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Sensory and chemical/nutritional characteristics of concept foods made from underutilized sweet potato roots and greens

Shinyoung Kim

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By

Shinyoung Kim

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Sensory and chemical/nutritional characteristics of concept foods made from underutilized sweet potato roots and greens

By

Shinyoung Kim

Approved:

Juan L. Silva
(Major Professor)

M. Wes Schilling
(Committee Member)

Stephen L. Meyers
(Committee Member)

Lurdes Siberio Wood
(Committee Member)

Marion W. Evans, Jr.
(Graduate Coordinator)

George M. Hopper
Dean
College of Agriculture and Life Sciences

Name: Shinyoung Kim

Date of Degree: August 9, 2019

Institution: Mississippi State University

Major Field: Food Science and Technology

Major Professor: Juan L. Silva

Title of Study: Sensory and chemical/nutritional characteristics of concept foods made from underutilized sweet potato roots and greens

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Candidate for Degree of Master of Science

Frozen desserts and a smoothie were developed from underutilized sweet potato roots and from greens, respectively. Frozen desserts were formulated with mashed sweet potato, coconut oil, and dairy, almond, or soy milk. Sweet potato greens were blanched and frozen before being made into a smoothie. Increased mash in the frozen desserts resulted in better ($p \leq 0.05$) color, overall intensity of flavor, and sweet potato flavor. Descriptive and consumer panelists found no differences ($p > 0.05$) in frozen desserts with difference base milk products. Almond milk frozen dessert was lower in total solids, protein and Brix ($p \leq 0.05$), compared to dairy and soy milk. Greens blanched for 30s showed complete peroxidase inhibition and acceptable texture. Blanching decreased carbohydrates and soluble minerals of greens mainly due to water. The results showed that consumers liked lactose-free sweet potato-based frozen desserts and showed that properly blanched greens could be used in value-added products like smoothies.

DEDICATION

I dedicate this thesis to my family. To my beloved parents, Juhwan Kim and Keumhee Lim, who have always inspired me to be a better person through their unconditional love. To my beloved sister and best friend forever, Shinae Kim.

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CHAPTER I

INTRODUCTION

Sweet potato (*Ipomoea batatas*) is a dicotyledonous plant of the Convolvulaceae with edible tuberous roots and greens. It originated from Central and South America, and is mostly grown in tropical and subtropical climates (O'Brien, 1972). It is the seventh most consumed staple food in the world. Asia comprises over 90% of total production of sweet potatoes (FAO, 2011), with China at the lead producing 67%. Sweet potato is also considered as a food security staple in developing countries due to its adaptability to climate change and productivity under drought conditions (Bonvell-Benjamin, 2007).

This crop has a variety of nutritional benefits with respect to both macro- and micro- nutrients. Sweet potato roots are composed mainly of complex starch with dietary fiber and are abundant in antioxidants, and prominent in carotenoids when the flesh is orange (Burri, 2011). Sweet potato is considered a substitute for simple starchy foods such as wheat bread or potatoes, for diabetic and weight control diets (Jenkins et al., 1988) due to their low (below 50) Glycemic Index (GI) (Jenkins et al., 1981). Moreover, beta-carotene can be converted to retinol in the body to 1-12 Retinol Activity Equivalent (RAE) (Solomons, 2001). About 100g of sweet potato fulfills the recommended daily intake of vitamin A (van Jaarsveld et al., 2005). Vitamin A is involved in immune and vision functions, as well as cell division and growth. For those roles, pre-vitamin A contained in sweet potatoes can be an important nutrient to both children and pregnant women (Solomons, 2001). Therefore, sweet potatoes are considered as intervention in prevention of vitamin A deficiency for children in developing countries (van Jaarsveld et al., 2005). In addition, B vitamins, vitamin C, and antioxidants in sweet potatoes increase bioactivity in the human body, leading to potential medicinal use.

United States sweet potato production has greatly increased from 625 million kg (1.38 billion lb) in 2000 to 1.4 billion kg (3.1 billion lb) in 2015 (USDA NASS, 2018). In the U.S., sweet potato is primarily grown in the Southeast and California, where the climate is warmer with more frost-free days. North Carolina has been the No.1 sweet potato producing state since 1971. Their production has doubled in the last 15 years. Mississippi, the third biggest producer, has increased production by 155% since 2000 (Johnson et al., 2015). In 2018, sweet potatoes were grown on 29,000 ac in Mississippi yielding 245 million kg (540 million lb) and worth an estimated $118 million (MDAC, 2018). However, only approximately half of the sweet potato roots are USDA No. 1 grade. The remainder are either sold in value-added packaging, processing markets, left in the field, used for non-human food purposes, or discarded.

