- looks like yogurt
- looks smooth and creamy
- looks nice and smooth, but a bit runny
- This sample looks good too.
- uniform appearance _shiny, smooth surface_no speckles of color
- Smooth looking.... few speckles
- better than 339_
- Nice and smooth.
- looks quite liquidy, less specs in it than previous two, almost looks like a film overtop
- This is too runny for my liking. I like yogurt to be a little thicker
- runny
- Looks slightly runny
- looks like yogurt
- It appears to be a cup of yogurt
- not bad
- looks smooth and consistant, not too may brown spots
- smoother
- glossy,strong pink color
- more smooth than other sample, and color is lighter.
- it might be more white or red.
- too runny
- Has a creamier, more homogenous appearance than the others.
- looks watery around edge (~5mm from edge)
- looks watery (unappealing)
- looks more uniform
- Seems too watery.
- apperance is the same as the previous two samples_
- Looks like regular yogurt. Nothing good or bad about it.
- looks too runny
- Nice color and is nice and thick

- appears smoother not so grainy looking
- Too pale
- looks like normal yogurt to me
- light strawberry colour. has a piece of lint in it. generally good appearance.
- doesn't have the specles that 339 did, though this doesn't really matter...
- looks very tasty, creamy
- a little watery, but not like 988
- too watery
- looks kind of smooth
- Looks lumpy.
- a little too watery._
- looks uniform.
- seems like 988
- Quite consistent colouring and smooth when dripping off the spoon.
- The blobs floating at the surface were off-putting.
- once again, there were two colours - separating a light and dark
- looks very pretty and yummy
- looks homogenous_
- looks a little watery
- Looks as I'd expect yogurt to.
- some separation occurring; sort of muddy looking.
- looks normal

0.375 LSBG/175 g serving

- Nothing special about its appearance.
- the appearance looks good for color and doesnt look like it has any specks in it
- looks good
- OK
- looks like normal strawberry yogurt
- looks fine and smooth
- looks good, but quite a few bubbles in it
- looks a bit runny
- The appearance of sample 988 is good. Looks very smooth and creamy.
- consistent color_smooth, shiny surface
- Smooth with speckles
- less specs than 763, looks more liquid
- Looked like there was separation - some lumpiness in the middle with thinner outside
- runny
- looks like yogourt. not knowing what flavor, it's hard to know which kind it is
- looks fine
- looks smooth
- good color
- shiny, smooth, bit less pink
- The top layer seems transparent.
- a little runny
- Looks smooth & consistent.
- similar watery look as 339... resembles store bought so i don't mind it.
- Pretty loose looking.

- it's pretty much the same as all the rest_
- Looked a little bit lumpy, but not enough to detract from appearance.
- looks like a good consistancy_
- kind of dark and runny
- looks very smooth and thick
- looks like normal yogurt to me
- medium pink colour, typical yogurt appearance. not too light or rich in colour, looks good.
- looks like frozen and thawed yogurt. really watery
- looks like regular yogurt_
- thicker consistency than previous sample, but still a bit watery
- It looks a little bit weak.
- good colour
- looks smooth and soft.
- looks like normal yogurt
- Slightly dull compared to commercial brands.
- 988 appears to have a watery surface as if it were not mixed completely.
- in my sample there were two colours...light and darker. this took away from the appearence for me
- Looks really runny_
- a little watery
- Somewhat dark and grainy appearance detracts from overall appeal.
- looks like normal yogourt

0.75 LSBG/175 g serving

- Looks normal._
- slightly runny and smooth
- pleasing colour
- Not a nice looking some appearance of dark flecks_
- looks like yogurt
- too runny - dont like the colour of the yogurt
- some visible specks, but not too obvious
- a little watery in appearance
- looks smooth and creamy
- good, but a bit runny
- The appearance is fine. Looks like yogurt.
- consistent looking color_shiny surface
- A few speckles
- Black particle and grey color.
- looks quite evenly textured, colour good, less specs
- Still runny but better
- runny
- It looks a little thin.
- looks like yogurt. a little oily but overall good
- see above
- looks okay
- looks like regular yogurt
- smoother, color is good too_

- nice pink shiny color
- It is more red than th previouse ones.
- looks a little lumpy
- a little bit watery looking around edge (but less so than sample 521) and a small lump in the centre (sample 339 had more lumps)
- Looks consistent, still has few bubbles though.
- looks slightly thicker than others
- Looks a bit runny too. Not too firm.
- it looks the same as the previous sample_
- A few specks in it. Nothing you wouldn't expect to see in a fruity yogurt.
- I like yogurt to look thicker than this yogurt
- Appears smooth_
- Good consistency.
- Looks a little like there's a fine sheen of water or something on top which makes it took a little less appetizing than the others
- dark pink colour. Looks like it may be runny yet thick at the same time. Not all that appealing or unappealing.
- looks like yogourt!
- even less watery
- Nice consistency.
- It looks like it has lumps.
- The colour may be a little too strong for me.
- uniform, maybe ropy.
- like normal yogurt
- Slightly dull (less glossy and maybe slightly greyish) in color compared to regular comercial products.
- There are watery streaks on the surface. This sample appears to require more mixing. This is somewhat off-putting.
- looks creamy, little brown specs (dont take away from the appearence for me!)
- nice light color and thick
- looks smooth, maybe a bit watery
- looks lumpy_
- appears slightly watery
- A bit darker than what I'm used to for yogurt.
- not so muddy looking as 521
- looks normal

0.375 HSBG/175 g serving

- looks just like any (strawberry) yogourt.
- looks similar to regular yoghurt has a nice color and looks like it has some specks in it (fiber?)
- colour was pleasing and consistent
- better looking then763
- looks like yogurt_
- dull bland appearance
- looks like normal yogurt Kind of shiny surface
- a little watery looking
- looks kind of slimey

- seems to have a few bubbles which detract from its appearance_
- The appearance of sample 339 seems good.
- all fivew yogurts seemed to have the same appearance, meaning look only. If the ropiness were to be avaulated as a visual defect thre were differences!
- uniform color, but many speckles_shiny, smooth appearance
- Lots of speckles
- I personally like it thicker. It has a slight grey color.
- looks thicker and more uniform, has some specs in it
- Still too runny
- quite runny
- looks a little grainy
- It appears to be a cup of yogurt
- looks normal
- looks like regular yogurt
- pretty good_
- shiny, nice colour but see specs of particles in product
- I like some pieces in it.
- kind of runny
- slightly lumpy on top
- I can see air bubbles._
- not as watery looking as 521... but still a bit watery that it is not really appealing. Similar to store bought
- The appearance is fine.
- looks like it is smoother.
- Seems watery.
- nice smooth texture, it's not chunky. I don't like chunky yougurt. Overall though the texture doesn't disuade me or encourage me_
- Lots of dark specks floating around in it.
- I like yougurt to be thivker, brighter than one of the other samples though and I consider that good
- I like the coloured particles of red. More appealing
- Looks ok, maybe a little flat on the top where yogurt is often a little lumpier
- it's a light smooth pinkish colour, slightly orangish as well. Typical strawberry (stirred) yogurt appearance.
- looks like normal youghurt..._
- Looks just like other yogourts- colour is also very nice
- are all yogurts watery? this one's not as bad; like 988
- looks less watery than 988
- good consistency
- Looks ok
- thick uniform
- appearance seems fine
- Thick with small air bubbles incorporated and visible pieces of fibre present.
- This sample appears 'okay' but I wonder about the little dark flecks in it.
- it looked runny, and there were little brown specs in it (this does not take away form the appearence for me)
- looks a little slimy_
- looks good....

- looks normal to me_
- Looks average.
- firm, nice colour
- looks normal

0.75 HSBG/175 g serving

- Quite normal, except that small, bran-like speks are visible
- looks more grainy and thicker in texture
- seemed thicker
- Looks a little brown
- lots of dark specks, which doesnt look all that bad
- Granular appearance. A little dull in colour. Overall appearance - acceptable
- there were really obvious specks of brown. Looks contaminated or something.
- looks not that smooth
- perfect appearance
- small dark clumps look unappealing
- only a bit runny, but has a bunch of bubbles which detract from its appearance_
- The appearance seems good. There seems to be some very small, tiny grains in the yogurt but nothing big.
- consistent color, minor variations_smooth shiny surface
- Lots of speckles (doesn't look smooth)
- best appearance yet
- Grey color.
- looks like nice texture, has specs in it
- Nice thickness and uniform appearance
- looks fine. a little grainy. most comercial yogurt that my family likes doesn't have a grainy consistency
- looks good
- looks very much like regular yogurt
- a little bubbly
- bubbles and few specs detract the appearance
- some small pieces in it. not bad.
- Air bubbles make the sample look like it's going bad,_
- looks very thick
- looks much more granular
- looks not smooth at all.
- Looks appetizing.
- same as the rest_
- Lots of little specks floating around. Look like they could be raspberry seeds or something.
- doesn't have any chunks and I like that. Consistancy looks good though.
- nice and thick
- looks more grainy_
- I like the creamy texture. I like the sweet flavor.
- Looks just like normal yogurt to me
- darker richer more strawberry-y appearance. Good rich pink colour. Looks like lots of strawberry bits are present.
- the species add 'pizzaz'

- It looks good. I like the fact that there are obviously other, hopefully nutritous, components to it.
- Not watery! It looks good and fresh!
- looks bubbly
- I liked how it wasnt as watery as previous samples.
- Looks like it has some air bubbles, but in general color looks good and texture looks smooth.
- it looks too thick.
- uniform good color
- looks a little thick
- Very thick with many air bubbles. Not appealing.
- 763 looks alright even with all those little bubbles in it.
- it was less runny loooking (in comparison to 339) it also has brown specs in it (does not take away form the appearence for me)
- its thick which is good. nice pink color, very homogeneous
- looks good to me_
- lots of little bits can be seen
- not very runny; kind of gelatinous; okay colour
- looks a bit less watery

