An Ice Cream Sweetened with a Fructan-Rich Minimally Processed Syrup: Blue Agave Nectar

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AN ICE CREAM SWEETENED WITH A FRUCTAN-RICH MINIMALLY PROCESSED SYRUP: BLUE AGAVE NECTAR

By

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ABSTRACT

The consumption of whole foods has shown to offer more synergistic health benefits as compared to foods made with highly processed ingredients. The American food industry has a variety of food products that consist of refined, isolated or artificial ingredients (e.g. bread, beverages, snack foods and others). Although the sensory properties of several products are satisfactory, many consumers desire products made with minimally processed ingredients. The primary goal of the project was to develop a satisfactory alternative ice cream for an existing brand name ice cream using minimally processed sweetener, blue agave nectar, instead of sucrose that is commonly used in the brand name ice cream. The rheological properties of consistency, melting, texture (firmness) and surface appearance (color) were compared between the experimental and the control ice cream formulae. Five sets of data were collected for 2 different batches (10 data sets) of both formulae. The paired results indicated no significant difference in the melting rate \((p = .25)\) between the experimental \((16.15 \pm 2.75)\) and controlled formulae \((17.55 \pm 1.28)\). The average rate of flow (consistency) was also similar \((p = .95)\) between the experimental \((4.48 \pm 0.92)\) and the controlled \((4.50 \pm 0.65)\). However, there was a significant difference \((p = .001)\) in the exertion of force. The experimental samples averaged to be softer in texture with a mean force of \(0.30 (\pm 0.16)\) as compared to the control samples \((0.63 \pm 0.20)\) with distance and time being constant. Also, the experimental samples, on an average, were more yellow \((Y\,\text{glossy} = 1.09)\) than the control \((Y\,\text{glossy} = 0.96)\) as determined by the reflectometer readings. Based on the rheological tests, the experimental ice cream appears to be of comparable quality to that of the same qualities of the control. Overall, the experimental ice cream may provide an acceptable alternative to the ice cream sweetened with sucrose. However,
a human sensory analysis should be conducted to determine the overall desirability of the product.

KEY WORDS: Ice cream, texture, color, rheological properties, agave
CHAPTER 1

INTRODUCTION

The Food Guide Pyramid and the recent MyPlate are effective graphics in depicting the key concepts of a healthy diet (USDA, 2010). The graphics denote whole grains, whole fruits and vegetables, meat and beans with meagerly amounts of refined foods. However, the amount of refined foods consumption has increased in the United States contributing to many health problems. The consumption of refined carbohydrates, as high as 165g/day, has been shown to significantly and adversely influence the digestive process in humans (Kruis et al, 1991). The properly functioning of the digestive system is integral in the absorption of many micronutrients to maintain health and biological processes. Food industries try to meet the challenges of health conscious consumers by offering a variety of low fat/fat free and low/sugar free products. However, in many instances these ingredients are highly processed/refined or artificial. For example, most reduced and low-fat ice creams contain artificial stabilizers, thickeners, and are often sweetened with a refined sugar, such as sucrose (table sugar), or artificial sweeteners such as splenda, nutrasweet, and others. While useful, such ice creams lack one of the traits that consumers desire, use of a natural sweetener. Blue agave nectar, a natural sweetener, offers an opportunity to develop an ice cream without the use of refined sucrose. The primary goal of this project was to explore this possibility with a focus on assessing select properties to determine whether such development may lead to an acceptable product and an alternative to ice creams sweetened with sucrose.

Therefore the specific aims of this study were:

1. To develop a “novel” ice cream made with a minimally processed sweetener (blue agave nectar).
To compare the select properties of the novel ice cream with a commercially sold ice cream for consistency, melting, texture (firmness) and surface appearance (smoothness).

STATEMENT OF THE PROBLEM

Many dairy products consist of sucrose or artificial sweeteners as primary sweeteners. Although most of the results of the use artificial products are favorable, many consumers desire foods made with more minimally processed ingredients, ingredients that maintain most or all its original nutrients. There are several studies that involve the effects that refined fructans have on dairy products (Villegas et al, 2010; Glibowski, 2009; Akalm et al, 2008; Fagan et al, 2006; Tarrega et al, 2006; El-Nagar et al, 2002). The results were a sweeter and firmer dairy product with less calories and fat. However, the chemical and physical complexity of minimally processed foods and its synergistic effects offer better biological benefits to the human body (Kinmonth et al, 1982). It is therefore conducive to study the rheological characteristics of a fructan-rich minimally processed food, raw blue weber agave nectar, as a primary sweetener for ice cream.