In spite of increased sweet potato production, sweet potato has relatively limited uses in the U.S. unlike in many Asian countries. In Korea, for example, sweet potato is consumed boiled, baked, fried, dehydrated, semi-dried, and porridged, and various types of products are commercially sold. On the other hand, in the U.S. sweet potato is mostly sold fresh during the Thanksgiving and Christmas holiday season for domestic use in casseroles and pies (Parvin, Walden, & Graves, 1999). Commercial use of sweet potato is limited to pureed or dehydrated sweet potato, frozen fries, fried or baked chips, baked goods, frozen pre-made casseroles, or pet food (Smith, 2017). To increase the commercial use of sweet potatoes, The Sweet Potato Innovation Challenge was developed at Mississippi State University (http://spchallenge.msucares.com/). Students participated in the program to develop value-added products made from cull roots (roots not for sale in the raw or canners markets). Sweet potato-based ice cream or frozen desserts can be formulated from sweet potato products.

Ice cream is a sweetened frozen dessert made from milk, cream, and non-fat milk powder. Ice cream is a standardized product and as such is defined as a frozen food consisting of dairy ingredients, containing at least 10% of milk fat and at most 10% milk solids non-fat (MSNF) (Marshall et al., 2003; FDA, 2018). However, ice cream made from cow's milk cannot be consumed by those who are allergic to milk, intolerant to lactose, or vegan (Mäkinen et al., 2016). Non-dairy frozen desserts made from plant-based "milks" such as almond, soy, or coconut have recently been introduced in the market. The global non-dairy frozen dessert market reached $400 million in 2017 (Global Market Insight, 2018 http://gminsights.com/). In these dairy free frozen desserts, cream is replaced by vegetable oil to maintain the creamy smooth texture. Coconut oil is used in many commercial products for not only texture but also health benefits (Choo et al, 2010).

Coconut oil is a highly saturated vegetable oil with a sweet aroma. Coconut is a natural source of medium chain fatty acids (MCFAs) that contain more than 50% of the MCFAs out of total fatty acids by weight in oil. MCFAs consist of 6 to 10 carbons, and hence, the hydrolysis and absorption of MCFAs is more efficient than long chain fatty acids as the mechanism of its digestion is similar to glucose (Marten et al., 2006). Coconut oil is widely used in the baking industry for its health benefits and shelf stability.

Coconut oil's high melting/freezing point (24.4°C) enables the possibility of its use in frozen desserts.

In addition to its roots, sweet potato greens are nutrient dense with vitamins and minerals, that are comparable to other leafy green vegetables. Sweet potato greens are composed of essential minerals such as iron, calcium, zinc, as well as vitamins B and C, antioxidants and polyphenols (Islam, 2014). Sweet potato greens are rich in polyphenols, with as much to 17.1% in 100 g dry matter (Islam et al., 2002). These functional bioactive components are said to possess anti-inflammatory, anti-cancer, anti-mutagenicity, and anti-aging health benefits (Johnson & Pace, 2010). Sweet potato greens can be applied in nutrition intervention as a solution to food shortage due to its resistance to environmental changes and capacity for multiple harvests (6 times a year) (Islam, 2014). The consumption of green vegetables can also reduce the risk of chronic diseases in the U.S., which might lower cost of health care. By developing smoothie made from sweet potato greens, this byproduct can be utilized in nutritional interventions and possible chronic disease prevention.

The objectives of this study were to develop sweet potato based frozen desserts to add value to underutilized cull sweet potatoes, and to develop a smoothie product utilizing young sweet potato greens.

CHAPTER II

REVIEW OF LITERATURE

Sweet Potato and Mississippi Production

Sweet potato *(Ipomoea batatas)* originated in Central and South America. Sweet potatoes are now grown in Asia, Africa, Europe, North America, and Australia. Over 90% of sweet potato is produced and consumed in Asia. China produces approximately 80% of sweet potatoes. Sweet potato production in the world exceeded 112.8 million metric tons in 2017 (USDA NASS, 2018). As the seventh most important staple crop (FAO, 2011), sweet potato has been on the rise as a solution to food shortage and nutritional intervention in under-nourished developing countries (Iese et al., 2018).