Consumer panel comments on flavor

Control

- Stong strawberry flavour - it's good!
- taste like regular yoghurt and less strawberry flavour than 828
- sample seemed too sweet
- Almmost too much strwberry falvour_
- tastes good_
- Artificial flavour- sour after taste.
- tastes like normal yogurt
- It is a nice mild strawberry not overwhelming flavour
- fruit flavour was excellent
- good and sweet with no grain taste
- The flavour is good. There seems to be more of a creamier taste, but only slightly more.
- clean strawberry flavour
- too sweet
- sweet, strawberry_
- Didn't taste sour, relatively pleasing taste.
- better than 339
- flavour is good, a little sweeter than previous one
- Nice combination of fruit and acid
- Very sweet
- It has a pleasant, creamy taste.
- nice and strawberryey
- it's a little wierd
- very good
- sweeter, if it is a little ligher would be better
- berry flavour may be a little stronger than the others, no detectable secondary taste
- very strong fruit flavour, very nice aftertaste
- a little bit sourer than other sample
- Good
- intense sweetness at the end and old strawberry taste at beginning
- Really tart.
- too sweet for my liking. Aftertaste is more pleasant than regular yoghurt (soft sweetness)
- Very sweet.
- Rather pleasant tasting, like the normal types you see in stores.
- 521 is a little sweeter than the previous two samples
- Bit more sour than expected.
- very normal tasting. I like it.
- Nice aftertaste
- this flavor is not so sweet but tastes fruity
- It has a malty flavour. I don't like as much._
- Delicious! Very tasty!
- good flavour. Tastes like strawberries!! :) I enjoyed it!
- nice and creamy without the touch of an aftertaste like 339 did
- Love the flavour-tastes just like strawberries
- tastes like yogurt, a little sour tinge is good.
- tastes a little sweet

- a little sour
- taste pretty good & smooth :P
- Good flavour.
- sour
- i like it because it does not feel too sweet.
- too sweet (kind of fermented fruity)
- like 988
- Slightly stronger aftertaste left at the back of my mouth, but still a consistent flavour with commercial brands.
- The flavour of 521 was pleasant but not quite enough.
- a little too sweet
- a little sour
- slightly sweet, pretty good!
- Good taste... not much aftertaste which i like
- Very good flavour. You know you're eating yogurt.
- has a nice 'zing'!
- This one seems not as sweet as 988

0.375 LSBG/175 g serving

- This one has a lot of both barley (bran) flavour and strawberry.
- I can only taste a little of the strawberry flavour but no fiber taste to it.
- very flavourful, strong tart strawberry flavour
- taste better, texure dosen't take away from flavor
- tastes good_
- Dont like the taste or the flavour - artificial after taste.
- tastes like normal strawberry yogurt
- nice mild not overwhelming flavour
- good fruity flavour
- goof flavour
- This sample seems to have a more stronger flavour of fruit which is really good.
- god strawberry flavour, clean
- weak strawberry flavor_no aftertaste
- Not too sweet, smooth_
- very good
- more flavour than 763, more dominant
- Still a good combination of acidity and flavour.
- good
- Very good
- It isn't tangy at all. It tastes very smooth.
- very flavorful. :)
- not bad
- very good
- smooth and thick
- maybe the strongest berry flavour of all, possibly a little too strong
- very fruity flavour
- it seems a bit sour
- good except a bit too sweet
- Tastes like strawberry yoghurt. Nice sweetness & tartness balance.

- although too sweet, the sweetness/tartness ratio was pleasant
- very good taste, yet there is a liitle bit sandy after taste
- Far too sweet for me.
- this sample has a nice tangy flavour
- Very sweet, but not much flavour intensity (I assume it's supposed to be some kind of berry like strawberry).
- kind of plain, but doesnt taste bad
- sweet
- It is also sweet. It think it has more of a 'yogurt' flavor.
- Excellent flavour! I suspect that this is, in fact, normal yogurt...
- great flaour! Rich enough to be yummy but not overpowering. Very tasty!!!!
- stronger strawberry flavour than 521, and no aftertaste
- great!
- too sweet_
- Slightly high acid and lack of fine flavour.
- Feel a bit more spongy than the last one (521).
- Taste sour (high asid)
- tastes like normal yogurt_
- Slightly more acidic or less sweet than sample 828. I enjoy that flavour.
- 988 is flavourful but could be even more strawberry-like to be truly enjoyable.
- this one tasted good, creamy
- sour
- great, although leaves a sorta weird aftertaste_
- Good, non-overpowering flavour.
- oh...hang on. Bit of an aftertaste...
- It tastes pretty sweet, which is good

0.75 LSBG/175 g serving

- Fairly good flavour.
- a bit sour but a nice strawberry flavour
- seemed too sweet, not tart enough
- Good falvour
- very strong strawberry flavor
- Too sour. Not enough flavour.
- tastes like normal strawberry yogurt
- tastes like strawberry jam
- nice fruit flavour
- texture is somewhat gritty
- This sample is good. The fruit flavour is good and there is a good creamy smoot taste.
- clean strawberry flavour
- sweet, strawberry, no bad after taste
- Right amount of sweetness (not too sweet, not too sour)
- good flavor. doesn't have a funny taste like some of the other ones
- flavour good, not as sweet as 521 and 988, still noticable and not overpowered by texture
- Nice combination of acidity and fruit flavour
- Tastes very jammy
- much stronger flavor than the other one. very good
- It's good.

- not too bad
- good flavour
- sweet ans sour mixure, good
- this has a superior flavour to the first two, no detectable secondary taste
- not so fruity, less acidic for a yogurt sample
- a bit of sour but fine
- much better than 339 and 521. good amount of acetaldehyde, strawberry flavour and sweetness.
- Less cereal-ly. Not sweet enough. Slightly tart_
- not too sweet and a bit tart
- good, decent taste.
- Pretty strong in flavor, not in a good way. Barley?
- I like the flavor of 828 more than 339._
- Tastes like strawberries.
- good flavour balance, sweet and sort of cerealish too.
- Nice aftertaste
- very fruity
- Too malty.
- A little less like strawberry than I would hope from strawberry yogurt, but still tasty
- rather sweet. Perhaps too sweet.
- strong flavour, tastes pretty much the same as sample 339
- Again, a nice pure strawberry flavour
- it's tastes like yogurt. sweet and sour. regular taste.
- tastes very powdery. a little too sweet
- Strong strawberry flavor.
- Very sour.
- tasts like yoghurt, good sweetness
- It seems to be a liitle too sweet for me.
- high fermented fruity taste but not very sweet.
- tastes pretty normal
- Very similar taste to other strawberry yogourts I have tasted in the past.
- 828 has a pleasant flavour with just the right 'bite' or sharpness to indicate that it really is yogurt that I am tasting.
- THIS ONE IS REALLY GOOD!
- taste like strawberry yogurt
- i like it-it is sweet not too thick_
- Good, not too sweet.
- hardly any flavor_
- lots of flavour
- Tastes sugary, a bit too sweet relative to first two samples.
- too much aftertaste, not enough strawberry
- Not as sweet

0.375 HSBG/175 g serving

- Tastes very strawberry-like... real strawberry flavour, not simulated.
- I can taste the fiber in the yoghurt but it is not as strong as 763. I like this yoghurt.
- sample seemed too sweet, not tart enough
- more barley taste

- Not nearly as heavy or gooy
- tastes good
- tart and gooy. Not sure I like it.
- doesn't entirely taste like yogurt because it has a bit of a cereal flavour. I like this flavour because it decreases the amount of tartness of the yogurt
- tastes like over-fermented
- very strawberry flavoured and it tatsed like real strawberries.
- to sweet for my taste
- tastes high in undercooked grains
- Tastes fine. I really like the after taste.
- noticeable off-flevour competing with the good strawberry taste
- tastes like strawberry jam on burnt toast, not like yogurt_not sweet, unexpectantly not sweet
- Dislike the taste. Almost sour tasting
- less flavour than 521 & 988, slimy mouthfeel, not as grainy as 763
- The acid taste of the yogurt is masked and so is the flavour
- not sweet enough
- Interesting flavor
- It is a little less sweet.
- i taste more strawberry in this one. a definate bonus.. but there's something else too.. not so good
- Tastes a bit like strawberry jam.
- tastes different
- good flavour
- a little sour and sweet mix, I like it
- again, two detectable flavours, but of course the berry is predominant
- fruity with some aftertaste, flavour lacks acidity of yogurt
- the flavour is good, just too sweet for me.
- It has a taste of hawthorn. Good
- does not taste like yogurt! has a grainy taste
- Can taste the toasted cereal flavour.
- too sweet and has a weird taste (burned) to it. the tartness was good
- A little sweet.
- a tiny bit too sweet.
- Aftertaste is not so great. Grainy.
- the yogurt leaves a waxy feeling in my mouth which I don't really like. The flavour is just fine but nothing exciting._
- Tastes very fruity at the end, kinda like strawberry jam, but an undescribable and unpleasant taste before that.
- this one also tastes like yogurt and cereal but I do like it.
- Has a funny aftertaste
- very flavorful, sweeter than 828
- The flavour is too strong. Can't explain it.
- Doesn't taste much like strawberry yogurt ... there's another flavour masking the strawberry-ness
- flavour is strong, but smooth and yummy!! Very strawberry-y.
- strong flavour, can really taste the strawberry
- Very good! A nice strong flavour.

