THE EFFECT OF DIETARY FIBER ON PHYSICO-CHEMICAL AND SENSORIAL PROPERTIES OF FROZEN YOGURT

A Thesis

presented to

the Faculty of the Graduate School

at the University of Missouri-Columbia

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

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DECEMBER 2014

The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

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presented by Julie Frank,

a candidate for the degree of master of science,

and hereby certify that, in their opinion, it is worthy of acceptance.

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ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Ingolf Gruen, for all his crucial guidance and support. His expertise in regards to research and enthusiasm to help was marvelous.

I would also like to thank the members of my committee for their insight and guidance. Thanks to Dr. Bongkosh Vardhanabhuti for sharing her knowledge and Dr. Catherine Peterson for her knowledge of nutrition and support.

I want to thank my sensory panelists, without you this work could not have been completed.

I would like to express my appreciation for Fernando Lakdas who shared his time and technical knowledge and for his friendship. To Rick Linhardt for sharing his lab, his time and abundance of knowledge. To Ayca Gedikoglu for her support and encouragement during the time we spent together in the lab.

I am extremely thankful for all my friends, who are too numerous to name, who encouraged and supported me the whole way through every step of this process. I could not have done it without you.

Most of all I would like to thank my family, my wonderful parents who always believed in me, supported my decisions, and encouraged me each step of the way. They motivated and inspired me to grow and to accept all the challenges that came my way. No words can really express my thankfulness for you all. I love you.

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THE EFFECT OF USING FROZEN YOGURT AS A SOURCE OF DIETARY FIBER

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ABSTRACT

Dietary fiber is currently added to a wide range of commercial food products including dairy, baked goods, and some frozen desserts. Different types of dietary fiber have different properties and functions when used in food. The most basic categories of dietary fiber are soluble and insoluble. Our objective was to determine if an acceptable frozen yogurt product supplemented with dietary fiber could be produced. Three different types of dietary fiber were used: Frutafit TEX! (inulin), Glucagel® (betaglucan), and Vitacel SMOOV 240 (cellulose). These three were used at the 3%, 5% and 7% levels in the frozen yogurt. Frozen yogurt base was manufactured using nonfat milk, heavy cream, sugar, corn syrup solids, nonfat dry milk, stabilizer, water, and vanilla. The base was mixed with yogurt (ratio of 80 : 20) that had been cultured from nonfat milk, and a yogurt culture containing *Streptococcus salivarius* subsp. *thermophilus, Lactobacillus delbrueckii* subsp. *bulgaricus,* and *Lactobacillus acidophilus.* Fiber was weighed and blended with the base before the yogurt was added. Vanilla flavoring was added, and the treatments were frozen using a batch ice cream freezer. Microbiological enumeration was conducted on the treatments before being frozen. Titratable acidity and pH were also measured on the treatments before and after being frozen. A descriptive sensory analysis, hedonic sensory study, viscosity, texture analysis, and melt rate test were conducted during storage. Lactic acid bacteria counts were found to be around 7.9 $x10^7$ CFU/ml. Titratable acidity and pH did not change when measured before and after freezing, and did not show a difference between types, or levels of fiber. The types and levels of fiber used had a significant effect on the flavor and texture of the frozen yogurt products, as well the overall liking. The results suggest that a frozen yogurt product could be successfully manufactured when fortified with 7% Frutafit TEX!.

CHAPTER 1

INTRODUCTION

Fiber has become an important ingredient in many food products today. Some consumers are beginning to make more health conscious food purchases, and may be more likely to purchase a product if it claims that it is a good source of fiber. Many products that do not naturally contain fiber are being researched for the possibility of fiber being added to that product, such as yogurt, ice cream, breakfast foods (toaster pastries, pancake mixes) and other such items. Many products have had success, many under the brand name FiberOne®.

According the U.S. Food and Drug Administration, the recommended dietary intake for individuals from 19-30 years of age, is between 25-38 grams of fiber. Average intake in the United States is far below the Recommended Dietary Intake level. The following figure (Figure 1.1) shows the average intake from 1999 to 2008 (King and others 2012) .

Though research has been done on ice cream as a source of fiber, there has been a lack of research on frozen yogurt as a source of dietary fiber. Frozen yogurt was first seen in the United States around the mid 1970's (Davis and others 2010). During this time, production and consumption was mainly limited to the New England area and the Northeast.

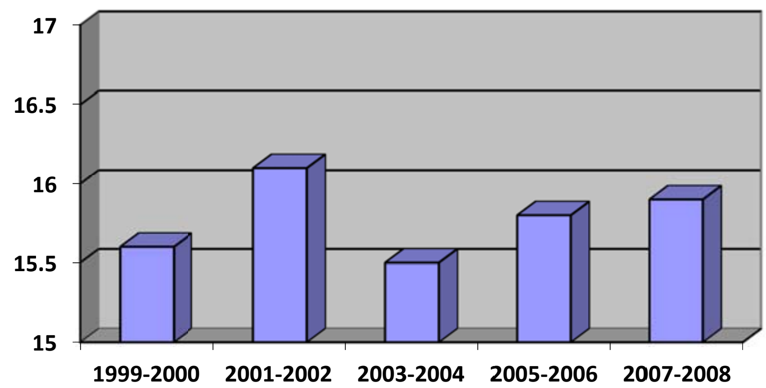


Figure 1.1 Fiber Intake in Grams per Day in the U.S. Between 1999-2008 (King and others 2012)

The 1990's saw the highest production rate at 152,097,000 gallons in 1995 (Davis and others 2010). Production has dropped off quite a bit since then, but in the past few years the frozen yogurt craze seems to have taken off again (Figure 1.2) with the concept of frozen yogurt bars.

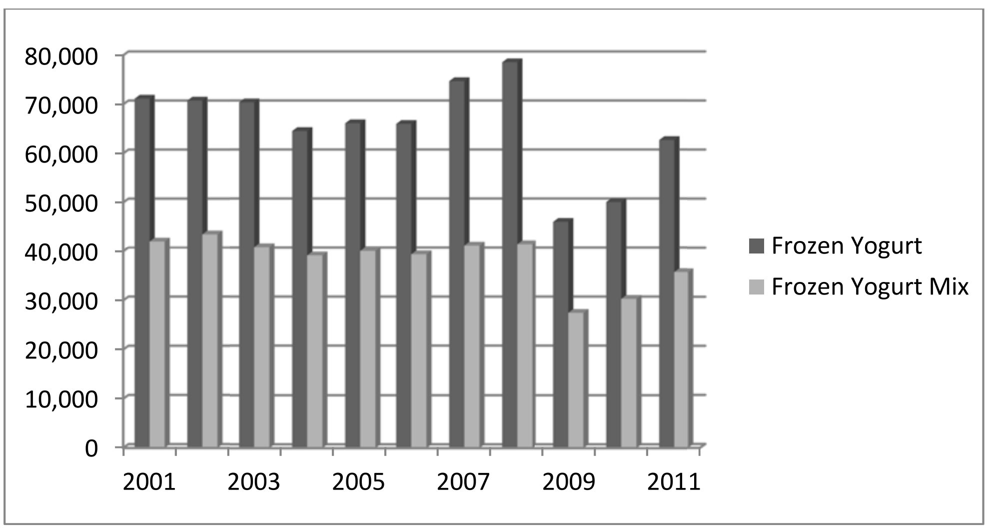


Figure 1.2 Frozen Yogurt vs. Frozen Yogurt Mix Producecd (in Gallons) in the U.S. from 2001-2011 (USDA Dairy Products Annual Summary)

For this project, the effect of adding different types of dietary fiber to hard frozen yogurt was tested. Three different types of fiber were used: barley fiber (Glucagel®), inulin (Frutafit TEX! Inulin), and cellulose (Vitacel Smoov 240). Each type was used at the three, five and seven percent levels.

The overall goals and objectives of this research were:

1) To formulate and manufacture a frozen yogurt product that contained different types of dietary fiber.
2) To produce a product that will be a good source of fiber that is acceptable to the consumer.
3) To perform a descriptive sensory analysis of these products.
4) To analyze the hardness, viscosity, and melt rate of these products.

CHAPTER 2

LITERATURE REVIEW

2.1 FROZEN YOGURT

Frozen yogurt and ice cream are frozen dairy desserts, but their nutrition information, ingredients, and production processes are slightly different. Table 2.1 shows a comparison of the nutrition information between a premium vanilla ice cream and a low fat vanilla frozen yogurt. The kilocalories are the same, however the amount of fat in the frozen yogurt is only 21.5% of that of the ice cream. It is the amount of carbohydrates in the frozen yogurt that accounts for the kilocalories being the same.

Table 2.1 Nutrition Information of Blue Bunny Premium Ice Cream Vanilla and Ben and Jerry's Low fat Vanilla Frozen Yogurt

	Blue Bunny Premium Ice Cream Vanilla (%D.V.)	**Ben and Jerry's Low fat Vanilla Frozen Yogurt**
Kilocalories	130	130
Fat calories (%)	60	14
Total Fat (g)	7 g (11%)	1.505 g (2%)
Saturated Fat (g)	4.5 g (23%)	1.004 g (5%)
Cholesterol (mg)	25 mg (8%)	20 mg (7%)
Sodium (mg)	40 mg (2%)	70 mg (3%)
Carbohydrates (g)	16 g (5%)	25.089 g (8%)
Sugar (g)	14 g	17.06 g
Protein (g)	3 g (5%)	4.014 g (6.7%)
Calcium	(10%)	200 (20%)

2.1.1 PRODUCTION OF FROZEN YOGURT

There are several different methods to produce the frozen yogurt mix before it is frozen: Direct acidification, indirect acidification, and blending method (Soukoulis and Tzia 2008). 1) The ingredients are mixed, pasteurized and homogenized. The bulk culture is added and the whole mix is fermented to a titratable acidity (TA) of 0.30% (Ordonez and others 2000). 2) A portion of the milk is fermented with the starter culture, and then an ice cream-type base is produced, cooled, and the fermented milk is added, and the whole mix is aged (Inoue and others 1998). 3) Lactic acid bacteria are added prior to freezing the product (Soukoulis and Tzia 2008).

If using the indirect acidification method, the yogurt is produced by pasteurizing milk then allowing it to cool to 42°C, at which point it is inoculated with the starter culture. The milk is fermented for 4-6 hours, to a pH 4.2-4.3, a titratable acidity (TA) of 0.85-0.90%, and a cell count of $2x10^7$ cells/mL for each microorganism. The yogurt is then cooled and chilled to approximately 5°C (Klein and others 2010). The base is produced from ingredients such as milk, cream, sugar, corn syrup solids, and stabilizer, which are pasteurized, homogenized, and then chilled. The amount of the acidified milk (yogurt) that is added to the mix after chilling can be anywhere from 10-20% (Marshall and Arbuckle 1996). The mix is then frozen in an ice cream freezer and hardened.

Table 2.2 shows a comparison of fat-free plain yogurt and low-fat vanilla frozen yogurt. There are twice the amount of carbohydrates, and have the amount of protein in the frozen yogurt compared to the plain yogurt. Plain yogurt is usually just cultured milk, with some added stabilizers, while the frozen yogurt may only contain 10-20 percent yogurt and many other added ingredients to be more consumer acceptable.

Table 2.2 Comparison of Nutrition Facts of Dannon Plain Fat-Free Yogurt vs. Ben and Jerry's Low-Fat Vanilla Frozen Yogurt

	Dannon Plain Fat-Free Yogurt [1]	**Ben and Jerry's Low-Far Vanilla Frozen Yogurt[2]**
Kilocalories	80	130
Fat (Total g)	0 g (0%)	1.505 g (2%)
Saturated Fat	0 g (0%)	1.004 g (5%)
Cholesterol	5 mg (2%)	20 mg (7%)
Sodium	115 mg (5%)	70 mg (3%)
Carbohydrates	12.0 g (4%)	25.089 (8%)
Sugars	12.0 g	17.06 g
Protein	8.0 g	4.014 g
Calcium	300 (30%)	200 mg (20%)

2.1.2 YOGURT BACTERIAL CULTURES

Streptococcus salivarius subsp. *thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* are synergistic bacteria that are required in a yogurt starter culture. *Streptococcus salivarius* subsp. *thermophilus* is a Gram-positive, cocci that has an optimum growth temperature of 37°C. *Lactobacillus delbrueckii* subsp. *bulgaricus* is a Gram-positive, nonspore forming, bacilli with an optimum growth temperature of 45°C (Klein and others 2010). The rate of acid production is much greater when these bacteria are used together, than if used separately. The ratio of the organisms is generally 1:1. For production of yogurt, the milk is inoculated with the starter culture, then incubated at 42°C (a compromise in the optimum growth temperatures of both microorganisms).

[1] 6 ounces (170 grams) per serving

[2] 3.54 ounces (100 grams) per serving

Streptococcus salivarius subsp. *thermophilus* grows at a faster rate right after inoculation, and over the first 2 hrs of incubation it produces lactic acid, carbon dioxide, and formic acid which in turn causes *Lactobacillus delbrueckii* subsp. *bulgaricus* to grow at a faster rate. The initial drop in pH to 5 is brought about by *Streptococcus salivarius* subsp. *thermophilus,* the growth of which is decreased by the high concentration of lactic acid. *Lactobacillus d.* subsp. *bulgaricus* brings about the last reduction in pH to 4, and produces peptides and amino acids for use by *S. thermophilus* (Klein and others 2010). After four hours, the equilibrium between the two bacteria will be reached, and fermentation is complete.

2.1.3 PROBIOTICS IN YOGURT- *Lactobacillus acidophilus*

The FAO in 2001 defined probiotics as: "Probiotics are live microorganisms which when administered in adequate amount confer a health benefit on the host."

The recommended dosage that is required to be beneficial to human health is 1-10 billion CFU/day (Klein and others 2010). There are several different strains of bacteria that qualify as probiotics such as: *Lactobacillus rhamnosus, L. paracasei, L. acidophilus, Bacillus coagulans* GBI-30 6086, *Bifidobacterium breve, B .infantis* 35624, *B. animalis* subsp. *lactis* HN019 (DR10), *B. longum* BB536, and *Saccharomyces cerevisae* (boulardii) lyo (Maity and Misra 2009). One of the probiotics commonly found in yogurt and yogurt cultures is *Lactobacillus acidophilus.*

There have been many proposed health benefits attributed to consuming probiotics. Enhanced immune response (Gill and Guarner 2004), balancing of intestinal microbiota, helping with lactose digestion (Marteau and others 1990) and inflammatory bowel diseases (Gionchetti* and others 2000) are among a few of the proposed benefits of probiotics .

2.2 FIBER

2.2.1 DEFINITION

Dietary fiber as defined by the American Association of Cereal Chemists (AACC, 2005):

> "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 plants substances. Dietary fibers promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation."

Dietary fiber is also defined as "nondigestible carbohydrates and lignin that are intrinsic and intact in plants"(Food and Nutrition Board 2005.). There is a difference between dietary fiber and functional fiber which "consists of isolated or extracted nondigestible carbohydrate that have beneficial physiological effects in humans" (2005).

Dietary fiber is divided up into two categories: insoluble and soluble fiber. Total dietary fiber is the combined amount of soluble fiber and insoluble fiber that is in the product. Soluble fiber is described as soluble in warm or hot water, and once dissolved, can be precipitated out of solution again by ethyl alcohol (Spiller 2001). According to

Elleuch and others (2011), the solubility of fiber is associated with structure of the molecule, and if there is a COOH or SO_4^{2-} group, then the fiber is more soluble. Insoluble fiber is described as not being soluble in hot water (Elleuch and others 2011). Both soluble and insoluble fibers are not digested by the carbohydrate enzymes (amylase, alpha amylase, and brush border enzymes) in the human digestive tract. The human body does not contain the enzymes necessary to break certain types of chemical bonds in the different fibers (Spiller 2001).

Insoluble fiber is the most prevalent (75%) of the two (Topping and Cobiac 2005). The health benefits of insoluble fiber are relief of constipation (taken in conjunction with plenty of water), the possible reduction of the risk of colon cancer, and prevention of diverticulitis (Topping and Cobiac 2005).

Soluble fiber is the remaining 25% of total dietary fibers consumed by humans. There is evidence that soluble fiber helps to lower blood cholesterol, may help control blood glucose levels, and some types may increase mineral absorption (Topping and Cobiac 2005). It also creates a gel when solubilized in water, and therefore can help individuals experiencing diarrhea.

The recommended intake of soluble dietary fiber is 5-10 g/day according to the National Institute of Health. The USDA also requires that a claim of a “good source” of dietary fiber in a product must contain 10-19% of the Recommended Dietary Intake (RDI), and a claim of a “Excellent source” must contain at least 20% of the RDI. Examples of types of soluble and insoluble fibers are shown in Table 2.3.

Table 2.3 Types of Insoluble and Soluble Dietary Fibers

Types of Insoluble Fiber	Types of Soluble Fiber
Cellulose	Gum arabic
Hemicelluloses	B-glucans
Lignin	Pectins
Plant waxes	Xanthan gum
	Carrageenan
	Guar gum
	Locust bean gum
	Other gums

2.2.2 SOURCES OF DIETARY FIBER

There are many sources of dietary fiber, and most of these contain some of both soluble and insoluble fiber. A short list of common sources are as follows (Topping and Cobiac 2005):

Source	Total Fiber (g/100 g portion)	Insoluble	Soluble
Whole Wheat Bread	8.1	7.0	1.1
Oatmeal, cooked	1.9	1.2	0.7
Apple, Granny Smith, unpeeled	2.7	2.4	0.3
Bananas	1.7	1.2	0.5
Oranges	1.8	0.7	1.1
Source	Total fiber (g/100 g portion)	Insoluble	Soluble
Prunes, dried	7.3	3.1	4.2
Lentils, dried, raw	11.4	10.3	1.1
Pinto Beans, dried, raw	19.5	12.1	7.4

2.2.3 GENERAL FOOD USES

Dietary fiber has been used in many different food applications. The technological properties are Water Holding Capacity (WHC), Water swelling capacity (WS), Water retention capacity (WRC), Water solubility, Oil holding capacity (OH), viscosity, texturizing, stabilizing, gel-forming capacity, and antioxidant capacity (Elleuch and others 2011).

Water Holding Capacity	The amount of water that is retained by 1 g of dry fibers under specified conditions of temperature, time soaked and duration and speed of centrifugation. (Elleuch and others 2011)
Oil Holding capacity	The amount of oil retained by the fibers after mixing, incubation with oil and centrifugation. (Elleuch and others 2011)
Viscosity	Resistance to flow. The ratio of shear stress (Γ) to shear rate (γ). (Elleuch and others 2011)
Antioxidant capacity	Guards against the superoxide radical, hydroxyl free radical, lipid peroxidation and has potential for reducing power, and chelating metallic ions. (Zha and others 2009)

Dietary fiber has been used as a fat replacer, as a thickener and stabilizer in a wide variety of food products (Brennan and Tudorica 2008). It has water binding properties that are dependent on the type of fiber used, e.g. soluble fiber has a higher water binding capacity than insoluble (Seçkin and Baladura 2012). Certain fibers have the capacity to bind fat, so they are used to prevent excessive absorption of fat when frying batters. The fiber is combined with water first to fill the pores in the fiber and thus the fat is not allowed to absorb into the product (Borderías and others 2005). Pectins, gums and β-glucans were used to create viscous solutions, while viscosity changes from adding inulin were minimal (Borderías and others 2005).

2.2.4 PHYSIOLOGICAL EFFECTS

Dietary fiber is categorized into two categories, soluble and insoluble, and yet the types of fibers that fall into either category have different positive effects on the human body, to differing degrees (Caballero and others 2005). As mentioned earlier, dietary fiber is not digested by the enzymes in the human body, but to a certain extent it is fermented by the gut micro flora.

As described in the Encyclopedia of Human Nutrition (Food and Nutrition Board 2005.), food products that contain fiber have a longer transit time in the stomach, because of the body's necessity to break down the product into smaller particles. The example given was a raw apple versus apple juice, stating that rigorous muscle activity is required to breakdown a raw apple and thus slows the rate of absorption of glucose into the blood stream (occurring in the small intestine). It was also stated that, soluble fibers like guar gum, pectin and β-glucan increase total transit time from mouth to cecum.

2.2.4.1 CARDIOVASCULAR DISEASE

Cardiovascular disease (CVD) was the leading cause of death in the United States in 2011, followed by cancer (Centers for Disease Control and Prevention). The

American Heart Association reported a 32.7% decrease in deaths attributed to CVD from 1999-2009, although 1 in every 3 deaths were related to CVD (Go and others 2013). Greater than 2150 American deaths per day are due to CVD (Go and others 2013) . The four most common types of CVD are coronary heart disease, heart failure, stroke, and high blood pressure.

Risk factors for CVD include high cholesterol, glucose, and blood pressure. It has been estimated that 31.9 million adults aged 20 and over have a total serum cholesterol level of 240mg/dL or greater (Go and others 2013).

According to the American Heart Association, Coronary Heart Disease (CHD) is a term for the buildup of plaque in the coronary arteries, which is a risk factor for a myocardial infarction (Heart Attack). Risk factors for developing CHD are high Low Density Lipoprotein cholesterol (LDL), low High Density Lipoprotein (HDL) cholesterol, high blood pressure, diabetes, smoking, family history, being a post-menopausal woman or a man over the age of 45, and possibly obesity (Wilson and others 1998; Go and others 2013).