Blue weber agave tequilana (Agave Tequilana Weber var. azul) is a plant that is native to the Jalisco subtropical region in Mexico. It is primarily known for making the alcoholic beverage, tequila (Bousios et al, 2007). The plant grows and spreads runners from a “mother” plant. The runners mature in about 7 years and grow to more than 6 feet. The leaves are trimmed to expose the “pina” which is harvested and replanted or cultivated to make blue agave nectar. The blue-colored wax on the agave leaves gives the pina its bluish color and thus the name “blue” agave. According to Morales-Serna et al (2010), agave tequilana weber contains homoisoflavanones. Homoisoflavanoids have a similar structure as flavonoids and display many of its characteristics (Debnath et al, 2010; Kuo et al, 2004). Flavonoids can be classified into
groups such as chalcones, flavones, flavonols, anthocyanins and others. The displayed color of flavonoids depends on the number of hydroxyl groups on the B-ring. As for anthocyanins, the larger the number of hydroxyl groups, the bluer the pigment. This may explain the bluish color of the pina. Also, intermolecular stacking by self-associating molecules can stabilize anthocyanins and cause bluing and intense pigmentation (Tanaka et al, 2008).

After the fibrous blue pina is cut, it is pressed to release a fructan-rich juice. The juice is oxidized and filtered through carbon-activated filters. During this process the enzyme, fructan exohydrolase, releases the last fructose monomer from the fructan chain (Ritsema et al, 2003). After filtration, the juice is hydrolyzed at temperatures less than 161°F (72°C) to release Maillard compounds that make a dark sweet nectar as the fructan metabolizes to fructose (Mancilla-Margalli et al, 2002). Nectars that are hydrolyzed at temperatures below 118 °F (48 °C) maintain its natural nutrients and enzymes and are recognized as “raw” and a “whole” food. Lighter nectars undergo multiple filtrations and hydrolyzed to 161°F (72°C). The juice thickens during the evaporation process. The Organic Raw Blue Agave Nectar used in this experiment was hydrolyzed at temperatures below 118 °F (48 °C) (Appendix A).

The assumptions of this study were:

1. All the used ingredients were purchased locally and are of standard quality.
2. All the laboratory equipment were properly calibrated and provided valid and reliable results.
3. All the experimental samples were produced from the same formula and stored the same.
4. The integrity of the controlled samples was maintained during transport to the FSU Foods Laboratory.

The advantages of this study were:
1. All the ingredients are labeled and considered as safe according to GRAS and/or the USDA.

2. All the products were locally purchased (within a 25 mile radius of the FSU Foods Laboratory).

3. All the samples were made with the same formula and preparation instructions.

The possible limitation of this study was:

1. The storage temperature of the controlled sample may possibly vary during time intervals before its purchase.
CHAPTER 2
REVIEW OF LITERATURE

CARBOHYDRATES

Carbohydrates (carbon hydrate) are generally formulated as $C_x(H_{2x}O_x)$ and are called saccharides, or sugars. They are found mostly in plants. Carbohydrates are classified according to their size such as mono-saccharides, di-saccharides, and poly-saccharides. Monosaccharides are simple sugars that can be further classified by the number of carbons ($x$). For example, $x = 3$ (triose), 4 (tetrose), 5 (pentose) and 6 (hexose). It can also be classified by its carbonyl group, a carbon double bonded to an oxygen atom (Figure 1). Functional groups are a group of atoms that determine the chemical reactivity of a molecule. Aldehydes and ketones are functional groups that contain the carbonyl group that typically participate in oxido-reduction reactions. These functional groups are a part of carbohydrates as well as other compounds. For example, fructose is a ketohexose (a 6-carbon sugar molecule) that contains a ketone group. Aldehydes have 1 hydrogen and 1 carbon atom bonded to the carbonyl group (Figure 2). Ketones have at least 2 carbon atoms bonded to the carbonyl group (Figure 3). The presence of the carbonyl group creates a polar region where water attaches to create a hydrogen bond making aldehydes and ketones water-soluble (Bloomfield et al, 1996).

![Figure 1: Carbonyl group](image1.png)
![Figure 2: Aldehyde](image2.png)
![Figure 3: Ketone](image3.png)
SUCROSE METABOLISM

Sucrose is a disaccharide where the aldehyde group of the glucose molecule links with the ketone group of the fructose molecule (Figure 4). The linkage can be broken (hydrolyzed) by acids, yeasts or enzymes. The hydrolysis produces a mixture of fructose and glucose molecules, called invert sugars (Figure 4).