- I like it. definitely a taste of barley, but it gives it a richer flavour.
- tastes pretty good. Although I think it tastes a little powdery. There's a stronger aftertaste thann 988.
- Unique flavor. Didn't really taste like strawberry yogurt.
- taste kind of weird..doesnt really taste like strawberry
- Good flavour.
- It tastes much better than the last sample. But I still like the flavour of 521 more than this sample.
- jam taste, not sweet .
- tastes like normal yogurt_
- Very bland; the acidity is about all that I can taste, hardly any sugar or strawberry flavouring.
- There seems to be a minimum amount of flavour in this one.
- it was a little sweet for my tastes - kinda of tasted like strawberry jam.
- a little wheaty tasting, grainy flavor
- doesnt really taste like anything
- quite bland
- very strawberry flavour - much more than sample 763, yum!
- Good taste - nice fruit flavour that tastes as you'd expect yogurt to.
- too sweet
- tastes bland

0.75 HSBG/175 g serving

- Wow, lots of bran flavour in here. But since I don't mind yogourt with cereal, it's OK.
- I dont mind the fiber flavour and it seems to give it a thicker feel to it
- very sweet, taste seemed bland
- tasted good
- Nice tart flavour. Reminds me of pudding not yogurt.
- this sample had an obvious cereal-like, almost burnt flavour.
- tastes like over fermented
- has a odd wheat like flavour
- sweetness reminding me of an artificial sweetener
- tastes like it has undercooked grain in it
- The flavour of fruit is good. There is a different flavour which is only slightly less desirable.
- nice strawberry flavour, not much but some aftertaste
- good mild flavor
- tastes like jam on burnt toast, not yogurt_sour aftertaste
- Tastes sour.
- A bit of cereal taste.
- flavor is nice but seems to get overpowered by the texture. Makes the flavour seem weak.
- What flavour - it is diluted to point of non-existence. No acid and no fruit
- bland
- I can taste strawberries, but it is far over powered.
- gross, something wierd about it, i wouldnt eat it again
- good flavour
- too sticky

- there us another detectable flavour besides the berry flavour, and like moderately is not displaying in the right spot exactly on the screen.
- no fruit flavour, bad starchy flavour aftertaste, lacks yogurt tartness
- its taste is not like other sample, but it is not bad.
- Have some barley taste. Good
- peculiar taste
- doesn't taste like yogurt. has a grainy taste like 339 did.
- Has cereal flavour that you wouldn't normally associate with yoghurt.
- gross... has that burned taste and not a very good sweet/tart ratio... bad aftertaste
- not as strawberryie (is that a word?)
- taste is not good, little flavour.
- A bit jammy tasting.
- the flavour is overshadowed by the texture of the sample. the flavor is alright but I dislike this yogurt in my mouth because it feels slimy. I'll still eat the whole thing though.
- Similar to 339...but more intense, and not very pleasant.
- very good, can sort of taste the barley, but it tastes like yogurt with cereal. Very good.
- Doesnt taste like yogurt or like strawberries at all
- too sweet
- I like the sweet strawberry flavor. Maybe too sweet in larger portions.
- Good flavour, sweet and still like strawberry
- tastes strawberryish, but there's a conflicting flavour there. Still quite pleasant, but slightly different. Reminds me more of strawberry/banana flavoured yogurt because it has something else there.
- has an odd flavour... not very strawberryish
- Tastes too much like cereal. Don't like it at all.
- It's sweet (too many berries?).
- tastes the most like barley so far
- Tasted disgusting
- Very high acid and grainy.
- odd flavor, bad aftertaste___
- This sample does not taste as sharp as 521. I like the taste of 521 much better than this one.
- Jam taste. acid.
- can taste the barley a little
- Very bland, needs considerably more strawberry, sugar, and acid.
- Note enough flavour.
- i really liked the taste of this one, didnt seem as sweet as 339 to me! yummy!
- a little sour, but I like that
- um kinda funny tasting - not really too sure how to describe it_
- it doesn't taste like yogurt!!!_
- Taste like bananas. I'm not a monkey.
- Has a taste more akin to smoothies as opposed to the store-bought yogurt I'm accustomed to.
- Yuck! tastes like glutinous sawdust...
- Tastes sweeter than 339, but still not that great

Consumer panel comments on texture

Control

- It's a bit thin and runny.
- texture feels thin and slightly runny
- very nice texture...thick on the tongue, not runny or goopy
- Favorite texture, very smooth
- feels like yogurt
- Good texture. Smooth. Right consistancy.
- too watery
- nice smooth texture
- creamy
- thick enough on the spoon not to run much, but flows well in the mouth.
- This sample does not seems as solid, more viscous which is fine.
- good typical yogurt texture
- very smooth
- too runny_not grainy
- Smooth, not too thick
- not sticky
- best one so far, has lighter mouthfeel, creamier
- Mouth feel is good, but it is more like a drink than a yogurt
- Very smooth
- It has a very good consistency.
- Good'n creamy
- a little runny, but it's alright
- smooth, very good
- smooth, great
- very smooth, slightly thin texture
- it is a bit thin. Consumer may think it hasn't much content.
- pretty good; a little thick
- Too runny & grainy.
- not thick enough.
- less of a slimy texture than 339 and 828, but there wasn't any unpleasentness associated with either_
- pretty smooth texture.
- Nice and smooth.
- 521 doesn't leave a waxy feeling in my mouth but is is more runny than 828. I think it would be better is it was a little firmer_
- Texture as expected for yogurt.
- nice and smooth
- more watery than creamy
- Too runny.
- Just thick enough and not too sticky or stringy!
- very smooth liquidy texture. Very pleasant.
- smooth
- Goes down very well. A very smooth texture
- smooth, good!
- very smooth
- Very smooth.

- slightly weak
- the right thickness.
- grainy, thick.
- smooth like 988
- Added fibre is hardly noticeable... quite smooth.
- 521 has a pleasant, smooth texture._
- nice a smooth
- mmmm i really like the texture of this one - it is creamy without being too goey
- smooth
- Very good.
- The texture is a bit thicker

0.375 LSBG/175 g serving

- This one seems to combine a slightly thin, runny texture with the sticky after-'taste' (texture) of a sample with lots of barley.
- texture is a bit more runny and thinner than 339 and 763
- texture was a bit runny for my liking
- Goog texture
- nothing bad with how it feels_
- Texture too granular and gooy. Not palatable.
- slightly ropey and kind of watery
- nice and smooth yogurt
- too thin, slightly granular
- could be slightly firmer
- This sample is very smooth and creamy.
- sligtly grainy, otherwise good yogurt texture
- smooth but not too thick
- too runny, but not grainy
- Smooth
- texture is quite runny, mouth feel is ok
- This sample was a little thin and had a graininess to it that I did not like
- A bit thicker than last sample (521) - good!
- It isn't too thin or runny. It holds well on the spoon, and feels substantial when you put it in your mouth.
- just like yogurt should be
- Not sure what it is exactly. It just feels a little strange when it hits the tongue...as though it were sour, but it doesn't taste so.
- it's okay
- smooth
- good
- texture did not differ noticably for all samples
- smooth texture
- it's normal
- very slightly too thick - almost perfect
- Would have rated it higher, however, I can feel the grainy-ness of the sample.
- not thick enough (When I say thick, I am referring to real yoghurt thick... not fat free or light yoghurt)
- thicker almost slimy texture, but not unpleasent

- Texture is nice and smooth.
- the texture is good. It is not as runny as the precvious sample and doesn't leave a waxy feeling in my mouth._
- Bit too thick.
- nice and smooth
- right balance of creamy watery
- Mybe a little too runny.
- Excellent texture of the yogurt! Just like the real thing!
- is thick enough to feel like one is eating something, but not so thick that it's really hearty. Very pleasant balance is acheived.
- A slightly sticky feel to it.
- there's a bit of grain, but not bad
- it's fine nothing extradordinary_
- seemed a bit grainy
- pretty thick.. not bad! :)
- Texture seems ok.
- Feel a bit more spongy than 521. I'd like it to be less spongy. The taste of this is good though.
- thick, havey texture.
- very smooth, once again, like normal yogurt
- Quite smooth. Just a hint of graininess.
- 988 feels smooth and pleasant but with a slight hint of gumminess sticking to the tongue.
- not too thick.
- slightly grainy
- Nice dairy texture.
- It has normal yogourt texture

0.75 LSBG/175 g serving

- A bit thicker than what I'm used to for yogourt. Similar texture as when some bran is added to yogourt.
- too runny but a nice smooth texture
- texture was slightly thick; pleasant on the tongue
- Seems pretty good_
- feels like yogurt
- Very runny - too granular.
- like normal yogurt, but more watery
- very smooth in texture
- quite granular
- texture was gritty
- This sample has good texture. No problems.
- slightly grainy, slightly gooey
- kind of grainy_too runny
- Good texture, not too thick or too runny
- not too sticky
- Some particle detected in the month and it is hard to swallow.
- a little runny but better than the rest, not as slimy and does not dominate flavour

- This is more of the yogurt texture that I want - thicker with no watery characteristics in my mouth.
- not smooth, slightly lumpy
- I would like it better if it were a little thicker.
- good smooth yogurt
- little gritty.
- not bad
- a little lumpy
- gentle
- seems a little thinner than the others, but I would be OK with a wide variety of textures
- smooth but bit starchy mouthfeel
- it is too thin, not many pieces of barley, lack of milk
- still a little thick compared to other yogurts
- Really grainy.
- thicker than others... good... could be thicker. Has a weird aeratedness to it (lightness/bubble pockets)
- was not as smooth as i would like it.
- Seems like it has more body to it.
- the texture of 828 isn't as waxy as the texture of 339. I like 828's texture more_
- Not too watery or too thick. About right for yogurt.
- very good texture.
- Nice and smooth
- very smooth and creamy
- Doesn't feel as good in the mouth.
- Thicker than usual yogurt I think, but not unappetizing. The thickness even adds a little to its appeal
- smooth but not completely smooth... some particles are sensed in the yogurt.
- creamy, but a touch sticky, close to 339
- Good texture-a little gritty, but that could be my soda crackers.
- it's grainy.
- I found it too grainy.
- kinda thick
- Grainy.
- grainy pieces in mouth, slightly ropy
- Good consistency, not gluey or spongy.
- thick and feels the grains.
- maybe a little grittier than 988
- Slightly grainy texture. Doesn't go down the throat completely smoothly like fibre-free yogourt.
- This really felt good on the tongue and palate.
- its a normal yogurt texture, not too thick
- smooth! :) maybe a bit thin - could be creamier_
- The texture is also like jam, but I like it.
- way too thick
- A bit too 'dry' - tastes like I'm eating it with cereal. Other than that quibble, the texture is not bad.
- kind of gritty.