Dietary fiber has been documented as decreasing the risk of developing CHD. It has been noted that it is sometimes hard to verify if it is the fiber that is decreasing the risk or other components in the diet associated with a high fiber intake (Wilson 2010). Soluble dietary fiber has been shown to decrease the risk, rather than the insoluble form. The role of fiber in lowering the risk of CHD, is through lowering of LDL cholesterol, and total cholesterol, and possibly through lowering triacylglycerols (Parks 2002). There are several proposed mechanisms for lowering of cholesterol by dietary fiber (Bourdon and others 1999):

1) Dietary fiber binds to bile acids, thus cholesterol is carried from the body
2) Inhibition of liver synthesis of cholesterol by propionate, a short chain fatty acid (SCFA) which is produced by fermentation of dietary fiber by colonic bacteria.
3) Inhibition of liver synthesis of cholesterol by lower levels of insulin

MECHANISM 1

The food containing soluble fiber is masticated in the mouth, swallowed, and then churned into chyme in the stomach with a pH of about 3. The chyme is then released through the lower pyloric sphincter into the duodenum where the pancreas excretes bile into the chyme, to increase the pH. The viscous gel created by the soluble fiber captures the bile acids, and therefore does not allow for re-absorption in the ileum. The bile is then excreted in the feces. Bile is synthesized from cholesterol by the liver. The liver has two ways of obtaining cholesterol, 1) from blood, 2) from re-absorption in the ileum. If the bile acids are being excreted in the feces rather than absorbed in the ileum, then the liver must obtain cholesterol from the blood. This is the proposed mechanism for lowering blood cholesterol (Bourdon and others 1999).

MECHANISM 2

A second proposed mechanism for lowering cholesterol is a by-product of soluble fiber fermentation by bacteria in the large intestine. When fiber is fermented, this produces short chain fatty acids (SCFA), one of which is propionate, which can inhibit synthesis of cholesterol. In the proximal colon, carbohydrates are fermented to SCFA's, hydrogen and carbon dioxide (Choque Delgado and others 2011). The SCFA's produced are acetate, propionate, and butyrate. Acetate is used by the liver as the sole precursor for cholesterol synthesis, propionate is used to both facilitate and inhibit gluconeogenesis, as well as inhibit cholesterol synthesis (Choque Delgado and others 2011). Butyrate is used as fuel for colonocytes, and helps to treat gut inflammation, and possibly cancer.

A study concluded, that the cholesterol lowering effect of SCFA's is the ratio of acetate to propionate (Wong and others 2006). While rectal infusions of acetate alone increased serum LDL, a mixture of 180 mmol of acetate and 60 mmol of propionate, showed a lower serum cholesterol (Margareta and Nyman 2003). While the acetate promoted cholesterogenesis, it appeared that propionate negated the effect of acetate.

Basic cholesterol synthesis is as follows:

Acetate →[3]Acetyl-CoA→[4]HMG-CoA→[5]Mevalonate→

[3] Acetyl-CoA reductase

[4] HMG-CoA Synthase

[5] HMG-CoA Reductase

Mevalonate pyrophosphate→Isopentenyl pyrophosphate→Dimethylallyl pyrophosphate→ Geranyl pyrophosphate → Farnesyl pyrophosphate→ Squalene→ Cholesterol

HMG-CoA Reductase is the rate limiting enzyme of cholesterol biosynthesis. Propionate inhibits hepatic cholesterol synthesis by possibly reducing the activity of HMG-CoA Reductase (Theuwissen and Mensink 2008). While inhibiting the enzymes that catalyze the synthesis of cholesterol is thought to be a good mechanism, it is hard to verify whether this mechanism is the one causing the reduction in serum cholesterol levels. Several studies have been done to test the cholesterol lowering capability of propionate, and yet have been inconclusive (Nishina and Freedland 1990; Topping and Clifton 2001; Levrat and others 1994; Strugala and others 2003).

MECHANISM 3

Insulin activates HMG-CoA Reductase (HMG-Co AR), so when a high glycemic load is consumed, blood glucose rises, insulin levels increase and this activates HMG-Co AR, which increases hepatic cholesterol synthesis (Gunness and Gidley 2010). When viscous soluble dietary fiber is consumed, digestion of macronutrients is slowed by delaying gastric emptying and decreasing glucose absorption (Queenan and others 2007; Bourdon and others 1999). With a low glycemic response, insulin levels remain low, which could cause an inhibition of HMG-Co AR, and reduce hepatic cholesterol synthesis (Lundin and others 2004).

While each of the proposed mechanisms above may decrease serum cholesterol, according to (Bourdon and others 1999), the only mechanism that is measurable is that viscous fiber traps the bile salts and they are excreted in the feces. The effects of propionate have not been thoroughly established, and the effect of insulin is complex, so it is hard to test the specific result on serum cholesterol (Bourdon and others 1999). The viscous nature of soluble dietary fiber is the property that is thought to be the greatest factor associated with decreased levels of serum cholesterol (Topping and Cobiac 2005).

Soluble and insoluble fibers used together have the greatest benefit to the host. The insoluble fiber decreases gut transit time, thus more of the bile acids are excreted rather than reabsorbed, and the by-products of the fermentation of soluble fiber, such as acetate, are not reabsorbed either. Both of these factors together have the greatest potential to lower serum LDL-C (Brownlee 2011; Elleuch and others 2011; Topping and Cobiac 2005).

2.2.4.2 DIABETES

Fiber has been investigated for possibly protecting against diabetes. Fiber has been shown to reduce glycemic response in several studies with 33 out of 50 studies that used viscous fibers, and 3 out of 14 in studies using nonviscous fibers (Food and Nutrition Board 2005.). The proposed mechanisms are 1) delay of glucose uptake and 2) attenuation of insulin response. These mechanisms were supported by The Zutphen Elderly Study (Feskens and others 1994). It was also suggested that diets high in glycemic load, and low in cereal fiber lead to increased risk and were up to 2.5 times more likely to develop diabetes than subjects who consumed a diet with a low glycemic load and a high intake of cereal fiber (Food and Nutrition Board 2005.). Dietary fiber may slow the digestion of starch which would slow the absorption of glucose and thereby reduce the insulin "response" (Topping and Cobiac 2005). As stated above, viscous fibers tended to have greater effect on insulin response than did non-viscous fibers, and it has been proposed that the viscosity may be part of the reason for the positive effect. The glucose may get trapped in the gel network in the gut lumen and thus be inaccessible to the villi to be absorbed (Topping and Cobiac 2005).

2.2.4.3 OBESITY

Results have differed with respect to whether fiber has any positive effect on weight maintenance or weight loss. Fiber is said to give the subject the feeling of fullness (satiety) when the meal is of low caloric value, and is supplemented with fiber. It is believed that this feeling of fullness will result in less caloric intake and thereby help with weight loss. However, the intake of fiber varied, and the greatest effect was seen with a high intake of 30+ grams a day (Food and Nutrition Board 2005.). Therefore, while there is correlation between subjects with high fiber intake, and having a low BMI (Davis and others 2010), there is very little correlation between high fiber intake and weight loss.

2.2.4.4 CANCER

Studies have been conducted on the possibility of dietary fiber reducing the risk of colorectal cancers. The results of some of the studies have been inconclusive, and it was suggested that the reason for this was the different analytical methods used in the different studies (Topping and Cobiac 2005). It was also concluded that 1) timing of the intervention, 2) confounding role of other dietary factors and 3) individuals may not consume sufficient quantity of fiber or the right type of fiber (Food and Nutrition Board 2005.). Yet mechanisms have been put forth by which dietary fiber may reduce the risk of developing cancer (Topping and Cobiac 2005; Food and Nutrition Board 2005.).

1) Increased stool bulk, mostly by insoluble dietary fiber. This decreases the gut transit time, thereby reducing contact with carcinogens.

2) Binding of bile acids thereby lowering concentration of mutagens

3) Modifying gut microbiota which lowers colonic ammonia by fixing nitrogen in the bacterial mass.

4) Production of short chain fatty acids which lower colonic pH, thereby decreasing absorption of toxic alkaline compounds. Also, butyrate is a preferred substrate of colonocytes (Roediger 1982) and promotes normal cell phenotype, and slows cancer cell growth.

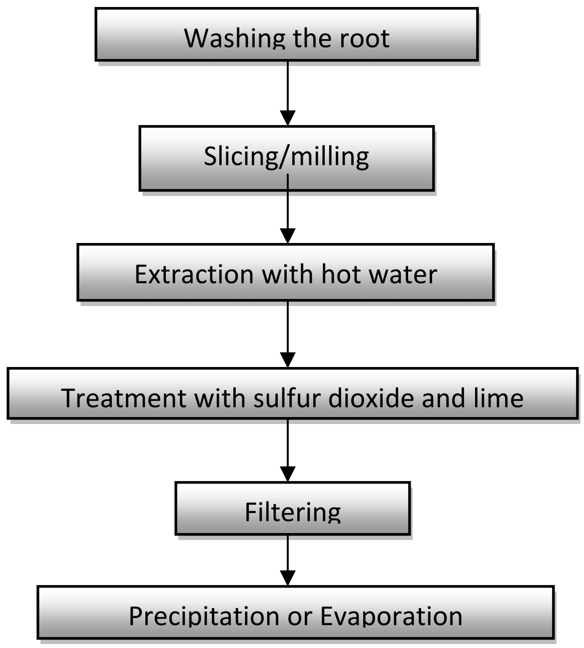
2.2.4.5 PREBIOTIC

Fiber can also function as a prebiotic. A prebiotic is defined as: a non digestible food ingredient that is beneficial to the host by selectively stimulating growth or activity of one or a number of colonic bacteria, and in so doing improves host health (Gibson and Roberfroid 1995). Gibson and Roberfroid also list four criteria that a food ingredient must meet to be considered a prebiotic: 1) It must not be hydrolyzed or absorbed in the upper part of the gastrointestinal system; 2) It must be a selective substrate of beneficial bacteria in the colon; 3) It promotes the growth of healthy bacteria, thereby modifying the colonic bacteria; 4) It stimulates the lumen of the gut and large intestine to produce end products that are absorbed into the blood that are beneficial to health.

According to (Gibson and Roberfroid 1995), fructooligosaccharides are considered a prebiotic. However, while some carbohydrates are classified as "Colonic Food," this does not necessarily result in being classified as a prebiotic.

2.3 INULIN

Inulin is a non-digestible fructooligosaccharide (FOS) which is defined as a chain of fructose units with a terminal glucose unit (Toneli and others 2010). While many vegetables contain inulin, the chicory root and Jerusalem artichoke are the sources used for commercial production (Toneli and others 2010). The dry matter of chicory root is approximately 14.5 percent inulin (Milala and others 2009). The dry matter of Jerusalem artichoke is between 16 and 20 percent inulin (Celik and others 2013; Bornet 2008). The basic steps for extracting inulin from chicory root are as follows (Toneli and others 2010).



In this study, the fact that inulin has low solubility at low temperatures was used to produce a concentrated solution. After evaporation the extract was frozen to -24°C, then thawed to 25°C, allowing for phase separation. The liquid phase was poured off, and the precipitate was spray dried. (Toneli and others 2010)

Inulin is composed of a glucose molecule linked via an α-(1, 2) linkage to a fructose molecule as in a sucrose molecule. The fructose molecule is then linked via a β-(2,1) linkage to repeating units of fructose which are also β-(2,1) linked (Causey and others 2000) (See Appendix A). Native inulin contains a mixture of oligomer and polymer chains with a differing number of fructose units, with a degree of polymerization of about 12. (González-Tomás and others 2009). According to this study, native inulin is subjected to partial enzymatic hydrolysis with the enzyme endo-inulinase, resulting in the production of oligofructose with a degree of polymerization (DP) of 2 to 7. To produce long chain inulin with a DP of 22-25, the oligomers are either filtered out using ultrafiltration, or crystallized out using crystallization (González-Tomás and others 2009). The smaller the molecule the more soluble the molecule is in water (Tárrega and others 2010). The temperature affects the solubility of inulin in water; at 10°C approximately 6%, 90°C approximately 35% (Silva 1996). The degree of polymerization of inulin is anywhere from 2-60. Differences in chain length result in different uses of the molecule. The function of inulin depends on the degree of polymerization. Inulin can be used in several different ways as a food additive, and also as a dietary supplement. As a food additive, it can be used as a fat replacer, sugar replacer, bulking agent or texturizing agent. As a dietary supplement, it functions as a prebiotic, soluble dietary fiber, increases the absorption of calcium, and lowers serum blood cholesterol (Causey and others 2000).

Type of Inulin	*Degree of Polymerization*
Standard[a]	2-60 units
High Performance[b]	~25 units
Oligofructose[c]	≤10 units

a.Polydisperse b.small weight oligomers have been removed c. enzymatic hydrolysis (Roberfroid 1999; Roberfroid and others 1993; Niness 1999)

2.3.1 FAT REPLACER

Inulin has the ability to form a gel network with water which is the property that leads to its use as a fat replacer (Franck 2002). Greater than 25% concentration of inulin results in a gel formation that mimics the characteristics of fat (Zimeri and Kokini 2002). The addition of hydrocolloids affects the gel formation of inulin in solution (Pszczola 1997). Inulin is a nondigestible polysaccharide that has characteristics that improve the mouthfeel of products; it was used in a frozen yogurt product, and the amount that was concluded to be desirable was 5% (El-Nagar and others 2002).

2.3.2 SUGAR REPLACER

Inulin can be used as a sugar replacer in dairy products, frozen desserts, fillings, fruit preparations, meal replacers, and chocolate (Franck 2002). The percentage of inulin used in the various applications differs, but in dairy products and frozen desserts it is suggested that the percentage should be 2-10 (% w/w). However, oligofructose powder is better suited for use as a sugar replacer since its average degree of polymerization (DP) is 4, compared with high performance inulin at 25 DP and standard inulin at 12 DP. Oligofructose was 35 percent as sweet as sucrose (Franck 2002).

2.3.3 DIETARY FIBER

Inulin is considered a soluble dietary fiber in light of the fact that it contains the β (2→1) linkages. The human small intestine does contain the enzyme required to hydrolyze this bond (González-Tomás and others 2009). Inulin is fermented in the colon by bifidobacteria.

2.3.4 PREBIOTIC

Increase in the number of *Bifidobacterium* and *Lactobacillus* will provide health benefits to the host, such as producing short chain fatty acids (SCFA). These SCFA's reduce the colonic pH, and produce bacteriocins which inhibit the growth of pathogenic bacteria. Other health benefits that are provided by intestinal bacteria are: improvement of digestions and absorption of essential nutrients, synthesis of vitamins (mainly B vitamins), stimulation of immune functions, and lowering of gas distention problems (Gibson and Roberfroid 1995). In the proximal colon, the supply of nutrients are much greater than in the distal colon, thus the microorganism activity and growth rate is much higher, and the pH much lower than in the distal colon. It is said, that in the distal colon, the pH comes close to neutral (Cummings and others 1987).

Colonic bacteria utilize dietary carbohydrates that were not digested or hydrolyzed by the upper gastrointestinal system (Gibson and Roberfroid 1995). In a study conducted by Yoram Bouhnik, it is stated that short chain fructooligosaccharides meet the definition given by Gibson and Roberfroid (1995) for a prebiotic (Bouhnik and others 2007) (See Section 2.2.4.5) Short chain fructooligosaccharides are fructose units with a terminal glucose molecule that can have differing degrees of polymerization. These are fermented in the colon by bifidobacteria, and this has been shown to retain or reduce the number of bacteriodes, clostridia and coliforms (Wang and Gibson 1993).

Yogurt was used as the medium for a study conducted in Turkey (Özer and others 2005). In this study a "classical" yogurt, a probiotic yogurt, an inulin fortified probiotic yogurt, and a lactulose fortified probiotic yogurt were compared. The "classical" yogurt contained *Lactobacillus bulgaricus* and *Streptoccocus thermophiles.* The probiotic yogurt contained the yogurt culture as well as a strain of *Lactobacillus acidophilus* and *Bifidobacterium Bifidum.* The yogurts were then tested for bacterial counts, and it was found that while the yogurt that contained inulin did have an increase in cfu/g compared to the unfortified yogurt, lactulose was found to be more effective. All of the yogurts whether fortified with prebiotics or not, were maintained above the recommended level of 10^7 cfu/g of probiotics (Hoier 1992). Table 2.4 shows the results of this study.

Table 2.4 CFU per Gram of *Lactobacillus acidophilus* in Probiotic Yogurt Fortified with Inulin and Lactulose

Trial #:	Count on Day 0 for *Lactobacillus acidophilus*	Count on Day 14 for *Lactobacillus acidophilus*
Trial B: Probiotic Yogurt	6.3×10^8 cfu/g	2.2×10^8 cfu/g
Trial C: Probiotic Yogurt with 0.5% inulin	7.0×10^8 cfu/g	3.5×10^8 cfu/g
Trial D: Probiotic Yogurt with 1% inulin	8.8×10^8 cfu/g	4.2×10^8 cfu/g
Trial E: Probiotic Yogurt with 0.25% lactulose	7.0×10^9 cfu/g	3.2×10^8 cfu/g
Trial F: Probiotic Yogurt with 2.5% lactulose	1.1×10^{10} cfu/g	6.9×10^8 cfu/g

2.3.5 HEALTH BENEFITS OF INULIN

There are several health benefits associated with inulin consumption apart from its function as a dietary fiber and a prebiotic. Inulin has been noted to increase calcium and magnesium absorption, and lower cholesterol.

2.3.5.1 CALCIUM AND MAGNESIUM ABSORPTION

Inulin in combination with oligofructose, was supplemented in 8 gram servings to adolescent girls with a 1500 mg/day intake of calcium. At the end of a 3 week period it was noted that there was an 18 percent increase in calcium absorption over the placebo group (Griffin and others 2002).

There are several proposed mechanisms by which inulin enhances mineral absorption, two of which are passive transport and active transport (Scholz-Ahrens and Schrezenmeir 2002). Passive transport is thought to occur when the inulin is fermented by the gut microbiota and short chain fatty acids (SCFA's) are produced, mainly acetate, propionate, and butyrate. This production of SCFA's lowers the pH which then increases the mineral solubility in the gut. Also, there is an increased exchange of H^+ ions for the luminal Ca^{+2}. Active transport is facilitated by the increased production of butyrate which is a substrate for cell growth, and with cell growth and proliferation comes an increased absorption area in the gut (Lupton and Kurtz 1993).

In the study conducted by Ohta and others (1994) it was stated that a diet of 5% fructooligosaccharides did increase the absorption of magnesium in rats, but in the end, it had no effect on serum magnesium concentrations.

2.3.5.2 LOWER CHOLESTEROL

Several human studies have been conducted on the cholesterol lowering effect of inulin, but results have differed. From animal studies, it appeared that one of the main mechanisms of inulin on blood lipids came from the inhibition of *de novo* fatty acid synthesis. If the human diet is high in fat, then *de novo* fatty acid synthesis rates in the liver are low (Williams and Jackson 2007). Therefore, the effect that inulin has on inhibiting this synthesis varies depending on the person's diet.

One of previously proposed mechanisms of lowering serum cholesterol levels is that inulin (or short chain fructooligosaccharides) binds to bile acids and results in increased fecal cholesterol concentrations. A four-week study conducted with elderly individuals fed 8 g/day short chain fructooligosaccharides, resulted in an increased fecal cholesterol concentration of a minimum 2.06 mg/g dry matter to a maximum of 8.68 mg/g dry matter, when compared with the basal period with no fructooligosaccharide feeding (Bouhnik and others 2007).

A 10 gram/day feeding of inulin resulted in a lowering of cholesterol, insulin levels, and triacylglycerol levels (TAG) (Jackson and others 1999). The greatest lowering effect on TAG was seen in patients with very elevated TAG levels before the study was conducted.

2.3.5.3 OTHER HEALTH BENEFITS

It has also been suggested that inulin improves insulin sensitivity and glucose tolerance. Pharmaceuticals used to treat insulin resistance contain Glucagon-like peptide 1 amide (GLP-1), which is an enteroendocrine-derived peptide. In healthy individuals, this peptide is released when food is consumed. When this peptide is released it promotes insulin secretion. However, for individuals with insulin resistance, they either needs to be an exogenous source (pharmaceutical) or a promotion of the release of endogenous GLP-1. For oligofructose (OFS) to have an “antidiabetic effect,” a GLP-1 receptor is required (Cani and others 2006). A suggested mechanism is that OFS increases the release of GLP-1 in the colon, “leading to a stimulation of insulin secretion and reduction of hepatic glucose production, fasting glycemia, and glucose tolerance.” (Cani and others 2006).

A study was conducted with 10 volunteers to ascertain if oligofructose promoted satiety in humans (Cani and others 2006). The subjects were given 16 grams of OFS per day for two weeks, and it was found to increase satiety, reduce hunger and food consumption. Thus, by increasing satiety this could be a possible treatment for overweight and obese patients with a goal of weight loss.

2.3.6 SIDE EFFECTS OF INULIN CONSUMPTION

Consumption of inulin was shown to increase the incidence of flatulence, bloating, cramping, and loose stools in participants who consumed 18 grams per day (Davidson and Maki 1999). The severity of the side effects ranged from “none reported” to “severe”, with only one participant out of twenty-one reporting severe side effects, and thirteen participants reporting mild side effects.

2.4 β – GLUCAN

β-glucan contains mixed linkages of (1→3) and (1→4)-β-ᴅ-glucan units (Cherbut and others 1991). It is a linear homopolysaccharide consisting of 2 or 3 consecutive β-ᴅ-glucosyl units with (1→4) linkages, followed by a β-(1→3) linkage (Lazaridou and others 2008b) (See Appendix A). This arrangement of linkages is always consistent, while the “cello-oligomers” that make up β-glucan are not (Cherbut and others 1991). According to Izydorczyk (2008), there are three different cello-oligomers that make up the chain, cellotriosyl (DP3), cellotetraosyl (DP4), and some longer oligomers (DP5) (Table 2-4). Lazaridou (2008) stated that the molecular makeup of the chain, the ratio of the three different oligomers, dictated the physical and physiological properties of the β-glucans. The physical properties determined by the molecular structure are water solubility, dispersibility, viscosity, and gellation (Biliaderis 2006).