![Figure 4: Sugar inversion- sucrose molecule hydrolyzed to a glucose and fructose molecule.](image)

In humans, when sucrose is consumed and enters the stomach a glycoside enzyme, hydrolase, catalyzes the hydrolysis of sucrose into glucose and fructose molecules (Figure 4). The molecules enter the duodenum where it is rapidly absorbed into the bloodstream. Any undigested sucrose molecules are hydrolyzed in microvilli lining of the duodenum by the enzyme, sucrase (or invertase) before entering the bloodstream. The molecules are then transferred to cells throughout the body by insulin and transported into those cells via glucose 4 transporters (GLUT 4) (Bray, 2007).

FRUCTOSE METABOLISM

Fructose is a monosaccharide found in fruits and plants and is the sweetest of all naturally occurring carbohydrates. It can also be produced by the hydrolysis of sucrose (Figure 4) and is molecularly the same (an isomer) as glucose but is structurally different. As previously mentioned, fructose is a 6-carbon sugar molecule containing a ketone group. When alcohol binds to its carbonyl group, the molecule cyclizes to form internal hemiketals (half ketones).
This causes the 6-carbon ring structure to cycle into a 5-carbon ring structure where the -OH (hydroxyl group) on carbon 5 is converted into the ether linkage to close the ring with carbon 2. The 5-carbon ring offers a sweeter taste.

Within the human body, fructose molecules are absorbed within the duodenum via facilitated transport by the glucose-5 transporter (GLUT 5). Facilitative transport systems proceed down concentration gradients. The downhill concentration gradient of fructose crosses the intestinal mucosa. GLUT 5 is a fructose transporter located on the apical border of enterocytes in the small intestine (Uldry et al, 2004). Facilitative transport occurs when fructose molecules pass across a biological membrane through specific protein portals embedded within the membrane. The glucose-2 transporter (GLUT 2) is secondary whereas fructose competes with glucose for absorption. This normally occurs when there is a deficiency or malfunction of the GLUT 5 transporter (Gatley, 2003) (Buchs et al, 1998). After the fructose molecule has been absorbed by the small intestine, it transfers to the liver via the hepatic portal vein. Within the liver, it is phosphorylated by the enzyme fructokinase to make fructose 1-phosphate (F-1-P). The fructose molecules are hydrolyzed by many enzymes to yield intermediates (in the gluconeogenic pathway) for glycogen synthesis. After the completion of glycogen synthesis and storage, the remaining fructose molecules undergo the fructolytic pathway for fatty acid (FA) and triglyceride synthesis (Rutledge et al, 2007). Excessive consumption of the fructose molecules from refined sources such as sucrose and high fructose corn syrups (HFCS) increases the threshold level of fructose absorption. Any unabsorbed fructose molecules are transported into the large intestine (the colon) and fermented by the colonic bacteria. This can produce carbon dioxide, short chain fatty acids, organic acids and gases (Skoog et al, 2004) that cause bloating, flatulence, diarrhea and gastrointestinal pain (Beyer et al, 2005). For glycogen synthesis, the increased concentration levels of dihydroxyacetone phosphate (DHAP) and
glyceraldehyde 3-phosphate in the liver direct the gluconeogenic pathway towards glucose and its storage as glycogen (Pamiak et al, 1988). For triglyceride synthesis, excessive acetyl-CoA can generate excessive citrate intermediates within the Kreb’s cycle (also known as tricarboxylic acid or citric acid cycle), causing citrate to transport out of the mitochondrion into the cytosol. The enzyme, citrate lyase, catalyzes the conversion of citrate and CoA into acetyl-CoA for further FA synthesis (Martin et al, 1962) (Sun et al, 2010). Another route towards FA synthesis is when DHAP is converted to glycerol 3-phosphate causing a glycerol backbone to be synthesized for the triglyceride molecule. Before leaving the liver, triglycerides are incorporated into very low-density lipoproteins (VLDL), which is stored in peripheral fat and muscle cells, leading to a high risk of obesity and heart disease (Rutledge et al, 2007).