- Seems thicker

0.375 HSBG/175 g serving

- not perfectly smooth
- Pretty standard.
- It is a bit grainy but has a nice feel because it is not too runny
- sample seemed too 'goopy'
- still a little slimy_
- feels a little bit thick but is good.
- Sticky texture.
- Thicker than normal yogurt, really ropey. I can feel some residue between my teeth when I 'bite down' on the yogurt. I like the thickness, but not the residue.
- seems like there is too much gum
- it was very smooth
- too thin
- runny on the spoon, thick in the mouth
- The texture of the yogurt is fine.
- sticky (gooey), ropy, grainy. Poor texture
- thick but not too stringy on the spoon
- sticky and grainy_too runny
- Really thick_
- a little too sticky
- I bit gummy.
- slimy mouthfeel, not as grainy as 763
- Muth feel is thick and gooey - not what I would expect from a yogurt
- slightly viscous
- Kind of sticky
- It is not quite as smooth as 988.
- tastes a little grainy.
- A little bit gritty
- gooey
- a little too thick
- smooth
- smooth but more like a mousse, foamy
- very smooth
- Good. The flavor of hawrhorn and barley is apparent. But lack of milk
- runny
- way too thick. very ropy (I am on the UofA Dairy Tasting Panel)
- Kind of gummy.
- thickess and pastiness unappealing... coats my mouth.... yuck!!!!
- Texture is ok.
- it is good and smooth, no sandy feel to it.
- Feels gummy.
- Again I didn't like the waxy feeling the yogurt left in my mouth.
- Too thick and syrupy.
- The yogurt is a bit thick and sticky like the first one, but I think it is less thick so that might be better.
- doesnt go down very smoothly

- very smooth
- Harder to swallow.
- A little slimy for my taste... less smooth and creamy as normal yogurt would be
- smooth and silky. Quite liquid.
- creamy:)
- An interesteing texture- very creamy, but alos kind of gooey
- I like it. It's not grainy like 521.
- Smooth and creamy.
- Little bit ropy.
- grainy texture in mouth, slighty ropy
- Better texture than the last sample. But still too gluey for me.
- very very thick.
- a little thick but relatively normal yogurt
- Very smooth, but too thick, almost gooey
- 339 feels gummy or glutiny.
- i like the texture it was very smooth, although slightly runnny
- slimy, gooey very poor texture
- its a little gooey, but nothing too bad, dont hate but dont really like it_
- the texture is more like jam to me, though I like it.
- too thick
- slightly grainy
- Not quite the yogurt texture that I'm accustomed to, but good overall.
- smooth
- too thick, it feels like chocking

0.75 HSBG/175 g serving

- about same lack of smoothness as before
- Close to that of 'normal' yogourt, but I think the added barley is leaving a bit of a film on my teeth.
- has a grainy feel and thicker texture
- texture seemed gummy
- Very slimey_
- has a more viscus texture, feels kind of bubbly. nothing wrong with that though
- A little on the gooy side. Sort of sticky! Not smooth enough.
- super ropey and felt kind of grainy. There were also some air bubbles in the yogurt so it felt artificially light.
- too viscosy
- it has a slight stringy, thick texture
- gooey and clumpy
- looks a bit runny, but is far to sticky on the spoon and in the palate
- The texture is a little weird. I know it is still yogurt but the texture has less constinuency.
- sticky and grainy
- very sticky...runny and stringly on the spoon
- sticky_not runny_not grainy
- Too thick
- Hard to swallow.
- texture is slimey and it feels as though there are small lumps in it (somewhat grainy).

- Gummy and thick. Yuck
- lumpy and viscous, not smooth
- Kind of sticky
- It's a little sticky._
- texture's great. despite it's different appearance..
- Too thick, almost to the point of being stringy, and also more gritty than all the others.
- too gooey, kinda like glue
- very thick
- is ok
- foamy, too thick for yogurt product, particles left on tongue after swallowing
- it is more viscous than other sample, I like it.
- Smooth is good. But may be better if reduce the degree .
- rubbery
- way too thick
- Not very smooth.
- has that aeratedness like 828 but it coats the mouth... yuck!!!
- this sample is very thick and quite slimy in nature, to the point where it is verging on unpleasent (it kind of gets stuck in my throat)
- Hard to taste the flavor because the texture is so thick and grainy. Not a good yogurt at all.
- The consistency is quite stringy, like there is a binding to it.
- the texture is very waxy and slimy. it's like ooze in my mouth. I don't like it. I need another cracker to get rid of this taste.
- Very thick and syrupy. Can sometimes feel the graininess of whatever's floating in it.
- the texture is different in that it seems more sticky or thick than usual yogurt, but it is not a bad feeling
- Not smooth, too sticky
- texture is too grainy
- Texture is too viscous to be a yogurt product.
- The texture is what I like the most. It has a creamy texture.
- The texture is a little sticky compared to normal yogurt, and a little... slimier
- thick, more chewy yoghurt. seems more hearty as well.
- it's slightly gooey, or sticky.. yoghurt should be creamier
- It has a gooey, sticky feel to it.
- It's sort of even more grainier than 828. I don't like it.
- a little texture. not as creamy as the others
- I liked the consistency of this sample, but the taste was absolutely horrible. It took me half a glass of water to wash it down.
- Grainy and very ropy.
- very ropy and thick/gel like texture
- feels sticky
- Too spongy, too gluey, too thick.
- thick. not smooth.
- pretty thick, like dentist fluoride or something
- Super-thick (bad) and smooth (good) but some graininess (bad) also present.
- 763 is another gummy sample - too gummy.
- it was grainy

- its slimy, gooy, not like normal yogurt which is creamy and light
- its gooey, if that makes any sense_
- it is very thick and sticky!!
- It feels to thick. Sorta like slime
- very thick almost like a pudding, but not creamy.
- A bit too much like jam - not much of a dairy 'feel'. A bit like a smoothie in that regard.
- feels like glutinous sawdust, too.
- Very thick and gooey

Consumer panel comments on overall acceptability
Control

- Pretty good flavour, but a bit too thin (texture).
- not as likeable as 828 as it is too thin and runny texture
- Flavour seems to strong, texture good though_
- Sour after taste. Liked the texture. Tastes artificial.
- too watery, had no body
- very nice yogurt
- the creamy and smooth texture was good, but i would of liked it thicker
- This yogurt is good. Only less viscous or less solid than otherwise desired.
- good yogurt
- Very tasty (better than 763 and339, but not quite as good as 988)
- taste not quite as good as 988
- It's very good.
- I'm guessing this one is the control. I think it might have been better to start with this one just to know that that graininess was part of the actual yogurt. I liked all but the one right before this one.
- It was nice.
- not bad
- overall it looks and tastes very good
- taste is good, a little sweeter, nice color
- The biggest disadvantage is it is too thin.
- mainly just didn't like the flavour
- just a little too sweet.
- Other than it looking a bit watery on initial appearance, it tasted quite good.
- Nothing particularly good or bad about this sample.
- this tasted like any other yogurt I've had.
- nice taste and appearance
- this one had the best flavor but the texture was a little watery
- This one is also as good as normal yogurt would be to me!_
- great yogurt! I enjoyed it!
- yum!
- good! taste like regular yogurt!
- Good
- too sweet. not smooth.
- good like 988
- Approximately equivalent in appeal to sample 988.

- 521 has an appealling flavour and texture but it is not the best yogurt I have ever tasted.
- overall good, a little too sweet for me
- too sour, good texture
- This is very good yogurt.
- This yogourt has a bit more of an after taste in the back of my throat

0.375 LSBG/175 g serving

- Flavour was pretty good, but disappointing texture.
- It is similar to regular yoghurt on the market but slightly more runny in texture
- Good, seems like normal yogurt
- good stuff_
- Dislike this product.
- was like normal yogurt
- great overall yogurt
- i liked the fruit flavour in this one
- This is very good yogurt. Great taste.
- good clean taste, slightly on the too sweet side, no texture problems
- Tasty, not too sweet
- like the flavour, texture is a bit too thin
- Ho Hum
- It's very good.
- good yogurt.
- It tastes good.
- not too bad
- very tasty and smooth
- thicker and richer
- it's normal. Not having fspecilal features
- Probably my second favorite sample.
- just slightly too thick and too sweet - close to perfect
- Love the flavour, the texture can improve a bit.
- The best so far... but still too sweet
- taste was good, texture was a little sandy. I would eat it.
-
- If it wasn't for the sweetness, which to me is too much, I would purchase this yogurt.
- the sample size should be larger for 988.
- nothing unique about it
- a little too sweet but very good texture
- So good that I am inclined to believe that it's yogurt without any barley added
- overally this was a GREAT yogurt.
- good, but not good appearance
- This is not a bad sample texture and appearance wise, but the flavor could be better.
- color is good but the taste and texture are bad.
- wouldn't notice the difference that is a barley yogurt_
- Due to difference in texture, I like this sample slightly better than number 828.
- This was an enjoyable sample with a good flavour and fairly good texture.
- i really like this sample, all was good!
- It's good, but not overwhelmingly great with respect to all three attributes.

0.75 LSBG/175 g serving

- The bran-like texture is a bit unusual, but not necessarily bad.
- slightly sour and too runny for yoghurt
- smooth tasting
- has the same impression as normal yogurt
- Taste, texture and appearance not acceptable to me. Dont like after taste.
- it was too runny
- nice, but quite a few bubbles present
- this was good yogurt, but the graininess was a bit of a turn off
- This sample was good. It tasted just fine to me.
- good product, slight textural defec balanced with the good flavour
- Very tasty
- Best sample so far. Has all the based covered for me
- It was just okay. I would eat it, but probably wouldn't buy it again.
- better yogurt
- It was fine.
- good flavour and texture but slightly lumpy
- gentle and good taste
- the appearance is inviting. But taste lack its own features.
- The best so far... the texture could be thicker
- It is not one I would purchase. The overall taste of it is heavy and strong.
- Is this the reference?
- tastes refreshing
- Good flavour though not quite enough strawberry in it, and the thickness of the yogurt could get to be too much after a big bowl full. But very tasty still.
- nothing special, but rather sweet.
- If there were larger crunchy grains, it would make a good parfait.
- An otherwise good yogurt sample, if it hadn't been so grainy.
- Don't like the flavour.
- pretty similar to 988, not bad at all
- Good, as long as you're prepared for the altered texture from added fibre.
- Despite the initial appearance seeming to be quite negative, this sample proved to be a pleasant one.
- the texture was smooth, i really really like this one
- this is a good product, I would buy it
- Sugary taste and less than ideal texture make this sample sub-par.