Table 2.5 Percentage of DP3 and DP4 Cello-Oligomers Found In Barley, Oats, and Wheat (Biliaderis 2006)

	DP3	DP4	Molar Ratio (DP3/DP4)
Barley	52-69%	25-33%	1.8-3.5
Oat	53-61%	34-41%	1.5-2.3
Wheat	67-72%	21-24%	3.0-4.5

2.4.1 SOURCES OF β – GLUCAN

B-glucan is found in the cell walls of endosperm of cereals such as oats, barley, rye, and wheat (Lazaridou and others 2008b), also fungi and algae (Food and Nutrition Board 2005.). Beta-glucan isolated from algae is being investigated more for the use with animal feed than for human supplementation at the current time (Henderson 2012).

Table 2.6 Sources and Percentages of Betaglucan

Grains	**Percent of Beta-glucan in Grain**
Barley	2.3-11.3 %
Wild Barley (*Hordeum spontaneum)*	13.2 %
Prowashonupana	14.7-17.4 %
Oat	2.2-7.8 %
Rye	1.2-2.9 %
Wheat	0.4-1.4 %
Tricale	0.4-1.2 %
Sorghum	0.1-1.0 %
Rice	0.04 %
Fungi	0.22-0.53 %
Pleurotus ostreatus	0.38 %
Pleurotus eryngii	0.38 %
Pleurotus pulmonarius	0.53 %
Lentinus edodes	0.22 %

(Biliaderis 2006; Rop and others 2009; Manzi and Pizzoferrato 2000; Izydorczyk and Dexter 2008)

There are a couple of methods for extraction of β-glucan from barley. The first is an older method that involves deactivating enzymes in the grain, then extraction with water or alkali solutions, removal of contaminates, and lastly precipitating the β-glucan with alcohol and spray drying the extracts (Izydorczyk and Dexter 2008). The commercial product Glucagel® was produced using a simpler method. The β-glucan was extracted using hot water extraction, then the extract was frozen and thawed repeatedly, thus the β-glucan was precipitated (Izydorczyk and Dexter 2008).

β-glucan can be used in many different food applications such as enrichment of bread (Brennan and Cleary 2007), acid –set skim milk gels (Lazaridou and others 2008a), yogurt (Gee and others 2007), barley enrichment of bars, muffins and cookies (Berglund and others 1992). However, discoloration that occurs when barley is used in food products influences the appearance and thus the acceptability by consumers (Izydorczyk and Dexter 2008). Barley and oat flours, and brans are usually used for baked goods rather than β-glucan isolates. The isolates are used in food products as stabilizers, fat mimetics, and thickening agents for low fat, and low calorie foods (Biliaderis 2006).

2.4.1.1 TYPES OF β-GLUCAN

Native β-glucan is highly viscous, but when it is extracted it usually becomes degraded (Burkus and Temelli 2005). Molecular weight of β-glucan varies with the source (Biliaderis 2006) (see Table 2.7).

Table 2.7 Molecular Weight of Betaglucan from Different Sources

Barley	31 – 2700 x 10^3
Oat	35 – 3100 x 10^3
Wheat	209 – 416 x 10^3
Rye	21 – 1100 x 10^3

Solubility, also differs with the source of β-glucan, and it is thought that the ratio of (1→4)/(1→3) linkages is one of the reasons for this difference (Biliaderis 2006). Different genotypes of barley have different concentrations of β-glucan and the amount that is water soluble differs (Izydorczyk and Dexter 2008) (Table 2.8).

Table 2.8 Types of Barley, and Percentages of Total and Soluble Betaglucan

Barley Genotype	**Total β-glucans (%)**	**Water Soluble β-glucans (%)**
Hulled, normal starch	4.73	1.28
Hull-less, normal starch	4.14	1.46
Hull-less, waxy starch	7.68	2.82
Hull-less, high amylose starch	8.9	1.75

(Izydorczyk and Dexter 2008)

Brennan and Cleary (2007) concluded that the replacement of wheat flour with β-glucan in the form of Glucagel® at 2.5 and 5% decreased the pasting properties of wheat flour. It was suggested that the reason for this decrease was that hydration of Glucagel® limited the availability of water and consequentially would limit starch granules swelling. This would lead to a reduction in gelatinization of the starch granules.

Though the molecular weight and source of β-glucan causes some variation in viscosity, in general β-glucan creates a thixotropic solution (Biliaderis 2006). Also, as storage time increases, the solutions exhibited a shear-thinning characteristic at low shear rates. And, as the molecular weight increases, there is an increase in the viscosity of the solutions.

Aside from its ability to create a thixotropic solution, β-glucan also has the ability to create gels. If the gels are created through freeze-thaw cycles, they become cryogels (Lazaridou and Biliaderis 2004). Again, the ability to form gels is dependent on molecular weight, DP3/DP4 ratio, and temperature. It was found that gelation time decreased, and gelation rate increased as molecular size decreased, and the reason suggested for this was the higher mobility of smaller size chains (Biliaderis 2006). While oat and barley β-glucans of the same molecular weight do not differ significantly in flow viscosity, they do however, differ in gelation properties with barley gelling faster. This is due to the fact that barley β-glucan has a higher proportion of DP3 units (Wood 2007). Wheat β-glucan had the shortest gelation time and the highest gelation rate, followed by barley, and lastly oat (Böhm and Kulicke 1999; Cui and others 2000; Lazaridou and others 2004; Tosh and others 2004). The addition of sugars (30% w/v) increased gelation time, and glucose increased gel firmness while ribose decreased gel firmness (Irakli and others 2004). Burkus and Temelli (2000) studied the possibility of using barley β-glucan gum as a foam stabilizer in a whey protein gel and emulsifier in a 50% oil and aqueous whey protein emulsion. It was found that phase separation in the emulsion was significantly reduced, foam volume was increased, and drainage decreased when β-glucan gum was used (Burkus and Temelli 2000). Also, when sugar was used in tandem with β-glucan gum, foam stability significantly increased.

2.4.2 FAT REPLACER

Because of β-glucan's ability to form a gel network, it is considered a good product for use as a fat replacer. High viscosity β-glucan at a concentration of 1% (w/w) was found to be highly pseudoplastic, and had good potential for use as a fat replacer (Burkus and Temelli 2005). β-glucan isolates and concentrates serve well as fat mimetics (Biliaderis 2006). Biliaderis (2006) also stated that, high molecular weight β-glucans (110×10^3) stabilized oil-in-water emulsions strictly by increasing the viscosity, while low molecular weight β-glucans (40×10^3) stabilized emulsions by network formation. Oatrim can be used in gel form to replace the shortening in oatmeal-raisin cookies (Inglett 1997), and contains 1-10% by weight β-glucans, and is being investigated for use in a wide variety of low-fat, calorie reduced items such as yogurt, sour cream, muffins, meats, cheese spreads and salad dressings (Biliaderis 2006). It was found when this was used in meat, it had the same organoleptic properties of a full-fat meat product, and had higher yield (Jenkins and Wild 1996). It was also suggested that β-glucan could be used in ice cream since it inhibits ice crystal formation, resulting in smoother product (Morgan 2002).

2.4.3 DIETARY FIBER

β-glucan from barley, oat, and wheat is considered a naturally occurring dietary fiber, while β-glucans that have been extracted and isolated so that they can be added to food products, are considered functional fibers (Food and Nutrition Board 2005.).

2.4.4 HEALTH BENEFITS

There are several proposed health benefits of consuming β-glucan fiber in addition to it serving as a dietary fiber. It can function as a prebiotic, reduce serum cholesterol, and attenuate serum glucose.

2.4.4.1 PREBIOTIC

Certain lactic acid bacteria produce exopolysaccharides, one of which is a 2-substituted-(1,3)-β-D-glucan (Russo and others 2012). Because of this ability it was suggested that β-glucan may act as a prebiotic. The three probiotic strains used in this study were *L. plantarum* strain WCFS1, *L. plantarum* WCFS1β-gal, and *L. acidophilus* strain NCFM. β-glucan had a prebiotic effect for all three of the probiotics used, and for *L. plantarum* strain WCFS1, β-glucan improved adhesion to human intestinal epithelial cells. The *Pediococcus parvulus* glycosyltransferase gene in lactic acid bacteria is required to produce β-glucan (Kearney and others 2011). When *Lactobacillus paracasei* NFBC 338 (which carried this gene) was used in production of yogurt, it resulted in a two fold increase in viscosity and a decrease in syneresis, both of which were attributed to the presence of β-glucan.

2.4.4.2 LOWER SERUM CHOLESTEROL

There have been differing results among the studies conducted to test the efficacy of using β-glucan as soluble dietary fiber to lower cholesterol (Wood 2007). The FDA has determined that a dose of 3 or more grams a day of β-glucan, “may” or “might” be effective in lowering plasma cholesterol (FDA 1997). The overall decrease in plasma cholesterol levels differs based on level of β-glucan consumed per day, and initial level of plasma cholesterol prior to intervention. The greatest decreases are seen in patients that are hypercholesterolemic, rather than subjects that are either healthy, or mildly hypercholesterolemic (Tiwari and Cummins 2011; Wood 2007). The source (Tiwari and Cummins 2011) and molecular weight (Wood 2007) were also factors in the effectiveness of the β-glucan treatments. Brown and others (1999) concluded that consumption of 3 grams of soluble dietary fiber per day could decrease total cholesterol by approximately 2%. It was also concluded from the different studies included in this meta-analysis, that when soluble fiber was consumed above 10 grams per day, the response was no longer linear. However, all the oat studies that were used in this meta-analysis were either from oat bran or whole oats, no isolates, thereby making it hard to determine whether the positive effects were from the β-glucan portion of the diet or from the diet as a whole (Wood 2007).

One study used an isolated oat gum that was approximately 80% β-glucan, and had 19 subjects who consumed 2.9 grams β-glucan twice daily with meals (Braaten and others 1994). The β-glucan that was isolated was high viscosity/high molecular weight. Fourteen of the 19 subjects had a mean reduction in LDL-cholesterol of 13%. There was no change in HDL-cholesterol.

The simplified process used to extract β-glucan for the Glucagel® product has been shown to eliminate the health benefits that other traditionally extracted β-glucan products have had on serum cholesterol and glucose (Izydorczyk and Dexter 2008) (Keogh and others 2003). In the study conducted by Keogh (2003), it was suggested that the possible reason for the insignificant response could be due to the fact that Glucagel® is a low molecular weight β-glucan. However, it was shown to lower plasma cholesterol in rats that were fed up to 10% of their diet in Glucagel®, which equated to 5.8-5.9 grams beta-glucan per kilogram body weight per day (Jonker and others 2010).

The suggested mechanism for action of β-glucan for reduction of cholesterol levels is the increased excretion of bile acids. Many of the studies conducted suggest that viscosity is the probable reason for this. However, many of these studies have not conducted viscosity and solubility tests to verify this claim (Wood 2007). Therefore, more studies need to be conducted on molecular weight and solubility of the β-glucan fibers. Wood (2007) states that changes in 1) the amount of β-glucan in cereal grain, 2) the solubility, 3) extractability, 4) molecular weight and 5) structure of the fiber can all have major effects on the physiological function of the fiber.

Another proposed mechanism of action also is a function of β-glucan's ability to create a viscous solution. It is suggested that this increase in viscosity delays the nutrient absorption in the brush border membrane (BBM). This would in effect reduce the uptake of glucose and lipids, thereby reducing uptake of dietary cholesterol (Drozdowski and others 2010). Also, the ability of β-glucan to be fermented by the gut bacteria, and thereby produce SCFA's, mainly butyrate from oat β-glucan, may also be an additional mechanism of the hypocholesterolemic effect of β-glucan (Drozdowski and others 2010).

2.4.4.3 LOWER SERUM GLUCOSE

Tiwari and Cummins (2011) stated that though there appeared a dose-dependence of β-glucan in reduction/maintenance of normal blood glucose levels, the results are inconclusive to guarantee long-term effect. Another study used two different β-glucan isolates, Glucagel® and Barley Balance® (Chillo and others 2011). Glucagel® is low molecular weight (150,000 Da) and has a β-glucan content >75%, and Barley Balance is high molecular weight (650,000-700,000 Da) but has a β-glucan content around 25%. For the Barley Balance®, it was found to have a dose-dependent reduction in glycemic response and glycemic index, but even at 10% concentration of Glucagel®, there was no significant alteration in the glycemic index (Chillo and others 2011).

When resistant starch and β-glucan were used together, they significantly reduced postprandial glucose and insulin response and it was said to be most beneficial to those with elevated glucose and insulin, or those with reduced insulin sensitivity (Behall and others 2006).

A more recent study has been conducted on the effect of differently processed oat products on glycemic response (Regand and others 2009). In this study, crisp bread, porridge, granola and pasta were fortified with 4 grams of β-glucan and the viscosity, molecular weight, and concentration of β-glucan in the products were all measured. It was observed that baking caused depolymerization of the β-glucan, and that the granola, and porridge were the most efficient in attenuation of the peak glucose response. It was also stated that molecular weight x concentration was responsible for 73 percent of the bioactivity of β-glucan (Regand and others 2009). Viscosity is determined by molecular weight and concentration of β-glucan (Wood and others 2000). It was noted by Wood (2007), that the factor for a low glycemic response from foods and treatments with added β-glucan was the viscosity of the β-glucan.

2.4.5 SIDE EFFECTS OF CONSUMING β-GLUCANS

The possible side effects of consuming β-glucans are bloating, flatulence and diarrhea (Biörklund and others 2005). These side effects were found to be more prevalent in participants that consumed 10 grams of oat β-glucans (11 reports) rather than participants that consumed 5-10 grams of barley β-glucans. This study also reported that these gastrointestinal side effects gradually decreased after 1-2 weeks of ingestion.

2.5 CELLULOSE

Plant cell walls are primarily composed of cellulose which is a polysaccharide made up of linear β-(1,4)-linked glucopyranoside units (Food and Nutrition Board 2005.) (See Appendix A). Cellulose is isolated from cellulose pulp, which is manufactured from raw materials such as wood pulp or cotton linters (Phillips and Williams 2000). The polymer length varies among the raw materials, and thus the viscosity of the resultant isolate varies, so the desired end product determines the source.

Methyl cellulose (MC), sodium carboxymethylcellulose (CMC or cellulose gum) and hydroxypropylmethylcellulose (HPMC), hydroxypropyl cellulose (HPC), methyl ethyl cellulose (MEC), are all derivatives of cellulose used in food applications (Kohajdová and Karovičová 2009; Phillips and Williams 2000). HPMC is created by chemical modification of the cellulose chain by the addition of methyl and hydroxypropyl groups.

To manufacture the different isolates, first the cellulose pulp is mixed into an alkali solution, and then treated with different substituting reagents to obtain the derivatives. The substitutions occur at the hydroxyl groups on the cellulose chain (Phillips and Williams 2000). The reagents used to obtain the cellulose derivatives are as follows (Phillips and Williams 2000):

Chloromethane → MC

Propylene oxide → HPC

Chloromethane + propylene oxide → HPMC

Chloromethane + chloroethane substituents → MEC

Monochloracetic acid → CMC

Once the desired substitution reaction has occurred, the product is purified and washed, resulting in a purified product ready for food applications.

The cellulose chain is made up of two consecutive glucopyranoside units, that are then joined by 1,4 glucosidic linkages (Phillips and Williams 2000). Each unit has three hydroxyl groups that allow for substitution, and the average number of substitutions per unit is known as degree of substitution (ds). Three main factors determine the properties of the cellulose product: 1) Type of the substitution 2) Average chain length (degree of polymerization, DP), 3) Degree of substitution (ds). Viscosity is dependent on the DP, and the greater the DP the greater the viscosity (Phillips and Williams 2000).

HPMC is soluble in cold water, and has been shown to have a stable viscosity between the pH range of 3 to 11. On heating, the solution forms a gel when the temperature is raised above the incipient gel temperature (igt) of 63-80°C for HPMC, the greater the degree of substitution, the higher the igt. This gel is reversible when cooled (Phillips and Williams 2000).

CMC is soluble in hot and cold water, and has a viscosity of 5,000 mPas at 1% in an aqueous solution. When the solution is heated, there is a reversible reduction in viscosity, and CMC does not gel. The range of ds is 0.6-0.95 in the CMC that is used for food applications. A lower degree of substitution results in a thixotropic solution, while a high degree of substitution results in a pseudoplastic solution which gives a “smooth” mouthfeel (Phillips and Williams 2000).

CMC is ionic, and thus forms a complex with proteins such as casein, around the protein's isoelectric point. The most stable complex is formed between the pH of 3.0-5.5, and has a very high viscosity. The viscosity of the complex decreases when sheared (Phillips and Williams 2000).

Microcrystalline cellulose (MCC) is purified cellulose that is insoluble in water, dilute acids and alkali's at ambient temperatures (Phillips and Williams 2000; Ott 1954). It has a wide DP ranging from 50-3500, depending on the source and treatments. MCC is usually purified from wood pulp as the raw material. During the production process, high molecular weight cellulose fiber is produced, which is known as α-cellulose (Phillips and Williams 2000). These fibers are made up of microfibrils, and each of the millions of microfibrils has two regions, an amorphous and a crystalline region. Through strong mineral acid hydrolysis, the amorphous regions are removed, leaving the rigid, linear crystalline portion behind. This is then neutralized, washed, filtered, diluted and spray dried to produce non-colloidal MCC (Phillips and Williams 2000). To produce colloidal MCC, before the product is spray dried, it undergoes a mechanical separation step, and the MCC particles are reduced to submicron size, and co-dried with CMC.

2.5.1 USES IN FOODS

For examples of the food industry use of the different types of cellulose see Table 2.9 below. Powdered cellulose is used in the food industry as an anticaking agent, a thickener, and texturizing agent (Food and Nutrition Board 2005.). It is also used as an anti-staling agent in bread (Armero and Collar 1998; Gray and BeMiller 2003; Tavakolipour and Kalbasi-Ashtari 2007), and gives bread a greater volume and moisture content (Kohajdová and Karovičová 2009). CMC can be used in instant products, frozen products, sauces and dressings, soft drinks (0.025-0.5%), bakery products, and low pH milk products (0.3-0.4%). When used in bakery products around 0.3%, CMC improves volume yield due to the fact that when it is used, it requires more fluid, and when baked the viscosity reduces allowing for increased volume, and improved moistness. When dried fruit is used in a batter, it helps keep the fruit suspended in the baked goods (Phillips and Williams 2000).

Non-colloidal MCC is used as functional fiber, and as an anti-caking agent in oily products such as shredded cheese. Colloidal MCC is used as a texture modifier for emulsion stabilization, foam stability, fat replacement (salad dressings), heat stability (bakery products), and in frozen desserts for ice crystal control and heat shock stability (Phillips and Williams 2000).

Colloidal MCC sets up an insoluble structural gel network, and it is this strong network that is responsible for the wide variety of functions in various food applications (Phillips and Williams 2000). This network is shear thinning and thixotropic, thus it is desirable for oil and water emulsions. The system is also heat stable and shows no decrease in viscosity until temperatures reach about 80°C. This heat stability allows the products to hold up during baking, retorting, UHT processing, and microwaving (Phillips and Williams 2000).

Table 2.9 Types of Cellulose, Applications, and Studies

Type of Cellulose	Application	Food Product	Percent used	Results	Study(ies)
HPMC	Thermogellation	Potato croquettes	0.5%	As a binder	(Phillips and Williams 2000)
	Film Former	Onion rings	1% (low viscosity)	to reduce oil absorption	(Phillips and Williams 2000)
	Viscosity	Ice Cream	0.17%	Inhibition of ice crystal formation, control ice crystal size, Slow meltdown, Improved resistance to dripping, Heat shock resistance, Smooth texture, Increased overrun	(Phillips and Williams 2000)
	Loaf Volume	Bread	0.8%	Increased the loaf volume of partially substituted Banana pseudo-stem flour for wheat flour	(Go and others 2013)
CMC	Water binding	Donuts	0.3%	Decreased fat absorption	(Phillips and Williams 2000)
CMC	Suspension of Solids	Chocolate Beverage	0.45%	Suspension of Cocoa, Calcium, Vitamins,	(Phillips and Williams 2000)

	High Temperature Stability	Adult Nutritional Beverage	0.5-0.8%	Creamy Mouth feel Minimize processing time, Low viscosity/suspending network	(Phillips and Williams 2000)
MCC (Non-Colloidal)	Emulsion Stability	cooking cream	0.35-0.7%	Stabilization against oil globules coalescing	(Phillips and Williams 2000)
MCC (Colloidal)	Foam stability, Syneresis control, fat replacement	Vegetable fat whipping cream	0.45%	Thicken water phase, Structural integrity to protein film, Improves body/texture, Foam stiffness, Short whipping time	(Phillips and Williams 2000)
	Heat Shock Stability, Ice Crystal Control	Ice Cream	0.5-0.6%	Smooth, creamy texture, Controlled melt, Eliminate whey separation, Inhibition of ice crystal growth due to insolubility of MCC (restrict water migration)	(Phillips and Williams 2000)

2.5.2 DIETARY FIBER

Cellulose is classified as a dietary fiber because humans lack the enzymes to break β-(1,4) linkages, and so it is non-digestible (Food and Nutrition Board 2005.; Phillips and Williams 2000).

2.5.3 LAXATION

Cellulose was shown to increase fecal bulk by 3 g/g, though increased fecal bulk does not necessarily equate increased laxation (Food and Nutrition Board 2005.). Another study that compared pectin, lignin and cellulose, showed that cellulose (15 g/day) lowered fecal pH from 6.38 to 6.12, decreased transit time by 27% and increased fecal bulk by 57% (Hillman and others 1983). An *in vitro* study showed that cellulose was not viscous, and so therefore was recommended for laxation purposes (Zacherl and others 2011).