**FRUCTAN METABOLISM**

Polymers are repeatedly linked molecules. Fructans consist of linear and branched fructose polymers bound with a single glucose molecule (Figure 5) (Vijn et al, 1999). High concentrations of fructans are in tubers such as wild yam, Jerusalem artichoke, chicory, cassava, onion, garlic, agave and others. There are 3 types of fructans: Inulin, linear fructans generally linked by $\beta(2\rightarrow1)$ glycosidic bonds (Figure 8); Levan, linear fructans generally linked by $\beta(2\rightarrow6)$ glycosidic bonds; and graminan, branched fructans linked by both $\beta(2\rightarrow1)$ and $\beta(2\rightarrow6)$ glycosidic bonds (Waterhouse et al, 1993). Blue weber agave tequilana (agave tequilana weber var. azul) consists of graminan fructans due to its complex highly branched $\beta(2\rightarrow1)$ and $\beta(2\rightarrow6)$ glycosidic linkages (Figure 6: Group 1) (Mancilla-Margalli and Lopez, 2006).
Fructans are soluble non-digestible dietary fibers that yield fructose molecules when hydrolyzed (broken down). They do not naturally hydrolyze into monosaccharides during human digestion due to the lack of required metabolic enzymes. The fibers serve as a fermentable substrate in the colon and therefore do not elevate blood sugar levels. It remains intact as it passes through the stomach and duodenum.

Within the colon, fructans have the ability to stimulate the activity of probiotics such as bifidobacteria. These probiotics possess the enzyme, $\beta$-fructosidase, which ferments and metabolize the fructans into short-chain fatty acids (acetic, propionic, and butyric acid), lactic acid, hydrogen, methane, and CO$_2$ (Vrese et al, 2008).

In seeds, phytates are predominantly in the form of calcium, magnesium and potassium salts. These salts reduce the bioavailability of involved micronutrients causing them to be eliminated with the excretion of feces (Kim et al, 2010). Bifidobacteria, as well as lactobacteria, can release phosphorus from phytates and hydrolyze the phytates from the micronutrient making them water soluble and absorbable (Famularo et al, 2005). This process increases the bioavailability and thus the absorption of calcium, which has been known to reverse the effects of osteoporosis.
Many refined (isolated) fructan products are generally recognized as safe (GRAS) by the U.S. Food and Drug Administration (FDA) and are used in creating novel food products. There are molecularly different types of fructan products that can be used as low calorie fat and sugar replacements as well as bulking and texturizing agents (Tungland et al, 2002). Fructans can be classified by chain lengths or the average degree of polymerization (DP). Oligofructose are short-chained (2-7 monomers), native (12 monomers), and long-chained (22-25 monomers) (Gonzalez-Tomas et al, 2008). Lopez et al (2003) determined the fructan linkage type of agave tequilana by permethylation, reductive cleavage, acetylation and gas chromatography-mass spectrometry (GC-MS) analysis, respectively. The degree of polymerization (DP) was analyzed and confirmed by the...
C\textsuperscript{13} nuclear magnetic resonance (C\textsuperscript{13}-NMR) and the matrix-assisted laser desorption time-of-flight mass spectrometry (MALDI-TOF-MS). The analyses showed that the DP for agave tequilana ranged from 3 to 29 units with a complex mixture of $\beta(2\to1)$ linkages in the linear chain and some $\beta(2\to6)$ linkages in branching chains. Smaller chained fructans (oligofructose) exhibit a sweet taste and are more soluble than other chain lengths. Its sweetness is similar to sucrose (Villegas et al, 2007). Longer chains work as an emulsifier to promote fat-like textures (Vijn et al, 1999). They can also form microcrystals. The microcrystals interact to form aggregates that create fine and creamy textures that promotes a smooth sensation to the human tongue (Bot et al, 2004; Franck, 2002; Kaur et al, 2002). According to the DP of agave tequilana, the use of blue agave tequilana in dairy products should offer similar characteristics to ice cream as the refined short and long chain fructans. It is therefore, hypothesized that the "raw" blue agave tequilana nectar, would be a potential sweetener that would support the creamy texture of dairy products, specifically ice cream as compared to that sweetened with sucrose.
CHAPTER 3

MATERIALS AND METHODS

MATERIALS

The experimental novel ice cream samples were made with pasteurized non-homogenized Ocheesee Creamery (Blountstown, FL) whole cow’s milk and cream, pasteurized Organic Eggland’s Best (Jeffersonville, PA) large chicken eggs (the yolk), Organic Raw Blue Agave Nectar (Sugarland, TX), and Frontier Gourmet Uganda (Organic) Vanilla Extract (Norway, IA). The products were purchased from a local Publix grocery store and Earth Fare health food store.