0.375 HSBG/175 g serving

- I'm especially impressed by the flavour. Everything is seems pretty ordinary.
- I would not mind eating this yoghurt on a regular basis.
- Better then 763
- tastes, feels, and looks similar to the rest of the samples
- Sticky texture. Colour bland looking. Dont like this product.
- Slightly different from normal strawberry yogurt, but I like that
- very nice yogurt
- not too bad, but tastes like there is barley in it

- The taste to sample 339 is good. Tastes like yogurt which is a good thing. I really like the after taste.
- not a good yogurt, both textural and flavour defects
- taste is not much like yogurt at all, but no bad aftertaste
- Not pleasing at all.
- had a slightly funny taste
- Not a particularly desirable product. Would not repurchase
- It's pretty good, but I liked 988 better._
- meh.
- It's OK
- not good
- overall good
- taste good, looks nice , I like the gentle colorand taste good too
- product more like a dessert than yogurt
- it is good
- i can accept the flavor. The appearance has something to be improved.
- not representative of yogurt
- gross
- good yogurt.
- Didn't taste like a normal yogurt. The texture didn't seem right.
- Too thick, and doesn't taste good.
- Isnt extremely bad, but not a yogurt I would prefer
- Flavor is unusal.
- Texture and flavour need work on this one!
- overal just a great yogurt!
- It's my favourite so far (I've tried 828,988, and 521).
- Good texture, creamy, had a unique flavor to it.
- Overall good sample.
- bad texture and flafour
- like normal strawberry yogurt
- Too thick and not enough flavour, despite very smooth texture.
- 339 is 'okay' but not a product I would wish to purchase after a first taste.
- i seemed to get used to the sweetest of it by the third try, however it still was a little sweet for my tastes
- I would eat this only because of its nutritional qualities
- A good sample - fairly conventional in terms of taste.
- I wouldn't buy this yogourt

0.75 HSBG/175 g serving

- I suspect this one has the most barley so far, and it's getting to be a bit too much.
- it is quite different from regular yoghurt due to a grainy texture and a fiber taste but I would not mind eating it on a regular basis
- Slimmy, heavy tasting, too googy
- Dull colour - gooy texture - tart taste
- this is not what i expect yogurt to be like
- texture was the main problem
- poor appearance, texture and taste - seems to have too much barley in it - ehough to be tasted

- I still like this yogurt but it is noticeably different.
- main effect from the stickiness (almost gooey) , overshadows the good strawberry flavour
- doesn't really taste like yogurt
- Not enjoyable, too thick and sour
- don't mind, somewhat bland, texture dominates senses.
- Try again -Worst of the bunch.
- It's not as creamy as I would like.
- This Yogurt was not very goodd at all.
- i would only eat it if i was starving and it was the only thing available
- seem way to viscous for yogurt
- sticky, and thicker
- Good. it is a yogurt, right? it seems to be lack of milk.
- not representative of yogurt
- the worst by far
- not as nice as the other samples
- The texture kind of turned me off a bit, otherwise I could eventually get used to the flavor.
- the taste was sweet but there was a grainy flavour to it that I didn't like. I really didn't like the texture.
- Doesnt taste like yogurt, smells bad and is too sticky to the spoon
- too grainy and sweet.
- Texture is the main factor causing to low score.
- Appearance and taste are good, but the texture is a little dislikable, it's too sticky and stringy
- good yogurt. I would want to advertise the presence of something asides from strawberry to make it more appealing to the consumer given the flavour, perhaps the health benefits. But I liked it!
- not very good at all
- The grainy texture makes it feel like it's expired or something. it's also a bit on the sweet side and not sour enough
- Good consistency, horrible taste. Texture ok, a bit grainy.
- The sample is quite sour and ropy, when you put it in your mouth it also feels grainy.
- does not taste like yoghurt_
- Jam taste. not sweet. fruity fermented.
- i didn't like the thickness and barley taste too much
- Yuck.
- 763 is too gummy and without enough flavour to compensate for the way it feels in the mouth.
- the texture makes this product very unfavorable - the taste is pretty good, but its hard to like somthing with a poor texture
- gross, i didnt like it at all_
- too thick... flavor is way off...
- It has an appealing taste, but the texture and appearance are not what I would expect when it comes to yogurt.
- I wouldn't buy this yogourt either

Appendix C

Codes for ice cream treatments
Control- 262
0.375 BG- 819
0.75 BG- 594

Consumer panel comments on ice cream appearance
Control

- This one has the least brown specks of ?bran?, but still some ice crystals on top.It's been put in the cup almost artisically, so even though it looks hard (retains its shape), it looks pleasing.
- The appearance of the ice cream is whiter than expectation. It does not immediately register in my brain as 'ice cream.'
- It looks a bit rippled.
- looks like with ice crystals on the surface
- nice color and looks a little lumpy
- Looked a but melted but that was all
- nice, white and speck-free
- appears similar to 819 but slightly lighter in colour. Definitely lighter than 594. Overall, 819 and 262 more desirable but I don't put a large emphasis on the appearance.
- looks lumpy with big crystals
- Sample 262 has a good appearance. The ice cream looks creamy and tasty.
- Frosty looking, (sparkles) Looks like frozed yogurt. Not in the usual scoop shape
- doesn't look very creamy
- it seems to glitter.
- looks milky, sort of like frozen yougurt
- very soft-fluufy like appearance, comfortable feeling to me!
- crystalline appearance
- looks a little sorbet like in texture
- doesn't look smooth
- There seems to be lots of ice crystals on top. That is the reason that I don't like it more. The colour is very nice. It looks like it will not be
- smooth to taste, but I will tell you when I taste.
- again, there are ice crystals on top, _no brown specks, consistent and white_smooth appearance
- looks like ice cream - not frozen
- not as smooth as the other two
- looks like vanilla ice cream
- ok
- icy
- Does not look smooth and plain
- without color, it looks almost like frozen ice
- I like the crispy texture.
- looks more like traditional ice cream_
- again, it looks sort of like there are crystals on the surface that might not taste good.
- It doesn't look smooth like normal ice cream. I don't know if it is because the way they were put into the container

- does not look thick or creamy, it looks like refozen melted ice cream
- A little frosty, I am assuming from the freezer.
- fresh and frosty
- It appears chunky
- nice white color
- crystals.
- it looks like frozen whipped cream
- appears quite crystaline, and looks like it may be very hard.
- looks old
- Looks sting, does not look very smooth and creamy. Looks more like dry mashed potatoes.Crumbly
- reminds me of ice cream that has been thawed and refrozen. a definate crystal structure with in the ice cream.
- It's kind of sparkly, that's good
- it looked like fake icing that you see at christmas
- looks gritty like icing with too much icing sugar in it, not smooth and creamy
- Lots of ice crystals. Looks like it was melted and then re-frozen.
- looks 'fluffier' than the other one...
- This looks good. It looks like dessert
- looks cold white and crystalline. Very pure looking, and icy.
- It looks really cold and icey.
- Looks like ice cream from Marble Slab (R). Looks good and creamy.
- looks lumpy and not creamy
- clean and pure
- the crystal of ice cream is too big. Therefore, it makes product look like icy dessert more than ice cream.
- It looks like 'normal' ice cream creamy and a little chunky
- looks soft, shiney, appealing texture
- looks like it has freezer burn. been sitting in the freezer a little too long
- looks like frozen yogurt
- I liked the look because it looked like it had more substance and it reminded me of mashed potatoes.
- I like the homemade-whipped appearance._
- It looks like it melting or has been spraied with water
- it is kind of soft, it shows a weak structure (compacted). Looks like soft cream...
- it looked freezer burnt (very crystally) and kind of boring (just plain white)
- Looks thrown in
- the color is too light
- it somehow looks softe than sample 819 and not as thick or hard looking for a frozen ice cream.
- smooth
- icy/chunky
- it looks more natural and creamy than 594
- I like the fact that it's not clearly wite and that it's not of a strong colour either, but the shade could have been a bit stronger (brighter)

0.375 g BG/125 g serving

- This ice cream also has ice flakes on top, making it look like it's mostly water. Again, you can see little specks of what looks like bran.
- This ice cream hasn't moulded itself to the cup very much, which gives the appearance that it will be very hard.
- This looks more like compact snow than it does ice cream. The top appears granular and unappetizing.
- Other than the ice crystals on top, it looks fine.
- looks icy, not like icecream
- looks similar to other samples
- looks very creamy, nice uniform light color
- The sample looks like yogurt and seems to be grainy in appearence
- looks kind of transluscent. just a few spots.
- Similar to 594 (e.g colour and smoothness)
- It's not very white, has flecks of colour in it.
- Sample looks creamy and looks very tasty.
- a little frosty, (not bad) Has brown specs. they dont bother me, could they be from vanilla bean? Probably just the barley.
- This one was placed into my dish a little nicer.
- Frosty like Sample 262, but with specks like Sample 594
- the ice-cream glitters like the first sample I tried.
- Looks clumpy,
- looks really hard, can see small flakes of brown
- due to shape in the container, looks like it has melted slightly then been refrozen
- same as #594
- has a crystilline appearance
- I could actually see some sparkly ice crystals, which is something that you see in stale ice cream, which might be a bad association
- for some, even though in this case I know it's fresh.
- doesn't look very smooth
- Very large crystals of ice on top. It looks like when at nome my ice cream melts and the freezes again. The appearance is poor.
- crystals on top, maybe just due to storage in freezer_unappetizing dollop in container
- still somewhat frozen
- unremarkalbe in apperance...creammy looking (not solid?)_
- it does not look great...mean to say it does not click to your eyes immediately
- no comments
- does not look like ice cream_
- it look like snow
- This sample appears to have a strange crystalline coating all over it.
- looks like froth and not ice cream
- looks sort of like there are crystals in it that I associate with that "freezer burn' that happens on ice-cream sometimes and doesn't taste very good.
- It is very frozen and wondered if it will look different when thaw. _I don't know if the black bits are part of the fibre that didn't get dissolved
- It looks very similiar to the sample 262. I appearance is ok but plain._
- nice white color, ice crystals on surface of ice cream
- it looks like it contains ice crystals. Plus looks fomy.
- looks hard and uncreamy