2.5.4 OTHER HEALTH BENEFITS

Cellulose has not been shown to lower serum cholesterol or lower postprandial glucose (Food and Nutrition Board 2005.). Nor does cellulose affect gastric emptying, thereby it is unable to be used as a weight-loss supplement (Berthold and others 2008).

2.5.5 SIDE EFFECTS OF CONSUMING CELLULOSE

In a study conducted using rats, it was found that a diet that contained 2% carboxymethylcellulose lowered absorption of calcium and magnesium (Vissia and Beynen 1999). This was found to be true in humans as well (Slavin and Marlett 1980). This was due to the decreased gut transit time which resulted in increased concentrations of calcium and magnesium.

CHAPTER 3

MATERIALS AND METHODS

3.1 MATERIALS

Three types of dietary fiber were used in this study: Frutafit TEX! Inulin (Sensus America Inc., Lawrenceville, NJ, USA), Glucagel® Betaglucan (PolyCell Technologies, MN, USA) and VITACEL SMOOV 240 Cellulose (J. Rettenmaier USA LP, MI, USA). Frozen yogurt base was made using skim milk, cream (35% fat), sugar, MALTRIN M200 corn syrup solids (Grain Processing Corporation, Muscatine, IA, USA), nonfat dry milk, and IcePro 2515 LF stabilizer (Danisco, Kansas, USA).

Frutafit TEX! is an inulin with a DP of approximately 25, and is a fine white powder from chicory that has a neutral pH, neutral taste, 0% sweetness, and 96.7 grams of soluble fiber per 100 grams. Vitacel SMOOV 240 is a combination of 30% Vivapur (90% MCC, 10% CMC) and 60% Vitacel (powdered cellulose). This is a fine white powder with a pH of 6-8, a neutral taste, and 92.1 grams insoluble fiber, and 2.6 grams of soluble fiber per 100 grams for a total of 94.7 grams of fiber per 100 grams. Glucagel® is a barley beta-glucan which is an off white powder, neutral pH, has a bland flavor and contains 77.6% β-glucan.

Frutafit TEX! is represented in tables as FT!, Glucagel as GL, Vitacel SMOOV 240 as VS 240.

Table 3.1 Percentage of Ingredients Used For All the Treatments

Treatment	Skim Milk	Yogurt	Cream	Sugar	CSS	NFSMP	Stabilizer	Water	Frutafit TEX!	Vitacel SMOOV 240	Glucagel®
Control	46.23	20	12.5	11.95	4.44	2.32	0.3	2.26	-	-	-
3% FT!	46.19	20	12.89	11.93	4.43	2.25	0.3	2.01	3	-	-
5% FT!	46.14	20	13.16	11.92	4.42	2.21	0.3	1.85	5	-	-
7% FT!	46.10	20	13.44	11.90	4.42	2.17	0.3	1.67	7	-	-
3% VS 240	46.19	20	12.89	11.93	4.43	2.25	0.3	2.01	-	3	-
5% VS 240	46.14	20	13.16	11.92	4.42	2.21	0.3	1.85	-	5	-
7% VS 240	46.10	20	13.44	11.90	4.42	2.17	0.3	1.67	-	7	-
3% GL	46.19	20	12.89	11.93	4.43	2.25	0.3	2.01	-	-	3
5% GL	46.14	20	13.16	11.92	4.42	2.21	0.3	1.85	-	-	5
7% GL	46.10	20	13.44	11.90	4.42	2.17	0.3	1.67	-	-	7

3.2 PREPARATION OF BASE

Frozen yogurt base was processed in 2-liter batches. Skim milk, cream, sugar, corn syrup solids, nonfat dry milk, Grindsted IcePro LF 2515 and water were weighed and mixed. The mix was pasteurized according to the method used by Barnes (Barnes 1998). The mix was heated to 80^{0}C for 25 seconds with slight agitation. After pasteurization, the mix was homogenized at a pressure of 2500 psi at 65^{0}C. The mix was cooled and aged at 4^{0}C.

3.3 PRODUCTION OF YOGURT

Skim milk was heated to 80 ^{0}C for 25 seconds, and then cooled to 40 ^{0}C and inoculated with the starter culture (Yogourmet, VMC, Weehawken, NJ) which contained 1 billion CFU/gram, according to the method laid out by (Ordonez and others 2000). This was allowed to ferment to a pH of 4.3 (~4 hours). The yogurt was then chilled overnight to set the yogurt, after which it was stirred for a smooth consistency.

3.4 PREPARATION OF FROZEN YOGURT

According to Marshall (Marshall and Arbuckle 1996), 10-20% of the weight of the total mix should be yogurt. For all treatments, yogurt was weighed out as 20 percent of the final mix, and the prepared base as 80 percent of the final mix. A commercial Hobart mixer was used to incorporate the fiber into the mix.

3.5 FREEZING AND HARDENING

Prior to freezing, vanilla flavoring was added at 0.45% of the mix. The mix was frozen in a batch freezer to a target overrun of 80 percent. The frozen yogurt was then packed in cartons and hardened.

Overrun was calculated using the below equation:

$$Overrun = \frac{(Volume\ of\ Frozen\ Yogurt - Volume\ of\ Mix\ Used)}{(Volume\ of\ Mix\ Used)} X\ 100$$

All treatments were performed in triplicate, and the replicates were produced on different days.

3.6 PH AND TITRATABLE ACIDITY

One gram sample was weighed and then diluted to 100 ml with distilled water. The pH was then measured for all samples with a calibrated pH meter. Titratable acidity was evaluated by titration with 0.1 N NaOH, until a phenolphthalein end point was reached and this was conveyed as a percent lactic acid (%TA).

$$\%\ TA = \frac{(ml\ NaOH\ xN\ NaOH\ x\ milliequivalent\ weight\ of\ lactic\ acid\ *)}{weight\ or\ volume\ of\ sample\ in\ grams\ or\ milliliters}\ x\ 100$$

*The milliequivalent weight of lactic acid is 90/1000 or 0.09

3.7 SENSORY ANALYSIS

3.7.1 HEDONIC SENSORY STUDY

A simple liking test was conducted using a nine-point Hedonic scale (1 = Extremely Dislike, 9 = Extremely Like) (see

APPENDIX for a sample Hedonic Sensory ballot). Each of the treatments/replicates was given a random 3-digit number. The given numbers were then completely randomized so that each judge was given 5 samples, and none of those 5 samples were the same number. There were a total of 101 participants.

3.7.2 TRAINED SENSORY PANEL

Eleven volunteer panelists who were students from the university and one volunteer from outside the university participated in four one-hour training sessions where characteristics of the frozen yogurt were discussed and decided on by the panelists. Two commercial frozen yogurt samples were used in training along with the prepared samples for comparison of characteristics. The characteristics were then defined, references chosen for each characteristic, and the panelists were tested for reproducibility. The panelists scored the samples on a ballot by making a vertical line on a 15-cm line with the chosen references, A (3-cm), B (12-cm), or R (7.5-cm) as points on the line (See APPENDIX C for a sample Descriptive Analysis ballot).

3.8 MICROBIOLOGICAL ANALYSIS

Bacterial enumeration of *Streptococcus salivarius* subsp. *Thermophiles, Lactobacillus delbrueckii* subsp. *Bulgaricus*, and *Lactobacillus acidophilus* from the samples was carried out using the pour plate method after the mixture was aged prior to freezing. Media that was used was de Man, Rogosa and Sharpe agar (MRS).

Media preparation

1. Bacteriological peptone diluents were prepared by dissolving 1 gram in 1 L of distilled water, and sterilized at 121^{0}C for 15 min.
2. MRS agar was prepared and sterilized at 120^{0}C for 15 min.

The plates were incubated at 37^{0}C for 72hrs, at which time no growth was noted, so the plates were incubated for an additional 48 hrs, at which time the colonies were counted.

3.9 TEXTURE ANALYSIS

Texture analysis was done using the TX-HDi analyzer that was fitted with a 50 kg load cell and a 4.75mm diameter puncture probe. The penetration speed of the probe was 1 mm/s to a distance of 15mm. Frozen yogurt samples were stored at -20^{0}C before analysis. The hardness of each sample was determined by its peak compression force (N) during the penetration. Stickiness was determined for each sample by its base compression force during retraction of the probe.

3.10 VISCOSITY

The viscosity of the melted frozen yogurt samples was determined at 6 ^{0}C by using a Brookfield TC-602I (Haake Buchler Instruments, Paramus, N.J., USA). Around 20 mL of melted frozen yogurt sample was placed in the cylinder. The viscosity (cP) was measured every 0.6 seconds for 60 seconds at a shear rate of 100 rounds/minute. Reading numbers 25-75 were used for data analysis.

3.11 MELT RATE

Frozen yogurt was allowed to temper overnight in a -15^{0}C freezer before testing. 120 grams of frozen yogurt were weighed and placed on a wire screen (36/cm^{2}), on a funnel that was placed over a pre-weighed cup. The cup collected the melted frozen yogurt at 25^{0}C. The amount of melted frozen yogurt was weighed every 10 minutes to determine the melt rate.

3.12 STATISTICAL ANALYSIS

Analysis of variance was conducted on the data sets using SPSS univariate and Fisher's LSD, alpha set at < 0.05. Pearson's correlation was conducted between gumminess (descriptive analysis), stickiness (texture analysis), and viscosity (instrumental analysis).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 OVERRUN

The target overrun was 80%, the control (mean = 68.5) had a slightly higher overrun (but wasn't significant) than the 3% Frutafit TEX! (mean = 61.6), 5% Frutafit TEX! (mean = 65.3) and 7% Frutafit TEX! (mean = 55.6). The Glucagel® treatments had overrun results that decreased as the concentration of Glucagel® increased, with 7% Glucagel® (mean = 17.9) being the treatment with the lowest overrun. Vitacel SMOOV 240 treatments was the only type of fiber to reach 80% overrun, 3% (mean = 80.1) and 5% (mean = 81.6).[6] The study conducted by Isik and others (2011) stated that the target overrun for their study was also 80%, and their overrun results were 70-78%. In this study, the frozen yogurt samples contained both inulin and isomalt simultaneously at percentages (8.0: 5.0), (6.5: 6.5), (5.0: 8.0), so both additives could have affected the results. The frozen yogurt formula for Isik and others (2011), and the formula used in our study were slightly different so this could also account for the difference in the overrun results for the treatments that contained inulin.

[6] Data for 7% Vitacel SMOOV 240 was unreliable

4.2 PH AND TITRATABLE ACIDITY

There was no significant difference in pH and titratable acidity among the different treatments, and thus the different types of dietary fiber had no effect on pH or titratability acidity. The results are recorded in Table 4.1, and the pH of the frozen yogurt was 5.77. The optimal pH of ice cream type frozen yogurt was found to be 5.5, which resulted in the most acceptable flavor, aftertaste, creaminess, and sweetness values when compared to the results at a pH of 4.5, 5.0 and 6.5 (Inoue and others 1998). According to Ordonez (2000), the target titratable acidity is ~0.30; the average titratable acidity of the treatments before and after freezing was 0.55, even though yogurt was added at 20% of the total weight of the final product.

Table 4.1 PH and Titratable Acidity Means

	Milk*	Milk**	Yogurt	Base	Base + Yogurt +Fiber	Frozen Yogurt
pH	6.67	6.45	4.34	6.56	5.68	5.77
TA					0.55	0.55

* pH of Milk before pasteurization
** pH of Milk after inoculation with yogurt culture, but before incubation

4.3 HEDONIC SENSORY

Each of the individual replicates of the treatments was tested over thirty times. On a scale 1-9 with 1 being “Dislike Extremely” and 9 being “Like Extremely” the average ranking for the control was 6.9 which corresponded to “Like moderately”. 3%

and 5% Frutafit TEX! had means related to "Like Moderately" as well. The mean of 7% Frutafit TEX! treatments was 7.6 which corresponded to "Like Very Much".

3% Glucagel® had a mean of 4.1 which was very close to "Dislike Slightly" on the ballot. 5% and 7% Glucagel® had means that came close to "Dislike Moderately" and "Dislike Very Much".

3% Vitacel SMOOV 240 had a mean similar to the control, and was liked "Moderately". 5% and 7% Vitacel SMOOV 240 had values that corresponded to "Like Slightly" and "Neither Like or Dislike".

The table below, (Table 4.2), summarizes the means of the different treatments and whether the values are significantly from each other. 7% Frutafit TEX! was the only treatment of Frutafit TEX! that was significantly more liked than the control. 5% and 7% Glucagel® were significantly less liked ($P < 0.05$) than the 3% Glucagel®, and 3% Glucagel® was significantly less liked than the control treatment.

Table 4.2 Hedonic Sensory Results (On a Scale of 1-9)*

	LEVEL OF DIETARY FIBER			
TYPE	**0%**	**3%**	**5%**	**7%**
FT!	$6.9 \pm .160^{b}$	$6.9 \pm .160^{b}_{A}$	$6.9 \pm .160^{b}_{A}$	$7.6 \pm .163^{a}_{A}$
GL	$6.9 \pm .160^{a}$	$4.1 \pm .157^{b}_{B}$	$2.5 \pm .160^{c}_{C}$	$2.3 \pm .163^{c}_{C}$
VS 240	$6.9 \pm .160^{a}$	$6.7 \pm .159^{a}_{A}$	$6.0 \pm .162^{b}_{B}$	$5.4 \pm .164^{c}_{B}$

Means with the same Superscript (a,b,c) within a row are not significantly different at $P < 0.05$.
Means with the same Subscript (A,B,C) within a column are not significantly different at $P < 0.05$.
* Average N was 31-36

7% Vitacel SMOOV 240 was significantly less liked than 5% Vitacel SMOOV 240, and the 5% treatment was also less liked than the 3% treatment, and control. 3% Glucagel® was less liked than 3% Frutafit TEX! and Vitacel SMOOV 240 treatments, but there was no significant difference in liking between the values of 3% Frutafit TEX! and 3% Vitacel SMOOV 240.

5% Glucagel® had a considerably ($P < 0.05$) less liked result from 5% Vitacel SMOOV 240 which was also less liked than 5% Frutafit TEX!. All the types of dietary fiber had significantly different results at the 5% level. The treatments at the 7% level had similar results to the 5% level.

The results from the 9-point Hedonic sensory test showed that the 7% Frutafit TEX! treatment received the highest degree of liking of all the treatments. This is consistent with the results of a study that was conducted using yogurt, and supplemented with 0.5%, and 1.5% β-glucan and 2%, and 6% inulin (Brennan and Tudorica 2008). Six percent inulin was more acceptable (mean = 4.6) than 2% inulin (mean= 3.7), 0.5% β-glucan (mean= 4.1), and 1.5% β-glucan (mean= 3.8).

4.4 TRAINED PANEL

Table 4.3 shows the Texture, Flavor, Melting and Other characteristics, definitions and references that the panelists decided to use.

Table 4.3 Texture, Flavor, Melting Characteristics, Definitions, and References Used

TEXTURE CHARACTERISTICS	DEFINITIONS	REFERENCE AND INTENSITY
Iciness	*Size and abundance of ice crystals that do not melt immediately.(Isik and others 2011)* *The measurement needs to be taken right after sample has been placed in the mouth.*	Ice Cream sample made with whole milk (7.5)
Gumminess	*Stringy, gumminess observed on the spoon when scooping, and felt in the mouth.*	0.3% Grindsted IcePro added to Ice cream base (7.5)
Mouth Coating	*Degree of fatty mouth or coated mouth after tasting*	10% heavy cream, 90% whole milk (3) 35% heavy cream, 65% whole milk (12)
Lumpy	*Noticeably different size pieces. Lumps that need chewing.*	Prepared tapioca pudding (7.5)
Chalky	*Powdery coating*	Yerba Prima Great Plains Bentonite Clay (7.5)
FLAVOR CHARACTERISTICS		
Sweetness	*The intensity of sweetness (sucrose-like)*	5% sucrose solution (3) 15% sucrose solution (12)
Milky Flavor	*The intensity of whole milk flavor*	50% whole milk, 50% water (3) Whole milk (12)
Cooked Flavor	*Aromatics reminiscent of heated of processed dairy products, similar to evaporated milk*	UHT-milk (7.5)
Yogurt Flavor	*Sourness, acidity due to the flavor of yogurt*	20% plain yogurt, 80% whole milk (7.5)
Vanilla Flavor	*The flavor of vanilla extract*	5 ml vanilla extract, 480 ml whole milk (7.5)
Caramel	*Caramelized sugar*	5 ml imitation caramel extract, 480 ml whole milk (7.5)

MELTING CHARACTERISTICS		
Watery	*Watery to thick liquid*	Skim milk (3) Heavy whipping cream (12)
Foamy	*Presence of small visible air bubbles*	Whipped cream* (7.5)
OTHER		
Color	*Appearance of frozen yogurt samples as they vary from white to yellow*	Glidden Muslin White WGW40 (3) Glidden Corn Silk WGY04 (12)

* 250 grams of heavy whipping cream, whipped in a KitchenAid Stand Mixer on speed 4, for 13:00 minutes

Table 4.4 shows the results of the Descriptive Sensory Analysis. All the Frutafit TEX! treatments were significantly less icy than the control. The Glucagel® treatments had means of iciness similar to the control. Vitacel SMOOV 240 treatments were significantly less icy than the control, but not different from each other. Addition of inulin decreased iciness in low fat yog-ice cream (El-Nagar and others 2002). Five percent Glucagel® was the only treatment that was significantly less gummy than the control, all other treatments had gumminess results similar to the control. El Nagar and others (2002) stated that the addition of inulin increased the stickiness of yog-ice cream, and this could be due to a gel matrix. In Soukoulis and others (2010), it was found that xanthan gum reduced the coarse, hard, brittle and watery attributes and increased gumminess and creaminess. This study also utilized CMC and HPMC and found that they also decreased the negative attributes and increased gumminess and creaminess, but were less effective than xanthan gum. It was stated that using 0.3-0.4% of hydrocolloids was sufficient to improve the perception of coarseness and decrease hardness. The creaminess of the samples was improve with lower percentages of hydrocolloids, otherwise the higher percentage led to sticky and very thick samples, which is not as desirable (Soukoulis and others 2010). Inulin at 6.7% created a chewiness in reduced fat ice cream that was suggested could mimic sensory perception of a full fat ice cream (Schaller-Povolny and Smith 1999).

Frutafit TEX! treatments all had mouth coating means similar to the control. 7% Glucagel® was similar to the control, but the other two treatments had significantly lower mouth coating results. The 5% and 7% Vitacel SMOOV 240 all significantly higher means than did the control, but 3% was not significantly different from the control or the 7% treatment.

Glucagel® had higher lumpy means (3%- 9.3; 5%- 10.2; 7%-10.4) than the control (mean = 0.7). Frutafit TEX! and Vitacel SMOOV 240 treatments all had similar results for lumpy compared to the control. 7% Vitacel SMOOV 240 was the only treatment that had a significantly higher chalky result (mean = 5.2) than the control (mean = 1.1)

Sweetness increased but not significantly for the Frutafit TEX! treatments. These results are consistent with previous research that demonstrated that inulin did not increase the sweetness perception in reduced fat ice cream (Schaller-Povolny and Smith 1999). In this study, a percentage of sucrose was replaced with corn syrup, then with 50:50 corn syrup and inulin, and lastly with 100% inulin. The 100% inulin (which equated to 6.7% inulin in the mix) decreased the sweetness of the product. Sweetness decreased significantly as the concentration of Glucagel® increased, with the 7% level being slightly sweeter than the 5% level. 7% Vitacel SMOOV 240 was significantly less sweet than the control. The treatments made with Frutafit TEX! had a milky flavor that was similar to the control. For the Glucagel® treatments the milky flavor means decreased, with 5% and 7% having less milky flavor than the control. Vitacel SMOOV 240 did not affect milky flavor.

For the cooked flavor, there was no difference among the treatments. Yogurt flavor decreased significantly with addition of Glucagel®. All the other treatments had similar yogurt flavor to the control.

Vanilla flavor decreased significantly when 5% and 7% Glucagel® was added. The other treatments all had similar vanilla flavor to the control. In a previous study, it was shown that inulin decreased the perception of vanilla flavor when compared to the use of corn syrup (Schaller-Povolny and Smith 1999). This was attributed to the fact that sometimes vanilla flavor and sweetness are hard to discriminate. In our study this would be worthy of note because the trend for both sweetness and vanilla flavors is the same with Glucagel® being the only type of fiber to decrease both flavors. There was no difference between the control and the treatments with fiber for caramel flavor.

The results of the melting characteristics are as follows. These characteristics were observed with the eye only. On the ballot the scale for watery was *thin-thick* with the mean of the control being 6.9, which is very close to the midpoint on the scale. The references used for this characteristic were skim milk at the 3-cm mark and heavy whipping cream at the 12 cm mark, with the thinking that as the number on the scale so did the observed thickness. As the concentration of Frutafit TEX! increased, so did the thickness of the melted sample. The 5% Glucagel® treatment was the thickest sample (mean = 12.8) followed closely by 7% Glucagel® (mean = 12.7).

The results of the Vitacel SMOOV 240 treatments was similar to the Glucagel® treatments. The 3%, 5%, and 7% Frutafit treatments were all significantly thinner than the 3%, 5%, and 7% Glucagel® and Vitacel treatments.

3% Frutafit TEX! and the control were less foamy than did the other Frutafit TEX! treatments. The 3% Glucagel® had a significantly higher foamy mean than did the control and the 5% and 7% Glucagel® treatments. The 7% Glucagel® treatment was less foamy than the control. The Vitacel SMOOV 240 treatments were all similar to the foaminess of the control. Isik and others (2011) found that addition of 6.5% inulin and 6.5% isomalt decreased foaminess of sugar free and reduced fat frozen yogurt. These results were similar to the results of the full fat with sugar control. When the ratio of inulin to isomalt was 8% inulin to 5.0% isomalt and 5% inulin to 8% isomalt the foamy quality increased. So this suggests there is a relationship between the concentration of inulin and isomalt at the 6.5% level since this had the optimal foamy results. In our study, the increase in foaminess for the 5% and 7% Frutafit TEX! treatments could be due to the formation of a viscous gel network, trapping the air bubbles in the melted product.