The equipment that was used included a General Electric refrigerator/freezer Model GTS18HCRERWW (Louisville, KY), Whynter Stainless Steel Ice Cream Maker Model CM-15LS (Santa Fe Springs, CA), calibrated cooking thermometer, a timer, 1 ½ quart stainless steel cooking pot, 2 ½ cup measuring cup, 4 ounce (½ cup) measuring glass, ¼ cup measuring cup, 1/8 cup measuring spoon, 3 bowls (1 quart capacity), 1 stainless steel strainer, 1 ladle, 1 whisk, 12 inches of double layered cheesecloth, 2-16 oz styrofoam cups (with lids), and a 5 inch sheet of plastic wrap.

The commercially sold Häagen-Dazs® Vanilla All Natural Ice Cream (Oakland, CA) served as the control. This brand was chosen because of its well-known quality and ready acceptance by the United States consumers. The ingredients (according to the container) were cream, skim milk, sugar, egg yolks and vanilla extract. One ½ cup serving is equivalent to 102 grams (250 calories). The ½ cup serving contains 10 grams (or 10%) saturated fat.
PREPARATION OF ICE CREAM

The experimental novel ice cream formula was made with 1 ½ cups of whole milk, ½ cup of cream, 5 egg yolks, ¼ teaspoon of vanilla extract and 2 ½ ounces of blue agave nectar. The egg yolks were separated from the albumin and stored in a bowl. The whole milk was heated in a pot to 130°F. About ¼ cup increments of the heated milk were stirred into the egg yolks. After ¾ cup of heated milk was added, the entire egg mixture was poured into the heated pot. The mixture was continuously stirred until heated to 160°F. The entire mixture was poured through a stainless steel strainer into another clean bowl and placed into the freezer for 45 minutes. Afterwards, the mixture was stirred while adding the cream and vanilla extract. It was then poured into another clean bowl through a stainless steel strainer layered with the 12 inches of double-layered cheesecloth. The blue agave nectar was stirred into the strained mixture. The mixture was then poured into the ice cream maker and churned to -20°C (for about 40-45 minutes). The frozen ice cream was transferred into the 16 oz styrofoam cups, covered with plastic wrap and a lid and stored in the freezer. The formula expanded to a 1-quart batch (907 g). The batch contained 81.5 g of milkfat (Table 1). One ½ cup serving contained 10% saturated fat.

Table 1: Fat composition of novel ice cream formula

<table>
<thead>
<tr>
<th>Non-homogenized pasteurized milk:</th>
<th>5% Butterfat in 64 oz or 8 cups (1814 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>= 91 g Butterfat in container</td>
</tr>
<tr>
<td></td>
<td>1.50 cups (used) x 91 g/8 cups =</td>
</tr>
<tr>
<td></td>
<td>17 g saturated fat</td>
</tr>
<tr>
<td>Non-homogenized pasteurized cream:</td>
<td>50% Butterfat in 32 oz or 4 cups (907 g)</td>
</tr>
<tr>
<td></td>
<td>= 454 g Butterfat in container</td>
</tr>
<tr>
<td></td>
<td>.50 cup (used) x 454 g/4 cups =</td>
</tr>
<tr>
<td></td>
<td>57 g saturated fat</td>
</tr>
<tr>
<td>Organic Egg:</td>
<td>1.5 g Saturated fat per 58 g egg</td>
</tr>
<tr>
<td></td>
<td>5 eggs (used) x 1.5 g/egg =</td>
</tr>
<tr>
<td></td>
<td>7.5 g saturated fat</td>
</tr>
<tr>
<td></td>
<td>81.5 g saturated fat/q</td>
</tr>
</tbody>
</table>
COMPOSITIONAL ANALYSIS

Unless otherwise reported, two different batches for each ice cream formula were analyzed in quintuplicate (totaling ten tests for each formula)

QUALITY ASSESSMENTS

Consistency

The consistency of the samples was assessed using the Bostwick Consistometer (CSC Scientific Company Inc., Fairfax, VA) (Figure 7), 15 mL test tubes, a calibrated cooking thermometer, and an electronic timer. The Bostwick Consistometer was used to measure the consistency by determining how far the sample traveled in 30 seconds (s) on the horizontal surface trough under its own weight. It is designed to stand at a horizontal (180°) angle. The equipment was calibrated by twisting two screws (located behind the sample reservoir) to either raise or lower it until the leveling bubble on the front of the instrument is centered. This process ensures that the platform is set at the appropriate horizontal position. It also allows the formula to properly flow along the sample trough without the influence of gravity, which can lead to a false reading