- It resembled old fashion icecream.
- looks mushy
- Looks a little bit grainy
- similar appearance to that of compressed snow. neither inviting nor repulsive.
- it looks kind of runny like it was melted then frozen again.
- too many ice crystals on top.
- Lots of dirty-looking brown specks, just like 594. Not particularly appealing even if you expect it to look that way.
- again, it looks better than 594
- Again, it looks inedible-kind of like foam
- It looks smooth creamy white and soft. It also looks cold and crystaline. Very nice appearance for soft ice cream!
- Looks like melted and refrozen ice cream.
- very nice, but looks like suger, not icecream
- There are a lot of small icy crystals cover the ice cream.
- It looks chunky enough to be normal ice cream but it also looks like it has freezer burn... little spiky ice pieces sticking up all over the surface.
- ice crystals formed on top; looks freezer burned and a bit dry
- it has specks of something, giving the appearance of being more than 'just vanilla'. a definate bonus
- the appearance is just plain and smooth looking__
- It looked too plain and very frosty.
- It does not look creamy
- nice and cold consistency
- lots of ice crystals
- it looked like the ice cream had melted and was re-frozen
- it looks like it had melted and then refroze.... looks a little freezer burnt (ice crystals on it)_
- Looks more natural
- this one looks better.
- looks very frozen, maybe a little overly frosty
- a lot of ice crystals
- Frozen, looks Hard
- looks like a little cloud

0.75 g BG/125 g serving

- Unlike 'regular' ice creams, this one has small ice crystals or flakes on top, making me think it has a higher water content and less fat. Also, there are some visible brown bits, which look like bran.
- The appearance looks more like iced porridge than it does ice cream.
- Looks creamy and smooth.
- surface icywith specs
- ice cream looks appealing but has a different look than regular ice cream
- few specs but similar to French vanilla ice cream
- looks like someone poured milk into a cup and let it freeze outside. Feels pasty trying to drag the spoon through it. The rest of the samples also had melted a bit but this sample is frozen solid still, kind of scary.

- the brown spots are quite prominant on the surface of the ice cream, but seemed less obvious when the ice cream was spooned
- appearance is similar to vanilla ice cream in the store.
- looks a little crystally with flecks in it.
- This sample has a slightly less favourable appearance than the previous samples. There appears to be small air holes or bubbles which do not seem right for ice cream.
- Foamy icy look
- appears to have more brown spots than the second sample. Flatter in the dish.
- looks like it was recrystallized from melted form_
- Dark specks within the ice cream (unsure of what they are)
- it looks dried out.
- smooth looking, not too odd, little bits of specks in it are kinda wierd
- looks like melted and then refrozen ice cream, quite dense
- looks like normal ice cream
- shiny, hard, not attractive
- bubbly appearance
- looks a little harder, a little creamier
- doesn't look smooth
- It looks foamy to me, I don't like that at all. It doesn't have large crystals like the other two samples which I think is good. Too bad there is a foamy, frothy look. I don't like that.
- many brown/black specks - looks dirty_ice crystal on top_under the ice crystals it looks smooth
- still frozen
- no attraction
- it looks dirty, little brown flects
- nothing in particular_
- does not look like ice cream
- looks more of bran !!
- this looks like white sand.
- looks like froth, not like ice cream_
- looks close to the same as 819.
- There are a lot of black bits on the ice cream although it looks more smooth than 262
- does not lok very creamy
- The appearance looks more liquiidy. The other samples were more lumpy. which I like.
- hard frozen
- brown specs not appealing. Looks like dust
- firm enough.
- Looks hard, and uncreamy
- looks like vomit
- Has flecks of grey in it. Not sure if those are vanilla bean flecks or what? Looks creamy.
- it shimmers as you move it around. It appears to have a much creamier/frothier texture than what sample 262 did.
- It looks like it was melted and frozen again
- i did not like the air bubbles at the surface and it looked really processed, too smooth.
- looks like fine grains of sand, not creamy smooth icecream!
- Not as many ice crystals as 262. Has small brown flecks, which makes it look like vanilla ice cream that has dirt and dust in it.
- Not particularly appealing if it's just supposed to taste like vanilla.

- looks not too soft
- it looks inedible
- Looks smooth and frozen, a little browner in colour than off-white. a little speckled
- looks really solid almost like a cream that's been sitting to long and has hardened.
- it looks like snow or fine grain sand
- looks like suger, very smooth
- A lot of small crystal cover the ice cream. Product looks coarse of texture by eyes.
- looks a little foamy to be ice cream, not as 'chunky' looking as normal ice cream is.
- looks a bit dry and old, ice crystal on top but does not look too heavy or rich (I dislike very rich hard ice creams)
- there are large chunks of something in it. not what one would expect for a vanilla ice cream
- It didn't look like ice cream. It looked too frothy like some frozen wipped cream or some old melted ice cream.
- The sample was completely frozen. I couldn't dig it out with my spoon.
- It looks very good, not too creamy and not too frozen
- I like a hard consistency, it looks compacted enough and for me acceptable.
- looks very hard
- it looked like the ice cream had melted and was refrozen - yuck
- looks like a solid chunk of refrozen melted ice cream - not very appealing. lot of ice crystals give the appearance of freezer burn
- If I didn't know beforehand that it was ice cream, I probably wouldn't have guessed that's what it was just by looking.
- Plain
- I do not like th appearance.
- it looks like its been sitting in the freezer too long after it has been lef to melt outside for a long time. looks very freezer burned.
- looks grainy. also looks like it has been melted and refrozen
- smooth and sparkles
- it looks quite sparkly and not natural but also a bit pleasing to the eye
- It looks fine, though a little bit plane and grey. It needs a bit more colour

Consumer panel comments on flavor

Control

- Good vanilla flavor, without the the wheaty taste. Very nice.
- This ice cream is sweet, but not memorably vanilla flavored. It is moderately pleasing.
- I'm not crazy about the flavor, once the ice cream has been swallowed. A bit too much.
- not creamyat all, feels like slush, too sweet
- not as intense of vanilla flavor as 594_
- mild good flavor
- This sample taste very...real would be the word I guess.
- good well-rounded flavor. Can taste the vanilla.
- Although tasty, this would be too sweet to eat a whole bowl of.
- vanilla flavor is very good!
- This sample also has a fine flavor to it. This sample tastes more like home made ice cream than regular store bought ice cream.
- good vanilla flavor
- much better flavor_
- Very nice vanilla flavor
- the flavor is not strong enough.
- Still not a strong flavor._
- Tastes relatively like simple vinella except it kinda has a little tinge of a soy kind of flavor, as if it was lacking the milkyness of regular ice cream
- good flavor
- creamy
- vanilla flavor just about right
- not bad, but not great. It is only medium.
- Very good vanilla flavor. I like it a lot.
- nice and light_sweet
- don't taste much of the barley taste. all 3 seem a bit 'anemic' - perhaps low on _ fat, not very creamy, like 'ice milk'
- very little flavor.....aftertaste...
- na.........
- almost no flavor
- The flavor was more mild than the texture suggested.
- can't taste much of anything
- tasty_
- it is not as sweet as normal ice cream but I can taste the vanilla flavor better than the 819
- just don't like the taste
- The flavor is quite sweet and I like it._
- flat, no flavor, not sweet
- Nunatural flavor. Has a bad taste.
- sweet, milk-like flavor
- Could stand to be a little sweeter
- hard to scoop
- Does not taste like ice cream. Has a chemical type taste. It almost tastes like flavored frozen water, like you froze milk. Not very sweet. Did not like the taste at all.
- the inital taste is nothing spectacular but the taste does linger in your mouth after the sample is gone.
- Great flavor

- it tasted very good I thought it had the best vanilla flavor
- tastes great! Nice and sweet, but not overwhelmingly so.
- Slight vanilla taste. Would prefer more intense vanilla flavor.
- good strong vanilla flavor (strong than sample 594)
- This has a stronger anilla flavor than the rest. I would serve it to my dinner guests!
- too sickeningly sweet. Reminds me of some sort of sweet milky concoction... not all together pleasant.
- Tastes like vanilla.
- It's good vanilla ice cream! Not too sweet and flavored just right. I also like how soft it is too.
- not very strong in flavor
- like not vey much sweet, tast is good
- it's less intense of flavor.
- It tastes a little plain, but it also tastes like normal vanilla ice cream to me. i think normal vanilla is a little plain - this one i would like to add some chocolate sauce to but it's a good flavor.
- nice intense vanilla flavor with being overbearing
- not very flavorful
- The flavor is satisfying for vanilla icecream, and it's not too sweet, so I could get easily addicted!!!
- It was creamy and had lots of vanilla flavor. A nice sweet taste.
- This has a 'light' product taste to it.
- It taste like a light ice cream, I dont like the taste of suggar, it needs to improve the flavor_
- I think is too sweet for me....
- without the texture in mind, the flavor was very good.
- flavor is better than sample 819, but i still think the vanilla flavor could be stronger!
- Vanilla is my favorite flavor of ice cream, so I enjoyed it very much! I did notice, howeve, that the flavor seemed to diminish as the ice cream melted in my mouth - a bit watery.
- Good taste but is is too too creamy
- a little bit less flavor
- the flavor is great, you can really taste the vanilla. It tastes as if it was freshly made, the quality of tastes compares to that of expensive store bought products.
- better than the 819
- good flavor - very strong vanilla taste
- not very natural tasting and tastes like cheap ice cream from the store
- It's not too sweet, which is good, and there's a slite taste of smthing else exapt of shugar. But this taste is not strong enough, or distinctive enough