The color of the melted Frutafit TEX! treatments were all similar to the color of the control. The 7% Glucagel® treatment was significantly darker than the 5% Glucagel® treatment, which was darker than the 3% Glucagel®, which was also darker than the control. The Vitacel SMOOV 240 treatments were similar to the control. Brennan and Tudorica (2008) found very little color differences when they used 0.5-1.5%

β-glucan compared to 2%-6% inulin. This could be a result of the low percentage of β-glucan used in the study.

Table 4.4 Results of the Descriptive Sensory Analysis (Measured in Centimeters)

	Texture Characteristics							
	Iciness				Gummy			
	0%	3%	5%	7%	0%	3%	5%	7%
FT!	$5.6 \pm .406^{a}$	$3.5 \pm .406^{b}_{B}$	$2.6 \pm .412^{b,c}_{B}$	$1.7 \pm .401^{c}_{C}$	$3.0 \pm .442^{a}$	$4.0 \pm .435^{a}_{A}$	$3.4 \pm .442^{a}_{A}$	$4.1 \pm .430^{a}_{A}$
GL	$5.6 \pm .406^{a}$	$5.5 \pm .406^{a}_{A}$	$5.2 \pm .401^{a}_{A}$	$5.4 \pm .406^{a}_{A}$	$3.0 \pm .442^{a}$	$2.0 \pm .442^{a,b}_{B}$	$1.5 \pm .430^{b}_{B}$	$2.3 \pm .435^{a,b}_{B}$
VS 240	$5.6 \pm .406^{a}$	$2.8 \pm .412^{b}_{B}$	$3.3 \pm .406^{b}_{B}$	$3.4 \pm .406^{b}_{B}$	$3.0 \pm .442^{a}$	$3.4 \pm .442^{a}_{A}$	$3.1 \pm .435^{a}_{A}$	$2.5 \pm .435^{a}_{B}$

	Texture Characteristics							
	Mouth Coating				Lumpy			
	0%	3%	5%	7%	0%	3%	5%	7%
FT!	$5.6 \pm .631^{a}$	$5.1 \pm .631^{a}_{A}$	$5.0 \pm .641^{a}_{B}$	$6.1 \pm .633^{a}_{A}$	$0.7 \pm .421^{a}$	$1.3 \pm .421^{a}_{B}$	$1.1 \pm .428^{a}_{B}$	$0.7 \pm .416^{a}_{B}$
GL	$5.6 \pm .631^{a}$	$3.2 \pm .631^{b}_{B}$	$2.8 \pm .623^{b}_{C}$	$3.9 \pm .661^{a,b}_{B}$	$0.7 \pm .421^{b}$	$9.3 \pm .421^{a}_{A}$	$10.2 \pm .416^{a}_{A}$	$10.4 \pm .421^{a}_{A}$
VS 240	$5.6 \pm .631^{b}$	$6.4 \pm .641^{a,b}_{A}$	$7.7 \pm .631^{a}_{A}$	$7.6 \pm .631^{a}_{A}$	$0.7 \pm .421^{a}$	$0.7 \pm .428^{a}_{B}$	$0.7 \pm .421^{a}_{B}$	$0.8 \pm .421^{a}_{B}$

	Texture Characteristics				Flavor Characteristics			
	Chalky				Sweetness			
	0%	3%	5%	7%	0%	3%	5%	7%
FT!	$1.1 \pm .450^{a,b}$	$1.8 \pm 0.450^{a,b}_{A}$	$2.0 \pm .457^{a}_{A}$	$0.7 \pm .444^{b}_{C}$	$6.5 \pm .441^{a}$	$6.3 \pm .441^{a}_{A}$	$7.4 \pm .448^{a}_{A}$	$7.0 \pm .436^{a}_{A}$
GL	$1.1 \pm .450^{a}$	$1.7 \pm .450^{a}_{A}$	$2.1 \pm .444^{a}_{A}$	$2.0 \pm .450^{a}_{B}$	$6.5 \pm .441^{a}$	$5.1 \pm .448^{b}_{A}$	$3.5 \pm .436^{c}_{C}$	$4.2 \pm .441^{b,c}_{B}$
VS 240	$1.1 \pm .450^{c}$	$1.9 \pm .457^{c}_{A}$	$3.2 \pm .450^{b}_{A}$	$5.2 \pm .450^{a}_{A}$	$6.5 \pm .441^{a}$	$6.2 \pm .448^{a}_{A}$	$5.7 \pm .441^{a,b}_{B}$	$5.0 \pm .441^{b}_{B}$

Means with the same Superscript (a,b,c) within a row are not significantly different at $P < 0.05$.
Means with the same Subscript (A,B,C) within a column are not significantly different at $P < 0.05$.

Table 4.4 Results of the Descriptive Sensory Analysis (Continued).

	Flavor Characteristics							
	Milky				Cooked			
	0%	3%	5%	7%	0%	3%	5%	7%
FT!	$5.4 \pm .512^{a}$	$4.5 \pm .512^{a}_{B}$	$5.7 \pm .519^{a}_{A}$	$5.8 \pm .505^{a}_{A}$	$1.7 \pm .397^{a}$	$1.8 \pm .397^{a}_{A}$	$1.7 \pm .403^{a}_{A}$	$1.8 \pm .392^{a}_{A}$
GL	$5.4 \pm .512^{a}$	$4.7 \pm .512^{a,b}_{A,B}$	$3.2 \pm .505^{c}_{B}$	$3.5 \pm .512^{b,c}_{B}$	$1.7 \pm .397^{a}$	$1.8 \pm .397^{a}_{A}$	$2.2 \pm .392^{a}_{A}$	$2.2 \pm .397^{a}_{A}$
VS 240	$5.4 \pm .512^{a}$	$6.1 \pm .519^{a}_{A}$	$5.8 \pm .512^{a}_{A}$	$4.9 \pm .519^{a}_{A}$	$1.7 \pm .397^{a}$	$1.8 \pm .403^{a}_{A}$	$2.1 \pm .397^{a}_{A}$	$1.9 \pm .397^{a}_{A}$
	Flavor Characteristics							
	Yogurt				Vanilla			
	0%	3%	5%	7%	0%	3%	5%	7%
FT!	$3.3 \pm .452^{a}$	$2.9 \pm .452^{a}_{A,B}$	$2.8 \pm .459^{a}_{A}$	$3.0 \pm .447^{a}_{A}$	$5.2 \pm .555^{a}$	$5.3 \pm .555^{a}_{A}$	$4.8 \pm .563^{a}_{A}$	$5.7 \pm .548^{a}_{A}$
GL	$3.3 \pm .452^{a}$	$1.7 \pm .452^{b}_{B}$	$1.1 \pm .447^{b}_{B}$	$1.4 \pm .452^{b}_{B}$	$5.2 \pm .555^{a}$	$4.3 \pm .555^{a,b}_{A}$	$3.4 \pm .548^{b}_{A}$	$3.1 \pm .563^{b}_{B}$
VS 240	$3.3 \pm .452^{a}$	$3.0 \pm .459^{a}_{A}$	$3.0 \pm .459^{a}_{A}$	$2.7 \pm .459^{a}_{A}$	$5.2 \pm .555^{a}$	$4.6 \pm .563^{a}_{A}$	$4.6 \pm .555^{a}_{A}$	$5.1 \pm .555^{a}_{A}$
	Flavor Characteristics				Melting Characteristics			
	Caramel				Watery			
	0%	3%	5%	7%	0%	3%	5%	7%
FT!	$1.3 \pm .337^{a}$	$1.2 \pm .337^{a}_{A}$	$1.1 \pm .342^{a}_{A}$	$1.5 \pm .332^{a}_{A}$	$6.9 \pm .516^{c}$	$8.7 \pm .524^{b}_{B}$	$10.0 \pm .524^{a}_{B}$	$10.6 \pm .510^{a}_{B}$
GL	$1.3 \pm .337^{a}$	$0.9 \pm .337^{a}_{A}$	$0.9 \pm .332^{a}_{A}$	$1.2 \pm .337^{a}_{A}$	$6.9 \pm .516^{b}$	$11.4 \pm .516^{a}_{A}$	$12.8 \pm .510^{a}_{A}$	$12.7 \pm .516^{a}_{A}$
VS 240	$1.3 \pm .337^{a}$	$0.9 \pm .342^{a}_{A}$	$1.1 \pm .337^{a}_{A}$	$0.9 \pm .337^{a}_{A}$	$6.9 \pm .516^{b}$	$11.8 \pm .524^{a}_{A}$	$12.6 \pm .516^{a}_{A}$	$12.2 \pm .516^{a}_{A}$

Means with the same Superscript (a,b,c) within a row are not significantly different at $P < 0.05$.
Means with the same Subscript (A,B,C) within a column are not significantly different at $P < 0.05$.

Table 4.5 Results of the Descriptive Sensory Analysis (Continued).

	Melting Characteristics				Other			
	Foamy				Color			
	0%	3%	5%	7%	0%	3%	5%	7%
FT!	$3.3 \pm .458^{b}$	$2.1 \pm .458^{b}_{B}$	$3.8 \pm .465^{a}_{A}$	$4.6 \pm .452^{a}_{A}$	$3.8 \pm .279^{a}$	$3.7 \pm .279^{a}_{B}$	$3.6 \pm .283^{a}_{B}$	$3.8 \pm .275^{a}_{B}$
GL	$3.3 \pm .458^{b}$	$4.8 \pm .458^{a}_{A}$	$2.3 \pm .452^{b,c}_{B}$	$1.5 \pm .458^{c}_{B}$	$3.8 \pm .279^{d}$	$4.8 \pm .279^{c}_{A}$	$6.2 \pm .275^{b}_{A}$	$7.5 \pm .279^{a}_{A}$
VS 240	$3.3 \pm .458^{a}$	$3.7 \pm .465^{a}_{A}$	$3.8 \pm .465^{a}_{A}$	$3.5 \pm .458^{a}_{A}$	$3.8 \pm .279^{a}$	$3.6 \pm .283^{a}_{B}$	$4.3 \pm .279^{a}_{B}$	$3.8 \pm .283^{a}_{B}$

Means with the same Superscript (a,b,c) within a row are not significantly different at $P < 0.05$.
Means with the same Subscript (A,B,C) within a column are not significantly different at $P < 0.05$.

4.5 MICROBIOLOGY

There was no significant difference in bacterial counts between the treatments with fiber and the control (mean = 7.9 x10^7 CFU/ml) in the mix before it was frozen.

4.6 TEXTURE ANALYSIS

Texture analysis was conducted on all treatments to measure the hardness and stickiness of each treatment. The quart samples (5-6 for each treatment) were transferred from a walk-in freezer set at -20ºC to a chest freezer (-20ºC) 12 hours prior to analysis. Each quart sample was placed on the Tx-HDi, and 3-4 punctures were done for each quart. After the quart was removed from the analyzer the temperature of the punctures were measured at -20ºC. The results for each quart were averaged and then the data was analyzed. Table 4.5 below shows the results of the Fisher's LSD test. 3% Frutafit TEX! was the hardest Frutafit TEX! level but it was not harder than the control or the 5% level. 7% Frutafit was the softest of the Frutafit TEX! treatments. El Nagar and others (2002), found the low fat control was harder than treatments that contained 5% and 7% inulin.

The hardness of 3% Glucagel® treatment was similar to the control, but 5% Glucagel® was much harder than the control and the 3% Glucagel® treatment. 7% Glucagel® was the hardest of all the treatments. The control was not different from any of the Vitacel SMOOV 240 treatments, however 3% Vitacel SMOOV was the softest treatment and 5% and 7% Vitacel SMOOV 240 were similar but slightly harder than the control.

For the 3% treatments, Vitacel SMOOV 240 was softer than the 3% Frutafit TEX! treatment. 3% Glucagel® was not different from either of the other fibers at the 3% level. 5% Glucagel® was significantly harder than 5% Frutafit TEX! and Vitacel SMOOV 240. 7% Glucagel® was also significantly harder than 7% Vitacel SMOOV 240, which in turn was harder than 7% Frutafit TEX!.

Table 4.5 Hardness Results (Grams of Force)*

	LEVEL OF DIETARY FIBER			
TYPE	**0%**	**3%**	**5%**	**7%**
FT!	$25057.89 \pm 2398.72^{a,b}$	$27473.62 \pm 2261.54^{a}_{A}$	$24140.81 \pm 2331.14^{a,b}_{B}$	$19886.82 \pm 2261.54^{b}_{C}$
GL	25057.89 ± 2398.72^{c}	$21892.16 \pm 2331.14^{c}_{A,B}$	$41867.41 \pm 2398.72^{b}_{A}$	$56174.50 \pm 2331.14^{a}_{A}$
VS 240	$25057.89 \pm 2398.72^{a,b}$	$18790.24 \pm 2210.48^{b}_{B}$	$293667.70 \pm 2331.14^{a}_{B}$	$29734.37 \pm 2331.14^{a}_{B}$

Means with the same Superscript (a,b,c) within a row are not significantly different at P < 0.05.
Means with the same Subscript (A,B,C) within a column are not significantly different at P < 0.05.
* Average N was 5-6

The results above show that increasing the concentration of Frutafit TEX! decreased the hardness of the sample but the decrease was only significant at the 7% level. This was somewhat contrary to the results of El Nagar and others (2002) which showed that increasing the percentage of inulin in yog-ice cream steadily increased the hardness. However, at the 5% level the hardness was significantly lower when compared to the low fat control, and the 7% and 9% levels were still somewhat less hard than the control (El-Nagar and others 2002). This could be due to the fact that in El Nagar and others (2002), the percentage of sugar was 14% in the frozen yogurt, and in our study it was 17.73%. The fat contents of both studies were similar; 5% in El Nagar and others (2002) and 4.94% in our study. The hardness of ice creams and frozen yogurt is inversely related to the fat and sugar content (Guinard and others 1997). However, the difference between our study and El Nagar and others (2002) is most likely due to the fact that they allowed their samples to temper for 10 minutes at room temperature before analysis.

Table 4.6 (below) show the stickiness results. 7% Frutafit TEX! was the least sticky of all the Frutafit Tex! treatments. 3% Frutafit TEX! was stickier than the 7% but not different from the control or the 5% level. 5% Frutafit TEX! was the stickiest of the Frutafit TEX! treatments. These results differ with the results of El Nagar and others (2002), which showed that at 7% level of inulin, stickiness was much higher than the control low fat yog-ice cream. This inconsistency could be due to the fact that El Nagar and others (2002) allowed their samples temper at room temperature for 10 minutes, and in our study the measurement was taken immediately after removal from the chest freezer.

3% Glucagel® had a similar stickiness to the control. The stickiness drastically increased at the 5% level, which similar to the 7% level. The 7% level of Glucagel® was the stickiest treatment of all. 3% Vitacel SMOOV 240 was the least sticky treatment over all. 5% Vitacel SMOOV 240 was stickier than the control but not as sticky as 7% Vitacel

SMOOV 240. The control and 3% Vitacel SMOOV 240 were also similar in stickiness. For treatments that contained Glucagel® and Vitacel SMOOV 240, the stickiness value appeared to increase as the percentage of Vitacel SMOOV 240 increased. The stickiness increased with the 3% and 5% Frutafit TEX! treatments then dropped as the concentration of inulin increased to 7%.

Table 4.6 Stickiness Results (Grams of Force)*

	LEVEL OF DIETARY FIBER			
TYPE	**0%**	**3%**	**5%**	**7%**
FT!	-1221.05 ± 159.13^{b}	$-1626.80 \pm 150.02^{a,b}_{A}$	$-1793.49 \pm 154.64^{a}_{B}$	$-1360.77 \pm 150.02^{b}_{C}$
GL	-1221.05 ± 159.13^{b}	$-1283.02 \pm 154.64^{b}_{A,B}$	$-2993.32 \pm 159.13^{a}_{A}$	$-3099.49 \pm 154.64^{a}_{A}$
VS 240	-1221.05 ± 159.13^{b}	$-919.64 \pm 146.64^{b}_{B}$	$-1798.62 \pm 154.64^{a}_{B}$	$-1823.67 \pm 154.64^{a}_{B}$

Means with the same Superscript (a,b,c) within a row are not significantly different at P < 0.05.
Means with the same Subscript (A,B,C) within a column are not significantly different at P < 0.05.
* Average N was 5-6

3% Glucagel® and Frutafit TEX! were not as sticky as 3% Vitacel SMOOV 240. 5% Frutafit TEX! was the least sticky of the treatments that contained 5% fiber. The 7% treatments were all different with the Frutafit TEX! treatment being the stickiest and the Vitacel SMOOV 240 treatment being the least sticky.

4.7 VISCOSITY

Samples of each treatment were melted (about 20 mL), and stirred prior to analysis with the viscometer set at 6ºC. The results of the viscosity test (Table 4.7) showed that of the treatments containing Frutafit TEX! 5% had the highest viscosity (95.0 cP). This was significantly higher than the 3% and 7% levels. The 3% and 7% levels had significantly higher viscosities than did the control.

Of the Glucagel® treatments, the only level that could be analyzed for viscosity was the 3% level. The 5% and 7% levels could not be tested for viscosity due to their gel-like structures. The 3% treatments had a significantly higher viscosity than did the control, and had the highest viscosity of all the treatments.

7% Vitacel SMOOV 240 had the highest viscosity of the Vitacel SMOOV 240 treatments. It was significantly higher than the 5% level, and the 5% level was thicker than the 3% level. The 3% level was also thicker than the control.

At the 3% level, the treatments containing Glucagel®, had a significantly higher viscosity than did the Vitacel SMOOV 240 treatments, which in turn was thicker than the Frutafit TEX! treatments. Vitacel SMOOV 240 had significantly higher viscosities at the 5% and 7% levels than did the Frutafit TEX! treatments.

The results for the inulin treatments are consistent with the literature that showed the addition of inulin significantly increased the viscosity of frozen yogurt and ice cream (El-Nagar and others 2002; Schaller-Povolny and Smith 2001; Isik and others 2011). According to Soukoulis and others (2009), the increase in viscosity in the treatments that contained inulin was due to water retention by the soluble fibers. The increase in viscosity for the Vitacel SMOOV 240 treatments could be a result of milk protein interaction with the fiber (Brennan and Tudorica 2008), or "the synergistic effect of both soluble and insoluble fibres" (Soukoulis and others 2009). The study conducted by Brennan and Tudorica (2008), showed that Glucagel® significantly increased the viscosity of fat free yogurt, though 2.5% was the highest concentration used.

Table 4.7 Results of Viscosity (centiPose)*,**

	LEVELS OF DIETARY FIBER			
TYPE	**0%**	**3%**	**5%**	**7%**
FT!	26.8 ± 1.097^{c}	$79.1 \pm 1.164^{b}_{C}$	$95.0 \pm 1.026^{a}_{B}$	$81.2 \pm 1.164^{b}_{B}$
GL	26.8 ± 1.097^{b}	$241.6 \pm 1.097^{a}_{A}$	---	---
VS 240	26.8 ± 1.097^{d}	$112.8 \pm 1.164^{c}_{B}$	$180.2 \pm 1.164^{b}_{A}$	$200.1 \pm 1.164^{a}_{A}$

Means with the same Superscript (a,b,c) within a row are not significantly different at P < 0.05.
Means with the same Subscript (A,B,C) within a column are not significantly different at P < 0.05.

* 5% and 7% Glucagel® were unable to be analyzed due to gel-like structure
** Average N was 2-3

4.8 MELT RATE

Table 4.8 shows the results from the melt rate test, and the results have been calculated in percent melted per minute. 3% Frutafit TEX! had a significantly higher rate of melt (Table 4.8) than did the control, and 5% levels of Frutafit TEX!. The 7% treatments of Frutafit TEX! had a rate of melt that was similar to the 5% or 3% Frutafit TEX!.

The treatments that contained Glucagel® had signficantly lower rate of melt that did the control. All the Glucagel® treatments had similar melt rates . The 7% level of Glucagel® did not melt at all.

Table 4.8 Meltrate Results (Percentage Melted Per Minute)*

	LEVEL OF DIETARY FIBER			
TYPE	**0%**	**3%**	**5%**	**7%**
FT!	$0.847 \pm .023^{b,c}$	$0.964 \pm .023^{a}_{A}$	$0.806 \pm .023^{c}_{A}$	$0.891 \pm .023^{b}_{A}$
GL	$0.847 \pm .023^{a}$	$0.057 \pm .023^{b}_{B}$	$0.001 \pm .023^{b}_{B}$	$0.000 \pm .023^{b}_{B}$
VS 240	$0.847 \pm .023^{a}$	$0.079 \pm .023^{b}_{B}$	$0.030 \pm .023^{b}_{B}$	$0.035 \pm .023^{b}_{B}$

Means with the same Superscript (a,b,c) within a row are not significantly different at P < 0.05.
Means with the same Subscript (A,B,C) within a column are not significantly different at P < 0.05.
*Average N was 2

The control had a significantly higher rate of melt than did any of the Vitacel SMOOV 240 treatments. At the 3%, 5%, and 7% levels, Frutafit TEX! had a higher rate of melt than did either Glucagel® and Vitacel SMOOV 240. Figures 4.1-4.3 below are graphs of the percent melted over time. In the graphs, the Frutafit TEX! treatments most closely resemble the control, which is consistent with the results of the study conducted by Isik and others (2011). The Vitacel SMOOV 240 and Glucagel® treatments show very low melt rates. The results of the cellulose treatments were consistent with the results that were found in Soukoulis and others (2010), which stated that CMC and HPMC decreased the melt rate, even though in this study CMC and HPMC were used at 0.2-0.4% which was much lower than in our study.