U.S. sweet potato production has greatly increased in the past 15 years, reaching 1.4 billion kg (3.1 billion lb) in 2015 (USDA NASS, 2018). Per capita consumption of sweet potato was 2kg (4.2lb) in 2000 and increased to 3.5kg (7.7lb) in 2015. Sweet potato is grown in Southern states, whose climate is warmer with more frost-free days (90-150 days required). Mississippi (MS) is the third largest producer of sweet potatoes, following North Carolina and California. Sweet potato, mostly grown in Northeast Mississippi, is the fourth most valuable state crop in the state following soy beans, cotton, and corn (Carter, 2017). Between 2000 and 2015, MS sweet potato production increased by 155% (Johnson et al., 2015) and in 2017, 29,000 ac were harvested with $123 million value (Carter, 2017). Sweet potato production has greatly impacted the Mississippi economy.

According to a Mississippi Sweet Potato 2012 Industry Evaluation by Morgan et al. (2012), the total effect of employment, including both direct and indirect, was 1,059 full time equivalents. With employment compensation and value added dollars, the total output from the sweet potato industry in 2011 was $132 million (Morgan et al., 2012). With the steady growth in the last years, the direct output has doubled from $66.4 million to $123 million (Carter, 2017) so that the total output in 2017 had a large impact on the Mississippi economy.

Nutritional Value of Sweet Potato

The main component of sweet potato is complex starch, yielding one of the densest caloric root vegetables, 86 Kcal /100 g (USDA, 2018). Sweet potato provides high energy, in addition to climate adaptability. It is considered a food source for nutrition intervention in developing countries. Orange-fleshed sweet potato is not only high in calories but also rich in pro-vitamin A. The carbohydrate-abundant crop has a lower glycemic index (GI) than simple carbohydrate sources (Jenkins et al., 1988). The abundance of fiber prevents the absorption of glucose in the small intestine, which reduces the rate of insulin secretion. Sweet potato is considered a good substitute for simple starchy foods such as white bread or potatoes for diabetic diets and weight control diets. (Jenkins et al., 1988)

There are a variety of sweet potatoes that vary in nutritional composition and flesh and skin color: white, purple, yellow, and orange. In orange-fleshed sweet potato, various carotenoids are included with beta-carotene as the most concentrated. Beta-carotene is converted into vitamin A in the body. Approximately 100 g of sweet potato (709 RAE/100 g) fulfills the recommended daily value (RDA) of vitamin A in children and female adults, and in pregnant women and male adults. Vitamin A is involved in immune function and night vision, as well as cell division and growth. Therefore, the pro-vitamin A that is contained in sweet potato is a good source of this vitamin for both children and pregnant women. Vitamin A deficiency in children inhibits growth and can result in birth defects in pregnant women. Sweet potatoes are considered an intervention for the prevention of vitamin A deficiency for children in developing countries (van Jaarsveld et al., 2005). In addition, B vitamins, vitamin C, and antioxidants in sweet potatoes increase bioactivity in the human body with potential medicinal uses.

Sweet Potato Leaves/Greens

Sweet potato leaves/greens contain essential minerals such as iron, calcium, zinc and vitamin C and B, as well as protein and fiber (Ishida et al., 2000). The leaves contain antioxidants: carotenoids, flavonoids, and polyphenols, which are associated with decreased risk of chronic diseases by oxidative free radical scavenging reactions (Johnson & Pace, 2010). Sweet potato greens are especially rich in polyphenols, at concentration as high as 17.1 g out of 100 g dry weight (Islam et al., 2002). Polyphenols have anti-inflammatory, anti-aging, anticancer, and anti-mutagenic properties. The nutritional and functional value of greens is more concentrated than any other comparable leafy vegetables (Islam et al., 2002). Moreover, sweet potato greens, in terms of cultivation, have high yields and are resistant to environmental changes. Sweet potato greens can be harvested every 10 to 15 days, up to 6 times per year, which allows for higher yields than other leafy (Islam, 2014). Despite the numerous potential benefits, sweet potato greens are underutilized in the U.S Stems and leaves, in addition to roots, are commonly consumed in many Asian countries. Although a small amount of greens are consumed by Asian and African Americans in the U.S. they are not considered as an edible vegetable in others living in the U.S (Johnson & Pace, 2010). The utilization of sweet potato greens can be associated with a decreased risk chronic diseases such as cardio vascular diseases (CVD), heart malfunction, diabetes, obesity, and cancers that are prevalent in the United States (Johnson & Pace, 2010). Sweet potato greens can be consumed as spinach alternatives or developed in southern cuisine as boiled or braised greens like collard greens. Juice or smoothie is also a possible product, substituting for spinach or kale, to be more accessible for consumers who are unfamiliar with the concept of edible sweet potato greens as micronutrients food source.