0.375g BG/125 g serving

- This one seems to have even more of the wheaty taste than 594, which is getting too much for my liking.
- Once the texture is out of the way, the taste is more vanilla flavor, and the ice cream tastes great, and not too sweet. It is this samples only redeeming quality.
- A little bland, but good.
- not enough creamy, less sweet than 262 but still too sweet
- like the intense vanilla flavor

- creamy flavor and not overly sweet
- Good taste but not excelent. Taste kind of plant like
- really great overall flavor. yum!
- A bit sweeter than 594, but not too sweet. Like this one the best so far due to level of sweetness
- vanilla flavor is good, but it has a little of ice cream cone flavor in it.
- The flavor of this sample of ice cream is very good. I would not be albe to tell if there was barley in this sample or not. The sample is very creamy and the flavor tastes good.
- The vanilla taste is less.
- has more flavor than previous sample
- Nice vanilla flavor.
- On my first taste, I didn't like the barley(?) flavor but when I had a couple more bites I didn't mind it so much.
- the flavor could be stronger and more distinct.
- It doesn't have a lot of flavor._
- nothing too extreme, but just a very simple taste... I like that.
- more creamy, has better vanilla flavor than 262
- i would not buy this icecream, tastes cheap, poor flavor, like has been freazer burnt.
- same as #594
- vanilla just right, creamy but not too creamy
- taste is ok, but not good enough. The good thing is not so sweet.
- The initial flavor I like very much but then it tastes bad to me. I do not like the after tast at all, it is like a drying sensation on my tongue. The vanilla flavor is nice but the after taste is too bad for me to like the overall flavor.
- is this vanilla ice cream?? I can't taste the vanilla_funny after taste
- bland and uneventful
- the vanilla flavor seems stronger than 594
- no flavor
- there is some sort of itchyness in the mouth after taking this sample. compared to the sample 594 this one is not good
- no flavor experienced
- 819 tastes less creamy than 594 but more watery than both of the other samples.
- fairly good vanilla flavor
- very tasty
- The vanilla flavor is not that strong and not that tasty
- taste quite similar to last one, but not quite a strong flavored
- The taste is not that great. I can't really place it but I like the sample262 better.
- Tasty..._
- flat, no flavor, not sweet
- Ok sweet. Not strong flavor.
- sweet and very creamy
- Not very sweet, weird taste (tastes sort of like ice cream that has been in the freezer for a long, long time)
- good flavor but it does tend to linger in the mouth for quite awhile. Good alone for a dessert but not on cake.
- It could have more flavor
- the taste was pleasing because of the skim milky aftertaste
- flavor was nice, but could have been sweeter. Also, had a slightly bitter aftertaste.

- Slight barley taste, slight vanilla taste. Not as overpowering as 594, but the vanilla flavor is still too weak.
- not as tastey as sample 262
- There's a good vanilla flavor to it. It could be stronger though.
- Very vanilla-y flavor. Strong yet palatable and smooth.
- tastes almost like nothing
- There's too much filmy substance in it. It's not bad but I like 262 best. Maybe if it had time to grow ice crystals in it may be better.
- the flavor could be a little bit stronger
- taste good, smooth and sweet
- The intense of flavor is stronger than product number 262 which I tasted before this product. However, this kind of flavor is unusual flavor to me.
- It tastes different than normal vanilla ice cream but it still tastes good. I don't know how to describe the different taste except that it's sweet in a different than sugar kind of way...
- initially tasteless, but once it starts to melt in the mouth, flavor comes out and very appealing
- full and rich flavor. very nice
- I think this icecram has a really unique taste. I like it. I have never tried anything like it before. If I had a sample of it in a store, and I knew it was ice cream that was good for me, I would buy it, no questiions asked
- It had a nice creamy taste like the ice cream in a revel. Yummy!!!
- This product is richer tasting than 262, but not as rich as 594.
- too low in suugar and also in flavor
- Really good, not that sweet, I like it
- I can't really put my finger on the taste - definately not vanilla. to me, it tastes like tiger ice cream.
- light vanilla flavor - would prefer a little stronger vanilla flavor ..... it's not bad!
- THe flavor was not ssstrong enough - very faint tast of vanilla - not enough for me.
- Tastes what a plain ice cream should tasted, no one tasted over powers the other
- too much flavor
- not too strong, just a light taste
- a little bland
- sweet, yummy
- kind of tastes chalky and gives not the best after taste
- it's not too sweet, which is very good. And it has something in its flavor that I never found in icecream, it's interesting, although tastes somewhat artificialy.

0.75 g BG/125 g serving

- Good vanilla flavor, but there is an unmistakable 'wheaty' flavor. Still, I'd buy and eat this if I knew if was a much healthier alternative to regular ice cream.
- Of the three samples, the taste is superior by far. It is just sweet enough, just vanilla-tasting enogh to be considered perfect by my opinion.
- First taste, was a strong barley flavor. Would have to get used to this one. Not totally unpleasant.
- slimy but not creamy
- has clean taste with vanilla flavor
- has a French vanilla taste but could be sweeter,

- The taste is like ice cream that has stayed in the freezer for a few two many years. I found it hard to swallow this sample more than once and was almost tempted to use my spit cup.
- slight cereal flavor. Not quite sweet or vanilla-y enough.
- Not too sweet (I don't really like overly sweet things to begin with) :)
- nice vanilla flavor but a faint taste like ice cream cone flavor.
- This ice cream has a good flavor to it. The ice cream is real creamy and smoot and the flavor is normal to that of any other ice cream.
- Needs more vanilla flavor
- very subtle flavor
- Not quick as vanilla-tasting as Sample 262. Slight aftertaste, almost a bit nutty-flavored.
- It doesn't taste bad but I have a preconception of what vanilla ice cream should taste like. I guess it would just take gettting used to the taste and it would be fine.
- it tastes like barley and warm milk. It doesn't really taste like ice-cream.
- unique taste, dislike at first, but after a little while it tastes pretty good_
- fine, not too sweet, milky taste
- Tastes a bit like grain
- creamy flavor and vanilla just about right, maybe a little less strong than the last one.
- it has more barley taste, which is quite good
- I like the flavor a lot. I think this is my favorite flavor. I really like the initial vanilla aroma and taste and it has no dry aftertaste. You did very well on this one.
- not pleasant - it doesn't taste like ice cream_not sweet, a bad aftertaste
- nice vanilla flavor
- ok
- flavor is good
- flavor is ok_
- not so good
- The flavor was nicely creamy; more flavorful than 292
- reminds me of asian 'white rabbit' candy, very sudtle vanilla flavor, could use more flavor_
- good level of sweetness
- I can smell the vanilla but the taste of vanilla is not that distinct
- The taste wasn't spectacular but I would probably eat a bowl of it.
- a slight wooden taste
- Nice and subtle flavors, elegantly balanced with a soft aftertaste._
- flat, no flavor
- taste not bad. knowing there is fiber.
- sweet, creamy
- tastes like barley or something_
- Sweet and chewy.
- the barley flavor is more prevalant than in sample 262 but that does give it an interesting appeal.
- It needs more flavor
- it tasted a little bland or chalky. it needed more vanilla flavor
- leaves a strange bitter flavor in mouth. Just tastes off.
- Doesn't taste like vanilla, as you would expect from white ice cream. Grainy, barley taste isn't what I would consider 'refreshing' or a 'treat'.
- doesn't have a very strong flavor

- There doesn't seem to be much taste to it. There is a hint of vanilla, but definately not enough of it.
- I don't know what the flavor is really, but it's good. It's also somewhat unusual. Tastes healthy.
- tastes less like vanilla than 262. I can taste the barley a lot more.
- it's not very strong in flavor; not very concentrated. Strange aftertaste, like eating solid milk.
- not much sweet, good, gentle
- Intense unusual flavor
- I really like the flavor, it's different from most vanilla ice cream, it's not as sugar-sweet but still very tasty.
- piercing flavor but tastes a bit artificial compared to previous samples
- tastes too much like barley. not appetizing
- The flavor is also unique, in a good way_
- The taste was like some cheap ice cream. It was kind of lemony and old tastting. I didn't like it one bit.
- It tastes like if it was done only with milk, the % of vanilla flavor it is too low
- It has a good flavor, a soft vanilla flavor, it is perceptible and enjoyable, not too sweet, thats good
- it tasted more like vanilla
- has a bit of a funny after taste.... not a strong one but it leaves your mouth feeling slightly numb or something i dunno it's weird
- The flavor seemed to be non-existant - couldn't taste vanilla at all.
- bitter and too creamy
- the flovor is pretty good.
- the flavor is not as strong as 262 and it does taste a bit too home made.
- the least I like among the three
- really good flavor!
- tastes very creamy...very tasty
- Tastes good, all ingridiens of the taste are in the right proportion.