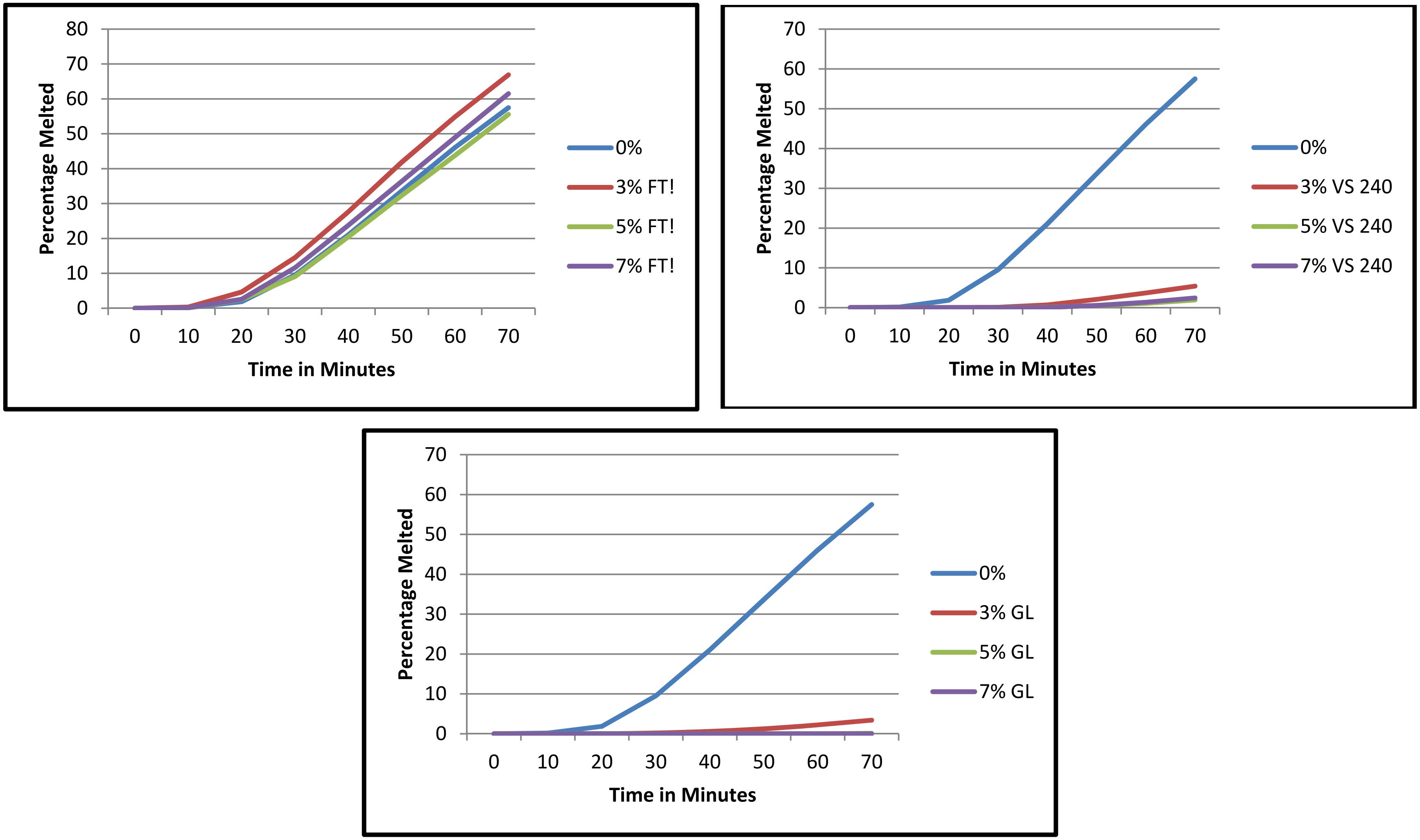


Figure 4.1 Percent of Treatment Melted Over Time in Minutes versus Control. Frutafit TEX! (Top Left), Vitacel SMOOV 240 (Top Right), Glucagel® (Bottom)

Pearson correlations were tested between gumminess (descriptive analysis), stickiness (texture analysis) and viscosity (instrumental analysis). Table 4.9 below shows the results. There were no significant correlations.

Table 4.9 Pearson's Correlation Coefficients and Significance for Gummy, Sticky, and Viscosity

	Gummy	Sig.	Sticky	Sig.	Viscosity	Sig.
Gummy	1.000	.000	0.320	.085	-0.353	.091
Sticky	0.320	.085	1.000	.000	.015	.944
Viscosity	-0.353	.091	.015	.944	1.000	.000

Overall, frozen yogurt samples that contained Frutafit TEX! were the most liked treatments. Inulin did not decrease the sweetness, vanilla or yogurt flavor. These treatments were less icy than the frozen yogurt that contained no fiber. Inulin was shown to create a more viscous melted sample than the control, which could account for the decrease in iciness due to binding of water and creating a gel network. It was miscible in the frozen yogurt mix thus there were little to no lumps, creating a smooth result. It had a very low chalky texture result, and the inulin did not change the color of the samples. The overrun was slightly lower for the inulin samples than for the control. While the viscosity for the inulin samples was higher than the control, the 5% sample had the highest overrun and the highest viscosity, with both results dropping as the percentage increased to 7%. After the initial increase of hardness with the 3% addition of inulin, the hardness decreased as the percentage of inulin increased. The 5% inulin sample had the highest overrun, viscosity, and stickiness and the lowest meltrate of the Frutafit TEX! treatments. The results of the meltrate, stickiness and viscosity tests for the Frutafit TEX! fiber seem to show an inverse relationship of viscosity and stickiness to meltrate. The results seem to show that at the 5% level inulin had created the strongest gel network, and at 7% level the inulin had super saturated the mix and therefore the network was not as strong leading to a higher meltrate, lower viscosity, overrun and hardness.

Samples made with Glucagel® were disliked by consumers. Glucagel® decreased the sweetness, vanilla, yogurt, and milky flavors, and drastically increased the lumpy texture. The color was also affected, so instead of off-white like the other treatments and the control, Glucagel® created a frozen yogurt sample that was tan to brown in color. The appearance, texture and flavor strongly affected consumer acceptance. Glucagel® was highly viscous (3% being the most viscous of all treatments). The overrun was decreased as the percentage of Glucagel® increased. The hardness initially decreased at the 3% level when compared to the control, but then severely increased at 5% and 7% levels. The stickiness reflected the results of the hardness, though at the 3% level the stickiness was similar to the control. The 7% level of Glucagel® was the stickiest sample and hardest sample. If the 5% and 7% levels were able to analyzed for viscosity, the hardness, stickiness and viscosity would most likely reflect one another. The meltrate was also very low to non-existent for these treatments. Glucagel® created a very strong gel network that negatively affected the overrun, meltrate, hardness, stickiness and viscosity of the frozen yogurt.

Frozen yogurt samples made with Vitacel SMOOV 240 was liked moderately, or neither liked nor disliked. Samples that contained Vitacel SMOOV 240 had an overrun of ~80% which was the target overrun. Vitacel SMOOV 240 increased the chalky texture which was undesirable which could account for the lower rating for simple liking results.

Iciness was decreased but not as much as Frutafit TEX! decreased the iciness. The sweetness was decreased at the 7% level, but there was no effect on the vanilla and yogurt flavors. There was an initial decrease in hardness at the 3% level when compared to the control, but an increase at the 5% and 7% levels, though similar to the control in hardness. The stickiness results reflected those of the hardness test, with the 3% level being the least sticky treatment of all. The viscosity was much higher than the inulin, and steadily increased as the concentration of Vitacel SMOOV 240 increased. The meltrate was greatly affected by Vitacel SMOOV 240 and was very low. The difference in these results compared to the inulin and betaglucan results could be reflective of the fact that both of those fibers were soluble and Vitacel SMOOV 240 was mostly insoluble. The Vitacel SMOOV 240 could have created an ionic bond with casein at it's isoelectric point (pH 3.0-5.5) which would have resulted in a strong network creation. This could have effected the viscosity, and meltrate results, but not strongly effected the hardness and stickiness results. This high viscosity network could be the reason for the decrease in iciness, and the increase in overrun.

CHAPTER 5

SUMMARY AND CONCLUSION

The goal of this study was to create a frozen yogurt product that is a good source of dietary fiber and acceptable to consumers. To be considered an "Excellent Source" of fiber, the product must contain 5 grams (20%) of fiber per serving, while a product that would be a "Good Source" would contain 2.5-4.75 grams (10-19%) of fiber per serving. Of the treatments in this study that contained 3% fiber, all had 2 grams (8%) of the Recommended Daily Intake, which was not enough to be considered for a "Good Source" claim. All 5% treatments contained 3 grams (12%) of fiber per serving, which qualifies for a "Good Source" claim. 7% Frutafit TEX! and 7% Vitacel SMOOV 240 contained 5 grams (20%) of fiber per serving which allows the claim of "Excellent Source". The 7% Glucagel® treatment only contained 4 grams (16%) of fiber, which still classifies it as a "Good Source". The Glucagel® product was only 75.6% dietary fiber, whereas Frutafit TEX! and Vitacel SMOOV 240 were at least 94.7% fiber. (See Appendix B for frozen yogurt treatment nutrition labels and nutrition information).

The Frutafit TEX! treatments were the most liked, followed by the Vitacel SMOOV 240, and the Glucagel® treatments were generally disliked. The 7% Frutafit TEX! treatment was the most liked treatment. The Descriptive Analysis showed that 7% Frutafit TEX! was thicker, more gummy and foamy, and less icy than the control. The treatments that contained Glucagel® were also thicker than the control, very lumpy, had decreased sweetness, vanilla and yogurt flavor, and the color was much darker. Vitacel SMOOV 240 resulted in samples that were thicker than the control, less icy, increased mouthcoating and chalky levels.

7% Frutafit TEX! was not as hard as the control, and the rest of Frutafit TEX! treatments were similar to the control. Vitacel SMOOV 240 was slightly harder than the control and the Glucagel® treatments were much harder than the control. 7% Frutafit TEX! was the stickiest treatment and 7% Vitacel SMOOV 240 was the least sticky.

All the treatments had a much higher viscosity than the control, but Frutafit TEX! was the lowest of the treatments. Vitacel SMOOV 240 had viscosities that were very high and this may have been due to the fact that at pH values between 3.0-5.5, cellulose creates a very high viscosity gel with casein in milk. Though the pH of the mixes were slightly above 5.5, this may still have been a factor. Glucagel® formed a gel-like network when combined with the mix, so only the lowest concentration could be tested for viscosity.

The melt rate data showed similar results to the viscosity data, with 3% Frutafit TEX! having the highest rate of melt, and the Vitacel SMOOV 240, and Glucagel® treatments having extremely low to non-existent rate of melts.

While betaglucans have excellent health benefits associated with consumption, in this study, the use of Glucagel® did not result in a frozen yogurt product that was acceptable to consumers. Glucagel® may be better used in whole wheat baked goods so it would not affect the color and texture as much as it did in dairy products. Also, the process of producing Glucagel® eliminated many of the health benefits for which betaglucan is known. A different betaglucan product may have been more successful in this study than Glucagel®, one that may have had a lower fiber content, so it may have been less likely to gel and lump.

Vitacel SMOOV 240 treatments were more acceptable overall than the Glucagel® treatments. The overrun of the Vitacel SMOOV 240 treatments was closest to the target of 80%. As the concentration of fiber increased it became apparent that the cellulose fiber had a higher mouthcoating value than did the control, and was considerably more chalky. The cellulose treatments may have had better results if the frozen yogurt was a different flavor, such as chocolate or strawberry.

Frutafit TEX! treatments had overrun results that were less than the control. The 7% treatment was the most liked of all the treatments, so Frutafit TEX! could be used at the 7% level to produce a well-liked frozen yogurt product that is an excellent source of dietary fiber. If a higher overrun would be desired, possibly more research could be done by incorporating some cellulose (in the form of Vitacel SMOOV 240) into the mix which may result in a more well-liked product that contained both soluble and insoluble dietary fiber.

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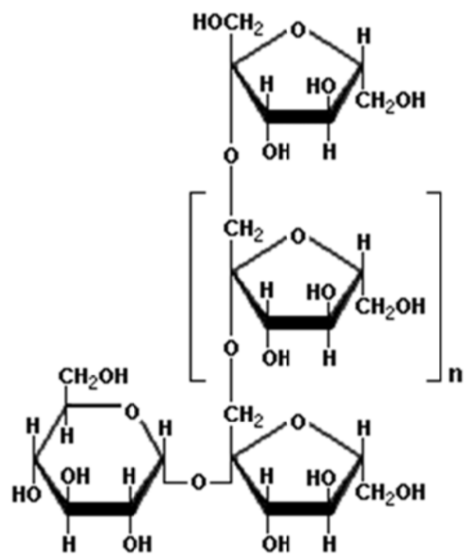
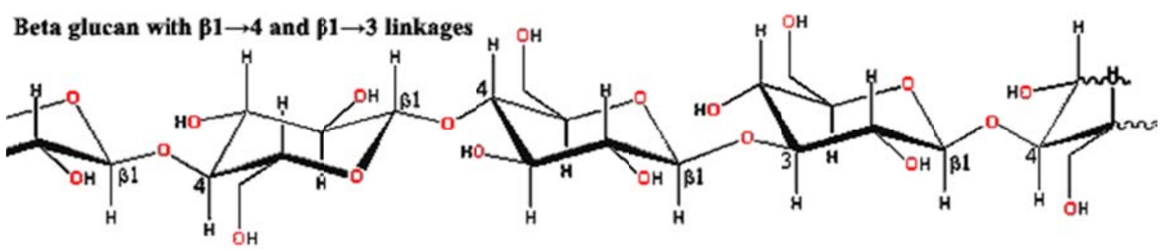
APPENDIX A

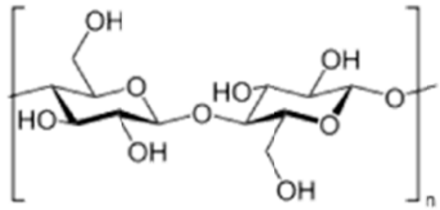
- **Structure of Inulin**
- **Structure of Betaglucan**
- **Structure of Cellulose**



Molecular Structure of Inulin



Molecular Structure of Betaglucan



Molecular Structure of Cellulose

APPENDIX B

- **Nutrition Labels for all Treatments**
- **Nutrition Information Per Serving, and Per 100 grams for all Treatments**

Nutrition Facts

Serving Size (72g)
Servings Per Container

Amount Per Serving

Calories 100 Calories from Fat 30

	% Daily Value*
Total Fat 3.5g	**5%**
Saturated Fat 2g	**10%**
Trans Fat 0g	
Cholesterol 15mg	**5%**
Sodium 45mg	**2%**
Total Carbohydrate 15g	**5%**
Dietary Fiber 0g	**0%**
Sugars 12g	
Protein 2g	

Vitamin A 8% • Vitamin C 2%

Calcium 15% • Iron 0%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Saturated Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

Nutrition Label for Control Treatment

Nutrition Labels for Frozen Yogurt Treatments Containing Frutafit TEX!, 3%(Left), 5%(Middle), 7%(Right)

Nutrition Facts

Serving Size (72g)
Servings Per Container

Amount Per Serving

Calories 100 Calories from Fat 30

	% Daily Value*
Total Fat 3.5g	**5%**
Saturated Fat 2g	**10%**
Trans Fat 0g	
Cholesterol 15mg	**5%**
Sodium 45mg	**2%**
Total Carbohydrate 17g	**6%**
Dietary Fiber 2g	**8%**
Sugars 12g	
Protein 2g	

Vitamin A 6% • Vitamin C 2%
Calcium 10% • Iron 0%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Saturated Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram
Fat 9 • Carbohydrate 4 • Protein 4

Nutrition Facts

Serving Size (72g)
Servings Per Container

Amount Per Serving

Calories 100 Calories from Fat 30

	% Daily Value*
Total Fat 3.5g	**5%**
Saturated Fat 2g	**10%**
Trans Fat 0g	
Cholesterol 15mg	**5%**
Sodium 40mg	**2%**
Total Carbohydrate 18g	**6%**
Dietary Fiber 3g	**12%**
Sugars 11g	
Protein 2g	

Vitamin A 6% • Vitamin C 2%
Calcium 10% • Iron 0%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Saturated Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram
Fat 9 • Carbohydrate 4 • Protein 4

Nutrition Facts

Serving Size (72g)
Servings Per Container

Amount Per Serving

Calories 100 Calories from Fat 30

	% Daily Value*
Total Fat 3.5g	**5%**
Saturated Fat 2g	**10%**
Trans Fat 0g	
Cholesterol 15mg	**5%**
Sodium 40mg	**2%**
Total Carbohydrate 19g	**6%**
Dietary Fiber 5g	**20%**
Sugars 11g	
Protein 2g	

Vitamin A 6% • Vitamin C 2%
Calcium 10% • Iron 0%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Saturated Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram
Fat 9 • Carbohydrate 4 • Protein 4

Nutrition Labels for Frozen Yogurt Treatments Containing Vitacel SMOOV 240, 3%(Left), 5%(Middle),7%(Right)

Nutrition Facts (3%, Left)

Serving Size (72g)
Servings Per Container

Amount Per Serving

Calories 100	Calories from Fat 30
	% Daily Value*
Total Fat 3.5g	**5%**
Saturated Fat 2g	**10%**
Trans Fat 0g	
Cholesterol 15mg	**5%**
Sodium 40mg	**2%**
Total Carbohydrate 17g	**6%**
Dietary Fiber 2g	**8%**
Sugars 12g	
Protein 2g	
Vitamin A 6%	• Vitamin C 2%
Calcium 15%	• Iron 0%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

		Calories	2,000	2,500
Total Fat	Less than		65g	80g
Saturated Fat	Less than		20g	25g
Cholesterol	Less than		300mg	300mg
Sodium	Less than		2,400mg	2,400mg
Total Carbohydrate			300g	375g
Dietary Fiber			25g	30g

Calories per gram
Fat 9 • Carbohydrate 4 • Protein 4

Nutrition Facts (5%, Middle)

Serving Size (72g)
Servings Per Container

Amount Per Serving

Calories 100	Calories from Fat 30
	% Daily Value*
Total Fat 3.5g	**5%**
Saturated Fat 2g	**10%**
Trans Fat 0g	
Cholesterol 15mg	**5%**
Sodium 40mg	**2%**
Total Carbohydrate 18g	**6%**
Dietary Fiber 3g	**12%**
Sugars 11g	
Protein 2g	
Vitamin A 6%	• Vitamin C 2%
Calcium 10%	• Iron 0%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

		Calories	2,000	2,500
Total Fat	Less than		65g	80g
Saturated Fat	Less than		20g	25g
Cholesterol	Less than		300mg	300mg
Sodium	Less than		2,400mg	2,400mg
Total Carbohydrate			300g	375g
Dietary Fiber			25g	30g

Calories per gram
Fat 9 • Carbohydrate 4 • Protein 4

Nutrition Facts (7%, Right)

Serving Size (72g)
Servings Per Container

Amount Per Serving

Calories 100	Calories from Fat 30
	% Daily Value*
Total Fat 3.5g	**5%**
Saturated Fat 2g	**10%**
Trans Fat 0g	
Cholesterol 15mg	**5%**
Sodium 40mg	**2%**
Total Carbohydrate 19g	**6%**
Dietary Fiber 5g	**20%**
Sugars 11g	
Protein 2g	
Vitamin A 6%	• Vitamin C 2%
Calcium 10%	• Iron 0%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

		Calories	2,000	2,500
Total Fat	Less than		65g	80g
Saturated Fat	Less than		20g	25g
Cholesterol	Less than		300mg	300mg
Sodium	Less than		2,400mg	2,400mg
Total Carbohydrate			300g	375g
Dietary Fiber			25g	30g

Calories per gram
Fat 9 • Carbohydrate 4 • Protein 4

Nutrition Labels for Frozen Yogurt Treatments Containing Glucagel®, 3%(Left), 5%(Middle), 7%(Right)

Nutrition Facts (3%, Left)

Serving Size (72g)
Servings Per Container

Amount Per Serving

Calories 100 Calories from Fat 30

	% Daily Value*
Total Fat 3.5g	5%
Saturated Fat 2g	10%
Trans Fat 0g	
Cholesterol 15mg	5%
Sodium 40mg	2%
Total Carbohydrate 15g	5%
Dietary Fiber 2g	8%
Sugars 12g	
Protein 2g	

Vitamin A 6% • Vitamin C 2%
Calcium 10% • Iron 0%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

		Calories	2,000	2,500
Total Fat	Less than		65g	80g
Saturated Fat	Less than		20g	25g
Cholesterol	Less than		300mg	300mg
Sodium	Less than		2,400mg	2,400mg
Total Carbohydrate			300g	375g
Dietary Fiber			25g	30g

Calories per gram
Fat 9 • Carbohydrate 4 • Protein 4

Nutrition Facts (5%, Middle)

Serving Size (72g)
Servings Per Container

Amount Per Serving

Calories 100 Calories from Fat 30

	% Daily Value*
Total Fat 3.5g	5%
Saturated Fat 2g	10%
Trans Fat 0g	
Cholesterol 15mg	5%
Sodium 40mg	2%
Total Carbohydrate 15g	5%
Dietary Fiber 3g	12%
Sugars 11g	
Protein 2g	

Vitamin A 6% • Vitamin C 2%
Calcium 10% • Iron 0%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

		Calories	2,000	2,500
Total Fat	Less than		65g	80g
Saturated Fat	Less than		20g	25g
Cholesterol	Less than		300mg	300mg
Sodium	Less than		2,400mg	2,400mg
Total Carbohydrate			300g	375g
Dietary Fiber			25g	30g