A smoothie is a fruit-based blended beverage with a thick shake-like consistency. The beverage is highly versatile regarding the ingredients, yet rich in vitamins and minerals. Smoothies are also abundant in health-promoting compounds such as phenolic acids and antioxidants (González-Tejedor et al., 2017) and are often supplemented with vegetables or functional foods to increase bioactivity. In a study, moringa (*Moringa oleifera*) leaves have been added to fruit blended beverages to improve nutritional composition (Aderinola, 2018). The addition of moringa leaves decreased the overall acceptability of the smoothies. To satisfy consumer acceptability appropriate ingredients with specific concentration are necessary to go along with nutritional value. The global market size of smoothie and smoothie-like beverages is billion USD and is expected to grow by 6.8% between now and 2023 (Market research future, 2019 https://www.marketresearchfuture.com/) both in vendor and ready-to-drink products. However, ready-to-drink smoothies have limited shelf-life and quality changes during processing and storing due to the high concentration of bioactive compounds and enzyme activities in products. To prolong the shelf-life in consistent quality, thermal processing can be used. High temperature short time (HTST) thermal treatment of a green vegetable smoothies (with spinach) increased shelf-life with microbial reduction but greatly decreased vitamin C content (Castillejo et al., 2016). Thermal processing of smoothies can inactivate enzymes and shelf-life can be extended up to 45-58 days under refrigeration (Rodríguez-Verástegui et al., 2016) (Castillejo et al., 2016)

Ice Cream and Frozen Desserts

Ice cream is a semi-solid foam or custard made from dairy products such as milk, cream, and non-fat milk powder. This complex, sweet tasting colloid is frozen below the freezing point so that it is smooth and creamy (Goff, 1997). Commercially produced ice cream is incorporated with up to 50% of air overrun for desirable texture and increased volume. Ice cream in the United States is defined as a dairy frozen dessert with a minimum of 10% fat and less than 50% overrun (FDA, 2018). Ice cream is categorized into economy, premium, or super-premium depending on its fat content, total solids, and overrun. The greater the amount of fat added, and the less air incorporated will result in a smoother ice cream. However, dairy-based products including ice cream cannot be consumed by those with a dairy-free diet due to lactose intolerance, dairy allergies, and/or veganism.

Plant-based milk alternatives are opaque liquid extracted from legume or tree nuts, such as almond and soy. Compared to cow's milk, plant-based milk alternatives are lower in calories and comparable in calcium content (Mäkinen et al., 2016). Cow's milk can be replaced with fortified plant-based milk alternatives as a source of calcium, but nutritional content depends on its raw materials. Whole milk contains 3.3% protein and almond milk contains 0.5% protein, which is the lowest concentration out of 14 different milk alternatives on the market. The protein content in soy milk varies according to manufacturers. Almond milk and soy milk contain more fiber and less saturated fat than cow's milk (Mäkinen et al., 2016). Plant based milk alternatives are a source of calcium for cardiovascular disease (CVD) patients and consumers with special dietary needs (Mäkinen et al., 2016).

Non-dairy frozen desserts that are made from milk alternatives have recently been introduced and expanded in market share. In 2017, the global market for non-dairy frozen desserts reached $400 million. Although non-dairy frozen desserts are rapidly growing in the market, it is not as acceptable as ice cream. Ice cream made from 100% milk was preferred over 100% soy milk and any other plant-based milk alternative ice cream that was developed in the research (Bisla et al., 2012). In a sensory evaluation study on milk (whole, reduced fat, and fat-free) and soy milk (vanilla, fortified, and organic), regardless of participants ethnicity, milk was preferred (Palacios et al., 2009). Frozen desserts made from milk alternatives replace milk fat with vegetable oil to be vegan and lactose-free. Coconut oil, which predominantly consist of medium chain fatty acids (MCT) is used as a fat replacer in frozen desserts, this improves the quality changes of fat oxidation during storage when compared to highly unsaturated vegetable oil. (Choo et al., 2010) Moreover, MCT in coconut oil improves the texture of frozen desserts by functioning as an emulsifier (Aparecida et al., 2011).

CHAPTER III

MATERIALS AND METHODS

Experiment I- Frozen Desserts

Materials

Sweet potatoes (Beauregard), milk (Great Value Walmart, Bentonville, AZ, US), heavy cream (Great Value), almond milk (Silk, Danone North America, Broomfield, CO, US), soy milk (Silk), and refined coconut oil (Bettrbody Foods & Nutrition LLC, Lindon, UT, US) were purchased from Walmart (Starkville, Mississippi). Cane sugar (Extra fine granulated, United Sugar Corporation, Edina, MN, US), vanilla flavor (23-17-0032, Edgar A. Weber & Company, Wheeling, IL, US), and PGX-1 stabilizer (Danisco, Germantown, TN, US) were obtained from Mississippi State University's Edward W. Custer Dairy Processing Plant (Mississippi State, MS, US).