Consumer panel comments on texture
Control

- Much softer than the other two samples. And yet, it feels like it disappears too easily. Finally, it does leave a creamy mouth feel.
- This is the type of smooth, melt-in-your-mouth, type of texture I enjoy when eating ice cream. It is very good. Typically, a more 'creamy' texture is preferred.
- A bit more grainier than 819, but fine.
- icy in the beginning and watery later
- melts quickly in mouth, not as creamy
- not enough creamy texture, more like ice milk than ice cream
- The texture was pretty good. Did not feel as grainy as sample 819
- icey and melted too fast, not creamy enough
- extremely ice/grainy texture not desirable. But creaminess is good and rate of melting also good
- very full of crystals
- This sample has a texture synonamous with home made ice cream. It also has a grainy texture to it.
- nice and soft but there is a lot of ice crystals

- has a teeny crunch, like there is more frozen water. Melts in my mouth good! mmm
- too 'grainy'...crystals too big
- It feels like ice cream that has thawed and then been frozen again
- It was softer and creamier._
- Its a little bit grainy, but fairly similar to regular ice cream_
- isn't very creamy
- not very creamy
- tastes like it has ice crystals, not smooth, tastes like cheap icecream
- smooth
- gritty
- slight sorbet like texture, but also creamy when it melts
- not smooth enough
- The texture is lots of crystals in my mouth = bad, it is not smooth. I do not like that it makes my mouth feel dry, like a dry wine would. not too good of texture at all.
- not creamy, rough texture
- not very 'soft' or melted funny
- extremely good. not too sweet
- too sweet...taste is not taste...i dont know how to explain
- grainy
- 1st sample is the best among the three. there is some funny taste in the second and third sample
- mild sandiness experienced
- The coarse texture had a pleasantly rough feel on roof of my mouth and on my tongue. It was enjoyable.
- too grainy, feels like it falls apart in the mouth
- good texture. very smooth
- not too bad texture
- It is quite good for texture.
- a little dry
- Not as smooth or creamy as other ice-creams.
- very icy
- too icy and watery. Have unnatural flavor when first put it in the mouth.
- a little watery, lots of ice crystals
- It might have been a touch too 'icy'
- kinda hard_
- Crumbly, chunky in your mouth. Not smooth.
- tastes somewhat grainy most likely due the frozen crystals within the sample.
- It's not extremely creamy like the great ice-creams usually are.
- it had the texture of 'ice milk' used at DQ in the frozen cakes
- lots of ice crystals. not very smooth on my tongue
- Similar to any other ice cream.
- much softer than the first sample, melts nicer, creamier
- Yup- this is good stuff.
- melts very quickly. not all that great for texture. Like poorly made ice cream (if handmade)... or rather icy milk instead of ice cream
- (not detestable, but not very creamy.
- Not as creamy as icecream. But still melts niceley.
- Nice ice cream texture. Not too grainy or filmy.

- too grainy
- is fine
- it's o.k. but the reason I gave low score because I expect the ice cream has very smooth feeling on the tongue.
- very much like normal ice cream texture, maybe a little too frozen still becaues there are some slightly grainy textures in it, but that is also similar to normal ice cream.
- melts nicely but feels grainy
- very smooth tasting. not like it's appearance
- the texture isn't creamy like icecream. It's like sorbet_
- That had a nice melt in young mouth creamy texture.
- I think the ice crystals are quite noticeable.
- I melts faster, and it is not very hard to scup out
- acceptable...it is better than what it seems (appearance)
- it was grainy - crystally
- mmmm alot creamier than sample 819!
- It was a little hard scoop - perhaps due to the temperature? It was a little 'grittier' than 'regular' ice cream - not as smooth, but not necessarily a bad thing.
- Too soft, melts quickly in your mouth, feels like slime
- it is good, a little bit hard.
- the texture is great. its not too hard. very smooth when you put it on your tongue and it softens very fast to melt all over your pallet
- better than the first
- not quite as smooth as I like - too many tiny ice crystals
- too crystallized and icy....
- It's a little bit too hard, it may be because of the particles of iced water

0.375 g BG/125 g serving

- This one is less hard than the last sample - 594, but is still harder than regular ice creams. Same pleasing, rich texture upon melting.
- This is slightly odd, I feel a sandiness upon initial consumption, and it is unpleasant. Immediately thereafter, is a creamy, dairy type of flavor I did enjoy. I cannot decide whether this is good overall or poor.
- Other than the ice cream being rock hard, it tastes quite good. Not overly creamy.
- less sandy than previous
- smooth and creamy
- very smooth
- creamy sample, taste alot like a dixie cup but has a slight plant-like after taste
- nice full bodied. Didn't melt too fast
- not as grainy as 594. Melted in mouth with greater ease which is desirable. More creamy which is also good. (Also, not as hard to spoon out of cup)
- good crystal size and smoothness
- Texture is very good. The sample feels very creamy just like ice cream should. Very good.
- smooth, and thicker than the first one. I liked it_
- almost dry. not very creamy
- More like ice milk than Sample 594
- it has the same texture as regular ice-cream.
- texture was same as i associate with any enjoyable ice cream

- texture is smooth, isn't granular or icy
- has a bit of a gritty texture, not smoth mixture but as if has small ice crystals in it.
- same texture as #594, but the ONLY thing is a little more softer
- Just about the right density for the spoon, intermediate between the first and second samples.
- not smooth enough
- I thought it would be very crystal like from the appearance but rather the texture in my mouth was smooth. I like this sample.
- The texture is very similar to what I expect ice cream texture to be like.
- crystals, not creamy enough
- sweeter than the 262. It's sort of tangy
- seems smoother than 594
- no taste for me...i might be too choosy
- no comments_
- too hard
- slight sandiness of the icecream
- This sample feels smoother than it appears.
- a little icey, not smooth enough but bettter than 594
- very hard_
- it is pretty smooth but very cold
- •creamy, and not too hard
- The taste is different than the 262 sample. It's not that I don't like it but it wouldn't be my first pick._
- Too hard (too cold)
- icy
- little icy. OK sweet.
- very creamy, with a few ice crystals
- Not very creamy
- slightly grainy
- The creamyness is more dense. It's good
- it was a little gritty but otherwise good
- texture was pretty good. Not gritty at all. When it melted on my tongue it was very smooth and creamy.
- Slight mouthcoat...more than what I normally expect from ice cream.
- a bit harder than sample 262, but softer than sample 594, melts faster than both of the other samples
- I like the texture. A definately 'melt in your mouth' experience
- Very cold, solid yet creamy and smooth.
- It's like sample 594 but not as slimy or as hard. It's not bad of a texture though.
- would be better if it was creamier
- sticky, pretty good
- I feel grittiness.
- Much like real low-fat ice cream texture, i don't think I could tell any difference between this and the real stuff for texture.
- nice texture; not too hard , fairly smooth
- more substance. but still quite smooth. :)
- the texture again is like sorbet, very good_
- It had the same texture as regular ice cream.

- I like the consistency of this product_
- It is a little bit hard, and too low in suggar and flavor_
- Good!!!
- sample is quite hard
- it was kind of grainy, not as bad as 262, but not as good as 594
- its not very soft, i tend to prefer softer, creamier ice creams - although once it warms up in your mouth for a bit it gets better –
- i think that maybe if the sample was left out of the freezer for a little longer the texture would be more prefereable
- Texture is nice, but not as smooth as 594. Not bad, though.
- Softer
- it is soft and feeling good
- smooth_
- the texture was the best out of the three
- it's soft, very good

0.75 g BG/125 g serving

- Ice cream is really hard - the plastic spoon can barely scoop it. The texture is as you'd expect; harder and doesn't melt in your mouth too easily. Pleasing thickness once it melts.
- The texture is excellent, with only a slightly detectable sense of ice. It is creamy and smooth, and pleasant overall.
- Very smooth, almost too much so.
- a bit sandy and gummy
- smooth and almost creamy
- very creamy
- The ice cream did NOT melt in my mouth which was rather confusing. It also has the same texture as the stuff dentists use to make molds of your teeth, almost like eating vannila flavored silly putty
- seemed too light at first, more like iced milk than ice cream. Slimy aftertaste.
- relatively creamy but has a slightly grainy/icy texture (e.g. ice cream that has been taken out of the freezer for a while and then put back)
- a little crystally
- The texture of this ice cream is fine. It is good. There is a nice smooth creamy texture which is good for ice cream.
- Very hard to scope
- This one appeared to be gummy, and thicker
- Thick and creamy - very good!
- very nice smooth texture
- This ice cream is more creamy which is more like regular ice cream
- the texture is not as cold as the other sample, but it is harder.
- It doesn't feel like ice cream on your tongue. It doesn't melt the same as I expect.
- quite smooth texture
- has sort of a slimy thick aftertaste, it is quite dense, and contains ice crystals
- like normal icecream
- not too smooth but not too rough, ok
- at this temperature, its a little harder to get a spoonful because it is denser and finer in crystal size.

- it is smooth compare with the other two samples.
- I really like the texture of this sample, yummy! it is just like I think ice cream should be. It is very smooth and creamy and no large crystals in my mouth. I really like this texture.
- very smooth and creamy, lingers in the mouth
- a bit grainy
- it has too much texture too it and is very sweet
- slightly grainy, but normal for low fat ice cream
- taste is ok...but icecream is gummy
- sticky
- no comments
- Too hard.
- better than other two
- This sample felt gummy in my mouth.
- very hard, i like the creaminess
- a bit more of a crystally texture than 819. 819 has better texture
- it is the most creamy of all the 3 that I tasted
- a little icy
- I liked the texture.
- very smooth and creamy
- It is very hard... possibly because it's very frozen._
- Too hard
- icy, taste different. But not unpleasant taste.
- creamy, with some crystals
- Creamy and seems almost dry and flakey. Texture like cookie dough.
- very good texture. It has a very smooth grain to it which makes it good for initial taste but the texture remain thick after melting
- (like egg nog) this may discourage people from buying it more than once.
- It's a creamy but hard
- the texture was good the ice cream melted nicely in my mouth
- smooth on the tongue when it melts, but initially too solid.
- Left slight mouthcoat.
- it's very hard, icecream should be a bit softer
- I definately dig the smoothness of the ice cream
- soft and smooth texture.doesn't melt too quickly however.
- it's like eating phlem
- much more sticky then 819
- texture is viscous. No smooth mouthfeel as any ice-cream.
- not as creamy as ice cream, but as good as normal low-fat ice cream... the texture could be thicker/creamier
- once exposed surface of ice cream removed, the rest has a nice smooth texture, but a bit rich feeling for me
- heavy. thick. not appetizing
- this one was much creamier than the other two. The texture is more like ice cream, not sorbet_
- The texture was too slimy and melted way too soon.
- It has a gummy texture (like melted cheese), but I like that it melts faster in the mouth than the others and it feels that is not so cold
- good consistency, I really liked it

- seems to leave residue/coating in mouth
- it was very creamy - much better than 262's texture.
- although it looks like it would be very hard - it was surprisingly creamy once it softened up in my mouth_
- It was very smooth and velvety - YUM!
- bitter and too creamy
- it is ok. soft
- its feels a little oily to the pallet and it feels a bit too thick
- not as nice as 594
- smooth, slightly sticky
- soft and sticky, which is good