The “product gate” was closed by pulling and holding it down while pulling the lever arm upward to its fullest extent until it clamped the top of the product gate. Fifteen milliliters (mL) of the samples at temperatures ranging from 18°C and 20°C were poured into the sample reservoir. The lever arm was pressed down to release the sample. Simultaneously, an electronic timer set for 30 s was activated. After 30 s, the distance (cm) traveled by the sample (indicative of consistency) was recorded according to its placement on the graduation marks inside the trough. After each measurement, the apparatus was washed with soap and water and dried to prevent any surface moisture from decreasing the friction, leading to false readings.
Melting

The melting properties were assessed using 250 mL Erlenmeyer flasks, small-sized plastic analytical funnels, 15 mL polystyrene plastic measuring test tubes, a calibrated cooking thermometer, a tablespoon, teaspoon, and an electronic timer. The funnels were placed in the flasks. The temperature of the frozen batch was measured and recorded. The temperature of all batches ranged from -16.5 °C to -16.0 °C. Twenty mL of the ice cream were measured, placed in each funnel and allowed to melt into the flasks for 30 minutes (min) (Figure 12). After 30 min, the funnels were immediately removed from the flasks beginning from the first placed sample to the last. The melted samples were poured into test tubes (Figure 8) and measured as volume (mL) of drip.
Texture (Firmness)

The TA.XTPlus Texture Analyzer (Texture Technologies Corporation, Scarsdale, NY) with the Multiple Puncture Probe attachment (Figure 9) a calibrated cooking thermometer and 8 oz plastic containers with lids were used to assess the firmness of the frozen formulae. The texture analyzer was successfully calibrated using a 5 kg loading cell, which represented the projected maximum force on the tested products. Three different batches of each formulae were used. One-half cup of each frozen formulae was placed in the 1cup plastic containers. Ten samples for each formulae were prepared. The containers were covered with lids and stored in the refrigerator freezer to reset. The temperatures ranged from -7.6°C to -15.6°C. The conditions were the following: penetration distance = 13 mm, trigger force = 5g, probe speed during penetration = 2 mm s⁻¹, and probe speed post penetration = 10 mm s⁻¹. The analyzer captured the force, distance and time at a rate reaching 500 points per second. The results were displayed by a 32-bit computer software, Exponent, and were recorded manually. The temperature of the samples was measured immediately after force was applied to eliminate false readings from prior punctures.
Surface Appearance (Color)

The Photovolt Reflection Meter Model 670 (Photovolt Instruments Inc, Minneapolis, MN) and 30 mL beakers were used to assess the surface appearance (color) properties of the formulae. The reflection meter was successfully calibrated against a standard grey plaque that is used as a white backing in paper opacity tests (Figure 10). The meter was then adjusted by using the sensitivity buttons. The sensitivity was set to the standard 73.4 units. Five ml from each melted sample that was used to assess firmness were poured into a 30 mL beaker. The beaker was placed on the search unit. Three colored filters (amber, blue and green) were used to define the color of the samples. Each filter was individually inserted into the search unit. As the light reflected from the samples a mix of wavelengths were absorbed through the filters causing a reading. The triamber (A), triblue (B), and trigreen (G) reflectance measurements were recorded and converted to their color reflectance value (A, B or G) to be analyzed.
STATISTICAL ANALYSIS

Results are expressed as Mean ± Standard Deviation (SD). Statistical differences were determined using SPSS Base 19 (SPSS 2010, Chicago, IL) paired sample T-Test. The statistical significance was set at \( p \leq 0.05 \).
CHAPTER 4

RESULTS AND DISCUSSION

Melting

For the melting rate assessment, the Mean volume of the experimental (16.15 ± 2.75) and control samples (17.55 ± 1.28) showed no significant difference ($p = .25$) (Figure 12).

![Figure 12: Mean comparison of melting (mL) between ice cream formulae.](image)

Consistency

The comparison showed no significant difference ($p = .95$) between the experimental (4.48 ± .92) and the control samples (4.50 ± 0.65) (Figure 11).

Consistency (or viscosity) is a measure of the resistance to flow of a liquid. The measure
of consistency evaluates the mouthfeel of a food, the perceived textural qualities of a food while in the mouth. The Bostwick Consistomer was used to hypothetically measure the flow of the ice cream formulae once consumed.

Figure 13: Mean comparison of consistency (cm) between ice cream formulae

Texture (Firmness)

With the force of with a Mean force of $0.28 \pm 0.16$, the experimental samples averaged to be softer ($p = .001$) as compared to the control samples ($0.63 \pm 0.20$) with distance and time being constant (Figure 13).