Calories per gram
Fat 9 • Carbohydrate 4 • Protein 4

Nutrition Facts (7%, Right)

Serving Size (72g)
Servings Per Container

Amount Per Serving

Calories 100 Calories from Fat 30

	% Daily Value*
Total Fat 3.5g	5%
Saturated Fat 2g	10%
Trans Fat 0g	
Cholesterol 15mg	5%
Sodium 40mg	2%
Total Carbohydrate 15g	5%
Dietary Fiber 4g	16%
Sugars 11g	
Protein 2g	

Vitamin A 6% • Vitamin C 2%
Calcium 10% • Iron 0%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

		Calories	2,000	2,500
Total Fat	Less than		65g	80g
Saturated Fat	Less than		20g	25g
Cholesterol	Less than		300mg	300mg
Sodium	Less than		2,400mg	2,400mg
Total Carbohydrate			300g	375g
Dietary Fiber			25g	30g

Calories per gram
Fat 9 • Carbohydrate 4 • Protein 4

Frozen Yogurt Control Nutrition Information

Nutrients	Per Serving	Per 100g	Nutrients	Per Serving	Per 100g
Basic Components			Vitamin B12 (mcg)	0.27	0.38
Gram Weight (g)	72	100	Biotin (mcg)	0.13	0.17
Calories (kcal)	100.99	140.27	Vitamin C (mg)	0.84	1.17
Calories from Fat (kcal)	32.02	44.47	Vitamin D - IU (IU)	24.84	34.51
Calories from Sat Fat (kcal)	20.25	28.12	Vitamin D - mcg (mcg)	0.64	0.88
Protein (g)	2.48	3.44	Vitamin E - Alpha-Toco (mg)	0.1	0.14
Carbohydrates (g)	15.14	21.03	Folate (mcg)	3.58	4.97
Dietary Fiber (g)	0.05	0.07	Folate, DFE (mcg)	3.58	4.97
Soluble Fiber (g)	0	0	Vitamin K (mcg)	0.29	0.4
Total Sugars (g)	12.05	16.73	Pantothenic Acid (mg)	0.07	0.1
Monosaccharides (g)	0	0	Minerals		
Disaccharides (g)	9.43	13.1	Calcium (mg)	128.37	178.29
Other Carbs (g)	3.04	4.22	Chromium (mcg)	0.07	0.09
Fat (g)	3.56	4.94	Copper (mg)	0.01	0.01
Saturated Fat (g)	2.25	3.12	Fluoride (mg)	0	0
Mono Fat (g)	0.98	1.37	Iodine (mcg)	3.11	4.32
Poly Fat (g)	0.13	0.18	Iron (mg)	0.05	0.06
Trans Fatty Acid (g)	0.1	0.14	Magnesium (mg)	8.89	12.34
Cholesterol (mg)	13.28	18.45	Manganese (mg)	0	0
Water (g)	50.17	69.68	Molybdenum (mcg)	--	--
Vitamins			Phosphorus (mg)	72.45	100.62
Vitamin A - IU (IU)	350.71	487.1	Potassium (mg)	116.26	161.48
Vitamin A - RE (RE)	102.86	142.87	Selenium (mcg)	1.1	1.53
Vitamin A - RAE (RAE)	102.32	142.12	Sodium (mg)	42.89	59.58
Carotenoid RE (RE)	1.08	1.5	Zinc (mg)	0.29	0.4
Retinol RE (RE)	101.78	141.37	Poly Fats		
Beta-Carotene (mcg)	6.48	9	Omega 3 Fatty Acid (g)	0.05	0.07
Vitamin B1 (mg)	0.03	0.04	Omega 6 Fatty Acid (g)	0.08	0.11
Vitamin B2 (mg)	0.12	0.16	Other Nutrients		
Vitamin B3 (mg)	0.06	0.09	Alcohol (g)	0	0
Vitamin B3 - Niacin Equiv (mg)	0.11	0.15	Caffeine (mg)	0	0
Vitamin B6 (mg)	0.03	0.04	Choline (mg)	9.14	12.7

Frozen Yogurt Containing 3% Frutafit TEX! Nutrition Information

Nutrients	Per Serving	Per 100g	Nutrients	Per Serving	Per 100g
Basic Components			Vitamin B12 (mcg)	0.26	0.37
Gram Weight (g)	72	100	Biotin (mcg)	0.13	0.18
Calories (kcal)	100.93	140.17	Vitamin C (mg)	0.82	1.14
Calories from Fat (kcal)	31.96	44.39	Vitamin D - IU (IU)	24.16	33.56
Calories from Sat Fat (kcal)	20.2	28.06	Vitamin D - mcg (mcg)	0.62	0.86
Protein (g)	2.41	3.35	Vitamin E - Alpha-Toco (mg)	0.1	0.14
Carbohydrates (g)	16.71	23.2	Folate (mcg)	3.48	4.84
Dietary Fiber (g)	2.08	2.89	Folate, DFE (mcg)	3.48	4.84
Soluble Fiber (g)	2.03	2.81	Vitamin K (mcg)	0.29	0.4
Total Sugars (g)	11.67	16.21	Pantothenic Acid (mg)	0.07	0.1
Monosaccharides (g)	0	0	Minerals		
Disaccharides (g)	9.13	12.69	Calcium (mg)	124.89	173.46
Other Carbs (g)	2.95	4.1	Chromium (mcg)	0.06	0.09
Fat (g)	3.55	4.93	Copper (mg)	0.01	0.01
Saturated Fat (g)	2.24	3.12	Fluoride (mg)	0	0
Mono Fat (g)	0.98	1.37	Iodine (mcg)	3.05	4.24
Poly Fat (g)	0.13	0.18	Iron (mg)	0.05	0.07
Trans Fatty Acid (g)	0.1	0.14	Magnesium (mg)	8.63	11.99
Cholesterol (mg)	13.26	18.41	Manganese (mg)	0	0
Water (g)	48.7	67.64	Molybdenum (mcg)	--	--
Vitamins			Phosphorus (mg)	70.42	97.81
Vitamin A - IU (IU)	344.09	477.91	Potassium (mg)	113.11	157.09
Vitamin A - RE (RE)	100.88	140.11	Selenium (mcg)	1.07	1.48
Vitamin A - RAE (RAE)	100.34	139.36	Sodium (mg)	42.53	59.07
Carotenoid RE (RE)	1.08	1.5	Zinc (mg)	0.28	0.39
Retinol RE (RE)	99.8	138.61	Poly Fats		
Beta-Carotene (mcg)	6.48	9	Omega 3 Fatty Acid (g)	0.05	0.07
Vitamin B1 (mg)	0.03	0.04	Omega 6 Fatty Acid (g)	0.08	0.11
Vitamin B2 (mg)	0.11	0.16	Other Nutrients		
Vitamin B3 (mg)	0.06	0.09	Alcohol (g)	0	0
Vitamin B3 - Niacin Equiv (mg)	0.1	0.14	Caffeine (mg)	0	0
Vitamin B6 (mg)	0.03	0.04	Choline (mg)	8.91	12.38

Frozen Yogurt Containing 5% Frutafit TEX! Nutrition Information

Nutrients	Per Serving	Per 100g	Nutrients	Per Serving	Per 100g
Basic Components			Vitamin B12 (mcg)	0.26	0.35
Gram Weight (g)	72	100	Biotin (mcg)	0.13	0.18
Calories (kcal)	100.72	139.9	Vitamin C (mg)	0.79	1.1
Calories from Fat (kcal)	31.99	44.43	Vitamin D - IU (IU)	23.75	32.99
Calories from Sat Fat (kcal)	20.22	28.08	Vitamin D - mcg (mcg)	0.61	0.84
Protein (g)	2.34	3.25	Vitamin E - Alpha-Toco (mg)	0.1	0.14
Carbohydrates (g)	17.68	24.55	Folate (mcg)	3.39	4.7
Dietary Fiber (g)	3.37	4.67	Folate, DFE (mcg)	3.39	4.7
Soluble Fiber (g)	3.32	4.6	Vitamin K (mcg)	0.29	0.4
Total Sugars (g)	11.41	15.84	Pantothenic Acid (mg)	0.07	0.1
Monosaccharides (g)	0	0	Minerals		
Disaccharides (g)	8.92	12.39	Calcium (mg)	121.71	169.04
Other Carbs (g)	2.9	4.02	Chromium (mcg)	0.06	0.09
Fat (g)	3.55	4.94	Copper (mg)	0.01	0.01
Saturated Fat (g)	2.25	3.12	Fluoride (mg)	0	0
Mono Fat (g)	0.99	1.37	Iodine (mcg)	3.02	4.2
Poly Fat (g)	0.13	0.18	Iron (mg)	0.06	0.08
Trans Fatty Acid (g)	0.1	0.14	Magnesium (mg)	8.36	11.61
Cholesterol (mg)	13.27	18.43	Manganese (mg)	0	0
Water (g)	47.81	66.4	Molybdenum (mcg)	--	--
Vitamins			Phosphorus (mg)	68.37	94.96
Vitamin A - IU (IU)	340.36	472.72	Potassium (mg)	109.86	152.59
Vitamin A - RE (RE)	99.76	138.56	Selenium (mcg)	1.05	1.45
Vitamin A - RAE (RAE)	99.22	137.81	Sodium (mg)	41.89	58.18
Carotenoid RE (RE)	1.08	1.5	Zinc (mg)	0.27	0.37
Retinol RE (RE)	98.68	137.05	Poly Fats		
Beta-Carotene (mcg)	6.5	9.02	Omega 3 Fatty Acid (g)	0.05	0.07
Vitamin B1 (mg)	0.03	0.04	Omega 6 Fatty Acid (g)	0.08	0.11
Vitamin B2 (mg)	0.11	0.15	Other Nutrients		
Vitamin B3 (mg)	0.06	0.08	Alcohol (g)	0	0
Vitamin B3 - Niacin Equiv (mg)	0.1	0.14	Caffeine (mg)	0	0
Vitamin B6 (mg)	0.03	0.04	Choline (mg)	8.77	12.18

Frozen Yogurt Containing 7% Frutafit TEX! Nutrition Information

Nutrients	Per Serving	Per 100g	Nutrients	Per Serving	Per 100g
Basic Components			Vitamin B12 (mcg)	0.25	0.35
Gram Weight (g)	72	100	Biotin (mcg)	0.13	0.18
Calories (kcal)	100.67	139.82	Vitamin C (mg)	0.77	1.07
Calories from Fat (kcal)	32.03	44.48	Vitamin D - IU (IU)	23.35	32.43
Calories from Sat Fat (kcal)	20.23	28.1	Vitamin D - mcg (mcg)	0.6	0.83
Protein (g)	2.29	3.18	Vitamin E - Alpha-Toco (mg)	0.1	0.14
Carbohydrates (g)	18.63	25.87	Folate (mcg)	3.32	4.6
Dietary Fiber (g)	4.6	6.39	Folate, DFE (mcg)	3.32	4.6
Soluble Fiber (g)	4.55	6.33	Vitamin K (mcg)	0.29	0.4
Total Sugars (g)	11.17	15.51	Pantothenic Acid (mg)	0.07	0.09
Monosaccharides (g)	0	0	Minerals		
Disaccharides (g)	8.73	12.12	Calcium (mg)	119.24	165.61
Other Carbs (g)	2.84	3.95	Chromium (mcg)	0.06	0.09
Fat (g)	3.56	4.94	Copper (mg)	0.01	0.01
Saturated Fat (g)	2.25	3.12	Fluoride (mg)	0	0
Mono Fat (g)	0.99	1.37	Iodine (mcg)	2.99	4.16
Poly Fat (g)	0.13	0.18	Iron (mg)	0.06	0.09
Trans Fatty Acid (g)	0.1	0.14	Magnesium (mg)	8.17	11.34
Cholesterol (mg)	13.28	18.44	Manganese (mg)	0	0
Water (g)	46.92	65.17	Molybdenum (mcg)	--	--
Vitamins			Phosphorus (mg)	66.87	92.88
Vitamin A - IU (IU)	336.66	467.58	Potassium (mg)	107.5	149.31
Vitamin A - RE (RE)	98.65	137.01	Selenium (mcg)	1.03	1.43
Vitamin A - RAE (RAE)	98.11	136.26	Sodium (mg)	41.53	57.67
Carotenoid RE (RE)	1.09	1.51	Zinc (mg)	0.26	0.37
Retinol RE (RE)	97.56	135.5	Poly Fats		
Beta-Carotene (mcg)	6.51	9.04	Omega 3 Fatty Acid (g)	0.05	0.07
Vitamin B1 (mg)	0.03	0.04	Omega 6 Fatty Acid (g)	0.08	0.11
Vitamin B2 (mg)	0.11	0.15	Other Nutrients		
Vitamin B3 (mg)	0.06	0.08	Alcohol (g)	0	0
Vitamin B3 - Niacin Equiv (mg)	0.1	0.14	Caffeine (mg)	0	0
Vitamin B6 (mg)	0.03	0.04	Choline (mg)	8.64	11.99

Frozen Yogurt Containing 3% Vitacel SMOOV 240 Nutrition Information

Nutrients	Per Serving	Per 100g	Nutrients	Per Serving	Per 100g
Basic Components			Vitamin B12 (mcg)	0.26	0.36
Gram Weight (g)	72	100	Biotin (mcg)	0.13	0.18
Calories (kcal)	98.78	137.19	Vitamin C (mg)	0.81	1.13
Calories from Fat (kcal)	31.98	44.42	Vitamin D - IU (IU)	24.18	33.58
Calories from Sat Fat (kcal)	20.22	28.08	Vitamin D - mcg (mcg)	0.62	0.86
Protein (g)	2.41	3.34	Vitamin E - Alpha-Toco (mg)	0.1	0.14
Carbohydrates (g)	16.64	23.12	Folate (mcg)	3.46	4.81
Dietary Fiber (g)	2.04	2.83	Folate, DFE (mcg)	3.46	4.81
Soluble Fiber (g)	0.05	0.08	Vitamin K (mcg)	0.29	0.4
Total Sugars (g)	11.66	16.19	Pantothenic Acid (mg)	0.07	0.1
Monosaccharides (g)	0	0	Minerals		
Disaccharides (g)	9.12	12.66	Calcium (mg)	125.09	173.74
Other Carbs (g)	2.95	4.1	Chromium (mcg)	0.06	0.09
Fat (g)	3.55	4.94	Copper (mg)	0.01	0.01
Saturated Fat (g)	2.25	3.12	Fluoride (mg)	0	0
Mono Fat (g)	0.98	1.37	Iodine (mcg)	3.05	4.24
Poly Fat (g)	0.13	0.18	Iron (mg)	0.04	0.06
Trans Fatty Acid (g)	0.1	0.14	Magnesium (mg)	8.56	11.89
Cholesterol (mg)	13.27	18.43	Manganese (mg)	0	0
Water (g)	48.72	67.66	Molybdenum (mcg)	--	--
Vitamins			Phosphorus (mg)	69.95	97.15
Vitamin A - IU (IU)	344.32	478.22	Potassium (mg)	112.18	155.8
Vitamin A - RE (RE)	100.95	140.21	Selenium (mcg)	1.07	1.48
Vitamin A - RAE (RAE)	100.41	139.46	Sodium (mg)	41.44	57.55
Carotenoid RE (RE)	1.08	1.5	Zinc (mg)	0.28	0.38
Retinol RE (RE)	99.87	138.71	Poly Fats		
Beta-Carotene (mcg)	6.49	9.01	Omega 3 Fatty Acid (g)	0.05	0.07
Vitamin B1 (mg)	0.03	0.04	Omega 6 Fatty Acid (g)	0.08	0.11
Vitamin B2 (mg)	0.11	0.16	Other Nutrients		
Vitamin B3 (mg)	0.06	0.09	Alcohol (g)	0	0
Vitamin B3 - Niacin Equiv (mg)	0.1	0.14	Caffeine (mg)	0	0
Vitamin B6 (mg)	0.03	0.04	Choline (mg)	8.92	12.38

Frozen Yogurt Containing 5% Vitacel SMOOV 240 Nutrition Information

Nutrients	Per Serving	Per 100g	Nutrients	Per Serving	Per 100g
Basic Components			Vitamin B12 (mcg)	0.26	0.35
Gram Weight (g)	72	100	Biotin (mcg)	0.13	0.18
Calories (kcal)	97.4	135.28	Vitamin C (mg)	0.79	1.1
Calories from Fat (kcal)	31.99	44.43	Vitamin D - IU (IU)	23.75	32.99
Calories from Sat Fat (kcal)	20.22	28.08	Vitamin D - mcg (mcg)	0.61	0.84
Protein (g)	2.36	3.28	Vitamin E - Alpha-Toco (mg)	0.1	0.14
Carbohydrates (g)	17.6	24.44	Folate (mcg)	3.39	4.7
Dietary Fiber (g)	3.3	4.58	Folate, DFE (mcg)	3.39	4.7
Soluble Fiber (g)	0.09	0.12	Vitamin K (mcg)	0.29	0.4
Total Sugars (g)	11.41	15.84	Pantothenic Acid (mg)	0.07	0.1
Monosaccharides (g)	0	0	Minerals		
Disaccharides (g)	8.92	12.39	Calcium (mg)	123.03	170.87
Other Carbs (g)	2.9	4.02	Chromium (mcg)	0.06	0.09
Fat (g)	3.55	4.94	Copper (mg)	0.01	0.01
Saturated Fat (g)	2.25	3.12	Fluoride (mg)	0	0
Mono Fat (g)	0.99	1.37	Iodine (mcg)	3.02	4.2
Poly Fat (g)	0.13	0.18	Iron (mg)	0.04	0.06
Trans Fatty Acid (g)	0.1	0.14	Magnesium (mg)	8.36	11.61
Cholesterol (mg)	13.27	18.43	Manganese (mg)	0	0
Water (g)	47.79	66.37	Molybdenum (mcg)	--	--
Vitamins			Phosphorus (mg)	68.37	94.96
Vitamin A - IU (IU)	340.36	472.72	Potassium (mg)	109.61	152.23
Vitamin A - RE (RE)	99.76	138.56	Selenium (mcg)	1.05	1.45
Vitamin A - RAE (RAE)	99.22	137.81	Sodium (mg)	40.52	56.27
Carotenoid RE (RE)	1.08	1.5	Zinc (mg)	0.27	0.37
Retinol RE (RE)	98.68	137.05	Poly Fats		
Beta-Carotene (mcg)	6.5	9.02	Omega 3 Fatty Acid (g)	0.05	0.07
Vitamin B1 (mg)	0.03	0.04	Omega 6 Fatty Acid (g)	0.08	0.11
Vitamin B2 (mg)	0.11	0.15	Other Nutrients		
Vitamin B3 (mg)	0.06	0.08	Alcohol (g)	0	0
Vitamin B3 - Niacin Equiv (mg)	0.1	0.14	Caffeine (mg)	0	0
Vitamin B6 (mg)	0.03	0.04	Choline (mg)	8.77	12.18

Frozen Yogurt Containing 7% Vitacel SMOOV 240 Nutrition Information

Nutrients	Per Serving	Per 100g	Nutrients	Per Serving	Per 100g
Basic Components			Vitamin B12 (mcg)	0.25	0.35
Gram Weight (g)	72	100	Biotin (mcg)	0.13	0.18
Calories (kcal)	96.1	133.48	Vitamin C (mg)	0.77	1.07
Calories from Fat (kcal)	32.03	44.48	Vitamin D - IU (IU)	23.35	32.43
Calories from Sat Fat (kcal)	20.23	28.1	Vitamin D - mcg (mcg)	0.6	0.83
Protein (g)	2.32	3.22	Vitamin E - Alpha-Toco (mg)	0.1	0.14
Carbohydrates (g)	18.52	25.72	Folate (mcg)	3.32	4.6
Dietary Fiber (g)	4.51	6.26	Folate, DFE (mcg)	3.32	4.6
Soluble Fiber (g)	0.12	0.17	Vitamin K (mcg)	0.29	0.4
Total Sugars (g)	11.17	15.51	Pantothenic Acid (mg)	0.07	0.09
Monosaccharides (g)	0	0	Minerals		
Disaccharides (g)	8.73	12.12	Calcium (mg)	121.05	168.13
Other Carbs (g)	2.84	3.95	Chromium (mcg)	0.06	0.09
Fat (g)	3.56	4.94	Copper (mg)	0.01	0.01
Saturated Fat (g)	2.25	3.12	Fluoride (mg)	0	0
Mono Fat (g)	0.99	1.37	Iodine (mcg)	2.99	4.16
Poly Fat (g)	0.13	0.18	Iron (mg)	0.04	0.06
Trans Fatty Acid (g)	0.1	0.14	Magnesium (mg)	8.17	11.34
Cholesterol (mg)	13.28	18.44	Manganese (mg)	0	0
Water (g)	46.89	65.13	Molybdenum (mcg)	--	--
Vitamins			Phosphorus (mg)	66.87	92.88
Vitamin A - IU (IU)	336.66	467.58	Potassium (mg)	107.15	148.82
Vitamin A - RE (RE)	98.65	137.01	Selenium (mcg)	1.03	1.43
Vitamin A - RAE (RAE)	98.11	136.26	Sodium (mg)	39.64	55.06
Carotenoid RE (RE)	1.09	1.51	Zinc (mg)	0.26	0.37
Retinol RE (RE)	97.56	135.5	Poly Fats		
Beta-Carotene (mcg)	6.51	9.04	Omega 3 Fatty Acid (g)	0.05	0.07
Vitamin B1 (mg)	0.03	0.04	Omega 6 Fatty Acid (g)	0.08	0.11
Vitamin B2 (mg)	0.11	0.15	Other Nutrients		
Vitamin B3 (mg)	0.06	0.08	Alcohol (g)	0	0
Vitamin B3 - Niacin Equiv (mg)	0.1	0.14	Caffeine (mg)	0	0
Vitamin B6 (mg)	0.03	0.04	Choline (mg)	8.64	11.99