Fructans are water soluble and bind to water molecules to form a gel-like network (Franck, 2002). This gel-like network creates a soft, creamy and smooth texture in dairy products. Mancilla-Margalli and Lopez (2006) reported agave tequilana to have a very high
water soluble carbohydrate (WSC) concentration of 900 mg/g as compared to other agave species that ranged from 360-640 mg/g. Fructans were the primary WSC in agave. The TA.XTPlus Texture Analyzer was therefore used to measure firmness (softness as the peak compression force (g) during the penetration) of the formulae.

![Figure 14: Mean comparison of force (kg) on ice cream formulae.](image)

Surface Appearance (Color)

The results showed a significant difference between the experimental samples (Y glossy = 1.09) and the controls (Y glossy = .92) (Table 2). This suggests that the experimental formula may have smoother mouthfeel compared to the control. This is important because the quality of ice cream is determined by its smoothness (or coarseness). Therefore, the reflectometer was used to measure the amount of light (nm) reflected from the samples to assess its color.
(glossiness) which is a directly related to its smoothness. The quality was determined by its yellowness, Y glossy (or Y %), using the standard ASTM referenced equation \((A - B) / G\).

The stabilization of ice cream during storage is dependent primarily on the control of ice crystal growth through proper formulation and temperature (Hagiwara, 1996). The fat content and type of sweetener also affects the crystallization behavior of ice cream (Hartel, 1996). The degree of crystallization of ice cream shapes the perception that consumers have on its smoothness and cooling sensation. Large numbers of small ice crystals produce a smooth texture and storage stability. According to Hartel (1996), the critical threshold detection size must be determined to predict the smoothness of ice cream. The critical threshold detection size is generally the mean size of detected crystal distribution. Historically, the critical threshold detection size for the desirable smoothness of dairy products has ranged from 20-55 \(\mu m\) (Arbuckle, 1986 & 1960; Berger et al, 1972). Consequently, Wattendorff (1976) conducted 81 measurements on 25 micrographs to show that the crystal lamellate (membrane) of the

<table>
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<th>Novel</th>
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Mean | 65.7 | 10.99 | 50.42 | 71.89 | 16.37 | 57.73 |
SD  | 1.68 | 0.61  | 1.99  | 3.39  | 0.65  | 1.38  |

* Y%\(^\text{a}\) 1.09 0.96

\(^{a}\) Yellowness \(\% (Y\%) = (A - B) / G\)

The stabilization of ice cream during storage is dependent primarily on the control of ice crystal growth through proper formulation and temperature (Hagiwara, 1996). The fat content and type of sweetener also affects the crystallization behavior of ice cream (Hartel, 1996). The degree of crystallization of ice cream shapes the perception that consumers have on its smoothness and cooling sensation. Large numbers of small ice crystals produce a smooth texture and storage stability. According to Hartel (1996), the critical threshold detection size must be determined to predict the smoothness of ice cream. The critical threshold detection size is generally the mean size of detected crystal distribution. Historically, the critical threshold detection size for the desirable smoothness of dairy products has ranged from 20-55 \(\mu m\) (Arbuckle, 1986 & 1960; Berger et al, 1972). Consequently, Wattendorff (1976) conducted 81 measurements on 25 micrographs to show that the crystal lamellate (membrane) of the

22
Agavoideae species has an average thickness of 13.3 nm. This measurement is $10^3$ (or 1000) times smaller than the critical threshold detection of 20-50 μm, thus projecting possibilities of better smoothness and storage stability of ice creams sweetened with raw blue agave nectar. The tissues of the agavoideae species contain suberized styloid crystal cells. The cell walls are long and rectangular and exist in a crystal-like cross section where both ends taper off into a blade (Rothert et al, 1899). The cell walls and the sheath surrounding the walls are infiltrated with a waxy waterproof substance that makes the cells resistant to acidic environments (Meyen, 1837). Because of its molecular structure, fructans are highly soluble and difficult to crystallize within aqueous solutions. However, its binding abilities with water molecules, along with the high particle fat composition of the formulae, may produce the necessary characteristics of smoothness that is desired in ice creams.
CHAPTER 5

CONCLUSION

The main goal of the project was to assess whether using a minimally processed sweetener, blue agave nectar, as the primary sweetener in ice cream would lead to an acceptable product as compared to an ice cream sweetened with sucrose. The experimental ice cream formula was developed using comparable ingredients and fat content as the control. Four quality indices, melting (cm), consistency (mL), texture (firmness) (kg), and surface appearance (color); were used to compare the developed formula with the control. Five tests for 2 different batches of the experimental and the control formulae were assessed. The results predict the hypothetical functioning and sensation that the formulae would offer (in comparison to each other) during human consumption.