Frozen Yogurt Containing 3% Glucagel® Nutrition Information

Nutrients	Per Serving	Per 100g	Nutrients	Per Serving	Per 100g
Basic Components			Vitamin B12 (mcg)	0.26	0.36
Gram Weight (g)	72	100	Biotin (mcg)	0.13	0.18
Calories (kcal)	99.97	138.85	Vitamin C (mg)	0.81	1.13
Calories from Fat (kcal)	32.1	44.58	Vitamin D - IU (IU)	24.18	33.58
Calories from Sat Fat (kcal)	20.22	28.08	Vitamin D - mcg (mcg)	0.62	0.86
Protein (g)	2.39	3.32	Vitamin E - Alpha-Toco (mg)	0.1	0.14
Carbohydrates (g)	14.97	20.8	Folate (mcg)	3.46	4.81
Dietary Fiber (g)	1.62	2.26	Folate, DFE (mcg)	3.46	4.81
Soluble Fiber (g)	0	0	Vitamin K (mcg)	0.29	0.4
Total Sugars (g)	11.66	16.19	Pantothenic Acid (mg)	0.07	0.1
Monosaccharides (g)	0	0	Minerals		
Disaccharides (g)	9.12	12.66	Calcium (mg)	124.05	172.29
Other Carbs (g)	2.95	4.1	Chromium (mcg)	0.06	0.09
Fat (g)	3.57	4.95	Copper (mg)	0.01	0.01
Saturated Fat (g)	2.25	3.12	Fluoride (mg)	0	0
Mono Fat (g)	0.98	1.37	Iodine (mcg)	3.05	4.24
Poly Fat (g)	0.13	0.18	Iron (mg)	0.04	0.06
Trans Fatty Acid (g)	0.1	0.14	Magnesium (mg)	8.56	11.89
Cholesterol (mg)	13.27	18.43	Manganese (mg)	0	0
Water (g)	48.79	67.77	Molybdenum (mcg)	--	--
Vitamins			Phosphorus (mg)	69.95	97.15
Vitamin A - IU (IU)	344.32	478.22	Potassium (mg)	112.18	155.8
Vitamin A - RE (RE)	100.95	140.21	Selenium (mcg)	1.07	1.48
Vitamin A - RAE (RAE)	100.41	139.46	Sodium (mg)	41.44	57.55
Carotenoid RE (RE)	1.08	1.5	Zinc (mg)	0.28	0.38
Retinol RE (RE)	99.87	138.71	Poly Fats		
Beta-Carotene (mcg)	6.49	9.01	Omega 3 Fatty Acid (g)	0.05	0.07
Vitamin B1 (mg)	0.03	0.04	Omega 6 Fatty Acid (g)	0.08	0.11
Vitamin B2 (mg)	0.11	0.16	Other Nutrients		
Vitamin B3 (mg)	0.06	0.09	Alcohol (g)	0	0
Vitamin B3 - Niacin Equiv (mg)	0.1	0.14	Caffeine (mg)	0	0
Vitamin B6 (mg)	0.03	0.04	Choline (mg)	8.92	12.38

Frozen Yogurt Containing 5% Glucagel® Nutrition Information

Nutrients	Per Serving	Per 100g	Nutrients	Per Serving	Per 100g
Basic Components			Vitamin B12 (mcg)	0.26	0.35
Gram Weight (g)	72	100	Biotin (mcg)	0.13	0.18
Calories (kcal)	99.35	137.99	Vitamin C (mg)	0.79	1.1
Calories from Fat (kcal)	32.18	44.69	Vitamin D - IU (IU)	23.75	32.99
Calories from Sat Fat (kcal)	20.22	28.08	Vitamin D - mcg (mcg)	0.61	0.84
Protein (g)	2.34	3.25	Vitamin E - Alpha-Toco (mg)	0.1	0.14
Carbohydrates (g)	14.87	20.65	Folate (mcg)	3.39	4.7
Dietary Fiber (g)	2.62	3.64	Folate, DFE (mcg)	3.39	4.7
Soluble Fiber (g)	0	0	Vitamin K (mcg)	0.29	0.4
Total Sugars (g)	11.41	15.84	Pantothenic Acid (mg)	0.07	0.1
Monosaccharides (g)	0	0	Minerals		
Disaccharides (g)	8.92	12.39	Calcium (mg)	121.31	168.49
Other Carbs (g)	2.9	4.02	Chromium (mcg)	0.06	0.09
Fat (g)	3.58	4.97	Copper (mg)	0.01	0.01
Saturated Fat (g)	2.25	3.12	Fluoride (mg)	0	0
Mono Fat (g)	0.99	1.37	Iodine (mcg)	3.02	4.2
Poly Fat (g)	0.13	0.18	Iron (mg)	0.04	0.06
Trans Fatty Acid (g)	0.1	0.14	Magnesium (mg)	8.36	11.61
Cholesterol (mg)	13.27	18.43	Manganese (mg)	0	0
Water (g)	47.91	66.54	Molybdenum (mcg)	--	--
Vitamins			Phosphorus (mg)	68.37	94.96
Vitamin A - IU (IU)	340.36	472.72	Potassium (mg)	109.61	152.23
Vitamin A - RE (RE)	99.76	138.56	Selenium (mcg)	1.05	1.45
Vitamin A - RAE (RAE)	99.22	137.81	Sodium (mg)	40.52	56.27
Carotenoid RE (RE)	1.08	1.5	Zinc (mg)	0.27	0.37
Retinol RE (RE)	98.68	137.05	Poly Fats		
Beta-Carotene (mcg)	6.5	9.02	Omega 3 Fatty Acid (g)	0.05	0.07
Vitamin B1 (mg)	0.03	0.04	Omega 6 Fatty Acid (g)	0.08	0.11
Vitamin B2 (mg)	0.11	0.15	Other Nutrients		
Vitamin B3 (mg)	0.06	0.08	Alcohol (g)	0	0
Vitamin B3 - Niacin Equiv (mg)	0.1	0.14	Caffeine (mg)	0	0
Vitamin B6 (mg)	0.03	0.04	Choline (mg)	8.77	12.18

Frozen Yogurt Containing 7% Glucagel® Nutrition Information

Nutrients	Per Serving	Per 100g	Nutrients	Per Serving	Per 100g
Basic Components			Vitamin B12 (mcg)	0.25	0.35
Gram Weight (g)	72	100	Biotin (mcg)	0.13	0.18
Calories (kcal)	98.79	137.21	Vitamin C (mg)	0.77	1.07
Calories from Fat (kcal)	32.28	44.84	Vitamin D - IU (IU)	23.35	32.43
Calories from Sat Fat (kcal)	20.23	28.1	Vitamin D - mcg (mcg)	0.6	0.83
Protein (g)	2.29	3.18	Vitamin E - Alpha-Toco (mg)	0.1	0.14
Carbohydrates (g)	14.77	20.51	Folate (mcg)	3.32	4.6
Dietary Fiber (g)	3.58	4.98	Folate, DFE (mcg)	3.32	4.6
Soluble Fiber (g)	0	0	Vitamin K (mcg)	0.29	0.4
Total Sugars (g)	11.17	15.51	Pantothenic Acid (mg)	0.07	0.09
Monosaccharides (g)	0	0	Minerals		
Disaccharides (g)	8.73	12.12	Calcium (mg)	118.7	164.86
Other Carbs (g)	2.84	3.95	Chromium (mcg)	0.06	0.09
Fat (g)	3.59	4.98	Copper (mg)	0.01	0.01
Saturated Fat (g)	2.25	3.12	Fluoride (mg)	0	0
Mono Fat (g)	0.99	1.37	Iodine (mcg)	2.99	4.16
Poly Fat (g)	0.13	0.18	Iron (mg)	0.04	0.06
Trans Fatty Acid (g)	0.1	0.14	Magnesium (mg)	8.17	11.34
Cholesterol (mg)	13.28	18.44	Manganese (mg)	0	0
Water (g)	47.06	65.36	Molybdenum (mcg)	--	--
Vitamins			Phosphorus (mg)	66.87	92.88
Vitamin A - IU (IU)	336.66	467.58	Potassium (mg)	107.15	148.82
Vitamin A - RE (RE)	98.65	137.01	Selenium (mcg)	1.03	1.43
Vitamin A - RAE (RAE)	98.11	136.26	Sodium (mg)	39.64	55.06
Carotenoid RE (RE)	1.09	1.51	Zinc (mg)	0.26	0.37
Retinol RE (RE)	97.56	135.5	Poly Fats		
Beta-Carotene (mcg)	6.51	9.04	Omega 3 Fatty Acid (g)	0.05	0.07
Vitamin B1 (mg)	0.03	0.04	Omega 6 Fatty Acid (g)	0.08	0.11
Vitamin B2 (mg)	0.11	0.15	Other Nutrients		
Vitamin B3 (mg)	0.06	0.08	Alcohol (g)	0	0
Vitamin B3 - Niacin Equiv (mg)	0.1	0.14	Caffeine (mg)	0	0
Vitamin B6 (mg)	0.03	0.04	Choline (mg)	8.64	11.99

APPENDIX C

- **Hedonic Sensory Sample Ballot**
- **Descriptive Sensory Sample Ballot**

Date:________________

You will be given 5 samples of frozen yogurt. Please taste each sample and rank liking on the scale given, please select only 1 degree of liking for each sample. The sample code is above each column.

Code: xxx Code: xxx Code: xxx Code: xxx Code: xxx

Like extremely	Like extremely	Like extremely	Like extremely	Like extremely
☐	☐	☐	☐	☐
Like very much	Like very much	Like very much	Like very much	Like very much
☐	☐	☐	☐	☐
Like moderately	Like moderately	Like moderately	Like moderately	Like moderately
☐	☐	☐	☐	☐
Like slightly	Like slightly	Like slightly	Like slightly	Like slightly
☐	☐	☐	☐	☐
Neither like or dislike	Neither like or dislike	Neither like or dislike	Neither like or dislike	Neither like or dislike
☐	☐	☐	☐	☐
Dislike slightly	Dislike slightly	Dislike slightly	Dislike slightly	Dislike slightly
☐	☐	☐	☐	☐
Dislike moderately	Dislike moderately	Dislike moderately	Dislike moderately	Dislike moderately
☐	☐	☐	☐	☐
Dislike very much	Dislike very much	Dislike very much	Dislike very much	Dislike very much
☐	☐	☐	☐	☐
Dislike extremely	Dislike extremely	Dislike extremely	Dislike extremely	Dislike extremely
☐	☐	☐	☐	☐

Study of the effects using of Dietary Fiber

On Frozen Yogurt

Judge # __________ Sample # _________ Session # _________ Date_________

Directions:

1. Write your name and sample code on given lines.
2. Taste the references for the given attribute.
3. Rinse mouth with water
4. Open the cup containing the sample
5. Spoon contents into the mouth.
6. Taste, and swallow the sample.
7. Place a **vertical** mark on the horizontal line of each attribute at the position that best describes the perceived intensity of the given attribute based on the intensity of the given references.
8. Rinse mouth with water and crackers if needed
9. Repeat steps 2-9 for all attributes

Please be consistent! ☺

Texture Descriptors

Iciness

None High

|———————————————————————|

Gumminess

None High

|———————————————————————|

Mouth coating

None High

|———————————————————————|

Lumpy

None High

|———————————————————————|

Chalky
None High

Taste Descriptors

Sweetness
None High

Milky Flavor
None High

Cooked Flavor
None High

Caramel
None High

Yogurt Flavor
None High

Vanilla Flavor
None High

Melting Descriptors

Watery

Thin | Thick

Foamy

None | High

Other

Color

None | High

Take a few minutes break! ☺
Rinse your mouth with water and crackers if needed.

APPENDIX D

- **SPSS Printout for Simple Liking Data**

		N
Type	Control	101
	Frutafit TEX!	302
	Glucagel	305
	Vitacel SMOOV 240	299
Level	0	101
	3% Frutafit TEX!	102
	3% Glucagel	105
	3% Vitacel SMOOV	102
	5% Frutafit TEX!	102
	5% Glucagel	102
	5% Vitacel SMOOV	100
	7% Frutafit TEX!	98
	7% Glucagel	98
	7% Vitacel SMOOV	97
Replicate	3% Frutafit TEX! 2	35
	3% Frutafit TEX! 3	34
	3% Frutafit TEX! 1	33
	3% Glucagel 1	34
	3% Glucagel 2	36
	3% Glucagel 3	35
	3% Vitacel SMOOV 240 1	34
	3% Vitacel SMOOV 240 2	34
	3% Vitacel SMOOV 240 3	34
	5% Frutafit TEX! 1	36
	5% Frutafit TEX! 2	34
	5% Frutafit TEX! 3	32
	5% Glucagel 1	32
	5% Glucagel 2	34
	5% Glucagel 3	36
	5% Vitacel SMOOV 240 1	36
	5% Vitacel SMOOV 240 2	30
	5% Vitacel SMOOV 240 3	34
	7% Frutafit TEX! 1	32
	7% Frutafit TEX! 2	32
	7% Frutafit TEX! 3	34
	7% Glucagel 1	32
	7% Glucagel 2	35
	7% Glucagel 3	31
	7% Vitacel SMOOV 240 1	32

	N
7% Vitacel SMOOV 240 2	34
7% Vitacel SMOOV 240 3	31
Control 1	33
Control 2	36
Control 3	32

Tests of Between-Subjects Effects

Dependent Variable: Response

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3462.716[a]	29	119.404	46.031	.000
Intercept	30805.820	1	30805.820	11875.759	.000
Type	.000	0	.	.	.
Level	.000	0	.	.	.
Replicate	190.183	20	9.509	3.666	.000
Type * Level	.000	0	.	.	.
Type * Replicate	.000	0	.	.	.
Level * Replicate	.000	0	.	.	.
Type * Level * Replicate	.000	0	.	.	.
Error	2534.346	977	2.594		
Total	36690.250	1007			
Corrected Total	5997.062	1006			

Pairwise Comparisons

Dependent Variable: Response

(I) Level	(J) Level	Mean Difference (I-J)	Std. Error	Sig.[d]	95% Confidence Interval for ...[d] Lower Bound
0	3% Frutafit TEX!	.007[a,b]	.226	.975	-.437
	3% Glucagel	2.811[a,b,*]	.225	.000	2.370
	3% Vitacel SMOOV	.198[a,b]	.226	.382	-.246
	5% Frutafit TEX!	.049[a,b]	.226	.828	-.395
	5% Glucagel	4.371[a,b,*]	.226	.000	3.926
	5% Vitacel SMOOV	.939[a,b,*]	.228	.000	.492
	7% Frutafit TEX!	-.675[a,b,*]	.229	.003	-1.123
	7% Glucagel	4.592[a,b,*]	.229	.000	4.143
	7% Vitacel SMOOV	1.502[a,b,*]	.229	.000	1.053
3% Frutafit TEX!	0	-.007[a,b]	.226	.975	-.451
	3% Glucagel	2.804[a,b,*]	.224	.000	2.364
	3% Vitacel SMOOV	.191[a,b]	.226	.398	-.252
	5% Frutafit TEX!	.042[a,b]	.226	.852	-.401
	5% Glucagel	4.364[a,b,*]	.226	.000	3.921
	5% Vitacel SMOOV	.932[a,b,*]	.227	.000	.487
	7% Frutafit TEX!	-.682[a,b,*]	.228	.003	-1.129
	7% Glucagel	4.584[a,b,*]	.228	.000	4.137
	7% Vitacel SMOOV	1.495[a,b,*]	.229	.000	1.047
3% Glucagel	0	-2.811[a,b,*]	.225	.000	-3.252
	3% Frutafit TEX!	-2.804[a,b,*]	.224	.000	-3.243

Dependent Variable: Response

(I) Level	(J) Level	Mean Difference (I-J)	Std. Error	Sig.[d]	95% Confidence Interval for ...[d]
					Lower Bound
	3% Vitacel SMOOV	-2.613[a,b,*]	.224	.000	-3.052
	5% Frutafit TEX!	-2.761[a,b,*]	.224	.000	-3.201
	5% Glucagel	1.560[a,b,*]	.224	.000	1.120
	5% Vitacel SMOOV	-1.871[a,b,*]	.225	.000	-2.314
	7% Frutafit TEX!	-3.485[a,b,*]	.226	.000	-3.929
	7% Glucagel	1.781[a,b,*]	.226	.000	1.337
	7% Vitacel SMOOV	-1.308[a,b,*]	.227	.000	-1.754
3% Vitacel SMOOV	0	-.198[a,b]	.226	.382	-.642
	3% Frutafit TEX!	-.191[a,b]	.226	.398	-.633
	3% Glucagel	2.613[a,b,*]	.224	.000	2.173
	5% Frutafit TEX!	-.149[a,b]	.226	.510	-.591
	5% Glucagel	4.173[a,b,*]	.226	.000	3.730
	5% Vitacel SMOOV	.741[a,b,*]	.227	.001	.296
	7% Frutafit TEX!	-.873[a,b,*]	.228	.000	-1.320
	7% Glucagel	4.394[a,b,*]	.228	.000	3.946
	7% Vitacel SMOOV	1.305[a,b,*]	.229	.000	.856
5% Frutafit TEX!	0	-.049[a,b]	.226	.828	-.493
	3% Frutafit TEX!	-.042[a,b]	.226	.852	-.485
	3% Glucagel	2.761[a,b,*]	.224	.000	2.322
	3% Vitacel SMOOV	.149[a,b]	.226	.510	-.294
	5% Glucagel	4.321[a,b,*]	.226	.000	3.878
	5% Vitacel SMOOV	.890[a,b,*]	.227	.000	.444
	7% Frutafit TEX!	-.724[a,b,*]	.228	.002	-1.171
	7% Glucagel	4.542[a,b,*]	.228	.000	4.095
	7% Vitacel SMOOV	1.453[a,b,*]	.229	.000	1.005
5% Glucagel	0	-4.371[a,b,*]	.226	.000	-4.815
	3% Frutafit TEX!	-4.364[a,b,*]	.226	.000	-4.806
	3% Glucagel	-1.560[a,b,*]	.224	.000	-2.000
	3% Vitacel SMOOV	-4.173[a,b,*]	.226	.000	-4.616
	5% Frutafit TEX!	-4.321[a,b,*]	.226	.000	-4.764
	5% Vitacel SMOOV	-3.431[a,b,*]	.227	.000	-3.877
	7% Frutafit TEX!	-5.045[a,b,*]	.228	.000	-5.493
	7% Glucagel	.221[a,b]	.228	.333	-.227
	7% Vitacel SMOOV	-2.868[a,b,*]	.229	.000	-3.317
5% Vitacel SMOOV	0	-.939[a,b,*]	.228	.000	-1.386
	3% Frutafit TEX!	-.932[a,b,*]	.227	.000	-1.378

Dependent Variable: Response

(I) Level	(J) Level	Mean Difference (I-J)	Std. Error	Sig.[d]	95% Confidence Interval for ...[d]
					Lower Bound
	3% Glucagel	1.871[a,b,*]	.225	.000	1.429
	3% Vitacel SMOOV	-.741[a,b,*]	.227	.001	-1.187
	5% Frutafit TEX!	-.890[a,b,*]	.227	.000	-1.336
	5% Glucagel	3.431[a,b,*]	.227	.000	2.986
	7% Frutafit TEX!	-1.614[a,b,*]	.229	.000	-2.064
	7% Glucagel	3.652[a,b,*]	.229	.000	3.202
	7% Vitacel SMOOV	.563[a,b,*]	.230	.014	.112
7% Frutafit TEX!	0	.675[a,b,*]	.229	.003	.226
	3% Frutafit TEX!	.682[a,b,*]	.228	.003	.235
	3% Glucagel	3.485[a,b,*]	.226	.000	3.041
	3% Vitacel SMOOV	.873[a,b,*]	.228	.000	.425
	5% Frutafit TEX!	.724[a,b,*]	.228	.002	.277
	5% Glucagel	5.045[a,b,*]	.228	.000	4.598
	5% Vitacel SMOOV	1.614[a,b,*]	.229	.000	1.164
	7% Glucagel	5.266[a,b,*]	.230	.000	4.814
	7% Vitacel SMOOV	2.177[a,b,*]	.231	.000	1.724
7% Glucagel	0	-4.592[a,b,*]	.229	.000	-5.040
	3% Frutafit TEX!	-4.584[a,b,*]	.228	.000	-5.032
	3% Glucagel	-1.781[a,b,*]	.226	.000	-2.225
	3% Vitacel SMOOV	-4.394[a,b,*]	.228	.000	-4.841
	5% Frutafit TEX!	-4.542[a,b,*]	.228	.000	-4.990
	5% Glucagel	-.221[a,b]	.228	.333	-.669
	5% Vitacel SMOOV	-3.652[a,b,*]	.229	.000	-4.103
	7% Frutafit TEX!	-5.266[a,b,*]	.230	.000	-5.718
	7% Vitacel SMOOV	-3.089[a,b,*]	.231	.000	-3.542
7% Vitacel SMOOV	0	-1.502[a,b,*]	.229	.000	-1.952
	3% Frutafit TEX!	-1.495[a,b,*]	.229	.000	-1.944
	3% Glucagel	1.308[a,b,*]	.227	.000	.863
	3% Vitacel SMOOV	-1.305[a,b,*]	.229	.000	-1.753
	5% Frutafit TEX!	-1.453[a,b,*]	.229	.000	-1.902
	5% Glucagel	2.868[a,b,*]	.229	.000	2.419
	5% Vitacel SMOOV	-.563[a,b,*]	.230	.014	-1.014
	7% Frutafit TEX!	-2.177[a,b,*]	.231	.000	-2.630
	7% Glucagel	3.089[a,b,*]	.231	.000	2.636