The results indicated no significant difference in the melting rate ($p = .25$): experimental (16.15 ± 2.75) and controlled formulae (17.55 ± 1.28). This suggests that once the formulae are consumed, it would melt at a similar rate during similar temperatures.

The average rate of flow (consistency) was also similar ($p = .95$): experimental (4.48 ± 0.92) and the controlled (4.50 ± 0.65). After the melting process, it is suggested that the formulae would flow (towards the throat) at a similar distance during similar temperatures.

However, there was a significant difference ($p = .001$) in the exertion of force with the Mean force of 0.30 (± 0.16) for the experimental as compared to the control samples (0.63 ± 0.20) with distance and time being constant. The results leave an assumption that the frozen experimental formula would feel softer to the tongue as compared to the control formula.

The surface appearance (color) was also significantly different between the experimental ($Y\% = 1.09$) and the control ($Y\% = .96$), suggesting that the experimental formula will offer a smoother sensation as compared to the control formula.
The overall results suggest that the experimental ice cream may be an acceptable alternative to the control ice cream. However, overall satisfaction should be concluded by human sensory analysis.
APPENDIX A

Organic Raw Blue Agave Assurance Statement

Wholesome Sweeteners’ supplier of Organic Raw Blue Agave manufactures and processes Organic Raw Blue Agave exclusively for Wholesome Sweeteners—and does so according to rigorous standards. This is in line with guidelines and our understanding from the Raw Foods Constituency that:

“Raw foods are full of living enzymes that replace those exhausted cells. These enzymes are slowed down at temperatures near 118 degrees F and are completely destroyed at approximately 130 degrees F. Vitamins, minerals, proteins, basically everything required for a healthy life are destroyed at temperatures that "cooked" foods are heated up to.”

As stated on the label, the only ingredient in Wholesome Sweetener Organic Raw Blue Agave is pure Organic Raw Blue Agave. There are no additives or enhancers in the product.

Nigel Willerton
Chief Executive Officer
781-490-9751

November 9, 2006
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REFERENCES


United States Department of Agriculture. MyPyramid. Available from:


BIOGRAPHICAL SKETCH

A. Positions and Honors

*Professional Positions Held (Beginning with most current)*
Nutrition Educator/CEO/President (wHōlife International, LLC) - Currently
Outreach Nutrition Educator (Center for Health Equity) - Currently
Graduate Research Assistant (Florida State University- BHL Center) - Currently

*-WENT BACK TO SCHOOL-*
OPS Student Assistant – (Agency for Health Care Administration)
Medical Health Care Program Analyst (Agency for Health Care Administration)
Regulatory Analyst III (Agency for Health Care Administration)
Regulatory Analyst II (Agency for Health Care Administration)
Financial Examiner/Analyst I (Department of Financial Services)
OPS Student Assistant – (Office of the Auditor General)
OPS Student Assistant – (Leach Fitness Center – FSU)

*Selected Honors*
Silver Pickle Award – Agency for Health Care Administration
Beta Club award – James A. Shanks High School

*Other Experience and Professional Memberships*
American Dietetic Association (ADA)
National Organization for Blacks in Dietetics and Nutrition (NOBIDAN)
American Association of Family & Consumer Sciences (AAFCS)
Florida Dietetic Association (FDA)
Tallahassee Dietetic Association (TDA)
Student Dietetic Association (SDA)
Student Understanding Nutrition Now (SUNN) – Past Treasurer
Certified Peer Health Educator (at FSU) - Past
B. Selected Scholarly Activities

Presentations
Gadsden Federal Healthy Start Project (Team Leader) - 2011
Nutrition Curriculum & Training development - 2011
Outreach Nutrition Presentations – 2010 - 2011
Nutrition Seminars at FSU - 2009
Basic Nutrition Education to FSU students, 2008 - 2009

Publications
Improving Blood Pressure Control in African Americans: A Church-Based Project

(Co-Author and presenter of AAFCS Poster) - 2010

C. Research Support
An ice cream sweetened with a fructan-rich minimally processed sweetener: blue agave nectar, with
Dr. Shridhar Sathe.
Adult Health Literacy Foto-Novella Project, with Dr. Penny Ralston and Dr. Gail Bellamy.
National Institute of Health Cardiovascular Disease Church-based Intervention, with Dr. Penny
Ralston.
Capital Health Plan Hypertension Church-based Intervention, with Dr. Penny Ralston.

Scholarships and Fellowships
Fred May Scholarship (Gadsden County) - From 2007 to 2011
FSU Assistantship – 2009 to 2010