Sample Preparation

Sweet potatoes were baked at 190°C in a convection oven (Hobart HEC20, Troy, OH, US) for 60 min. After baking, the skin was removed, and the pulp was cooled for 30 min, and pureed at the high speed in a food processor (Cuisinart FP-8SV, Stamford, CT, US) for 3 min at the Ammerman-Hernsberger Food Processing Plant (Mississippi State, MS, US). After it was pureed, the sweet potato mash was stored frozen at -18°C and thawed before use. Milk, heavy cream, sugar, non-fat milk solids, stabilizer, and vanilla flavor were used to make dairy-based sweet potato frozen desserts with different amount of sweet potato mash. For frozen desserts made from different base beverage with 30% of sweet potato mash, heavy cream was replaced by coconut oil due to the similar melting temperature. Skim milk solids (MSNP) was omitted in the formula to develop lactose-free frozen desserts. Formulations are included in Tables 3.1 and 3.2. The ingredients for frozen desserts, without sweet potato mash, were mixed and heated in a pot (30cm diameter, 16cm high) until the mixture reached 50℃. The mixture was then homogenized with thawed sweet potato mash, which was thawed at 4℃ in a refrigerator for 24h, and vanilla flavor, in a food processor at the low setting for 60 s. The mixture was cooled at 4℃ in a refrigerator for 18 h. An ice cream machine (Breville BCI600XL, California, US) was used for initial freezing for 40 min and the samples were stored in plastic containers for the hardening process at -40℃ until they were analyzed.

Chemical Analysis

The Brix and pH of frozen dessert samples (2 replications) were thawed and measured using a pH meter (Fisher Scientific, Fair Lawn, New Jersey, US) and a reflectometer (Abbe-3L Refractometer, Bausch & Lomb, US). The pH meter was calibrated with buffer solutions at pH 4 and pH 7 prior to use. For Brix, a drop of each sample was placed on the prism of the refractometer and measured after calibration with distilled water.

Total Solids and Fat Analysis

Total solids and total fat of frozen dessert samples (2 replications) were measured. Total solids of the frozen desserts were measured according to AOAC method 925.21 (AOAC, 1999). The samples were dried at 105 C in an incubator (ISOtemp oven

200, Model 215F, Fisher Scientific, Hampton, NH, US) for 24 h. Total solids was measured in duplicates. The initial weight of the samples was subtracted from final weight and calculated as:

$$\text{Total Solids (TTS\%)} = 100 * \frac{Final\ weight\ (g) - dish\ weight\ (g)}{Initial\ weight\ (g)} \qquad (3.1)$$

Fat content was determined according to the AOAC method 905.02 (AOAC, 1999) using materials that were purchased from Fisher Scientific. Three g of frozen dessert samples were weighed with curved pipettes and 2 to 3 drops of phenolphthalein was added in each glass mojonnier flask as an indicator for fat extraction. Five ml of distilled water, 1.5 ml of ammonia hydroxide (NH_4OH), and 10 ml of ethanol were added to each flask and shaken for about 25 times with a lid on. Twenty five ml of ethyl ether and 25 ml of petroleum ether were added in each flask and shaken for about 25 times with lids on after each addition. The samples were centrifuged for 30 s. The clear liquid on the top was poured in a pre-weighed aluminum dish, leaving the pink solid sediments in the flasks. The extraction procedure was repeated with 5 ml of ethanol, 25 ml of ethyl ether, and 25 ml of petroleum ether, and it was shaken after each one was added. The clear liquid in the dishes was evaporated on a hot plate for 15 min. The dishes were vacuum dried (15 in Hg) for 5 min, cooled for 7 min, and weighed. The final weight was subtracted by each dish's initial weight. The approximate total fat content was calculated as:

$$\text{Fat (\%)} = 100 * \frac{Final\ weight\ (g) - dish\ (g)}{Initial\ weight\ (g)} \qquad (3.2)$$

Proximate Analysis of Frozen Desserts

Official AOAC methods 990.30 and 934.01 were used for protein and moisture determination, respectively (AOAC, 1999). All the materials were purchased from Fisher Scientific. The fiber was measured by AOCS Ba6A-05 (AOCS, 1997). To determine minerals, inductively coupled plasma mass spectrometry (ICP-MS) was used for metal analysis. Two g of frozen dessert was weighed and transferred to a microwave digestion tube with 3 ml of peroxide and 5 ml of nitric acid (HNO_3). The tube was capped and place in a carousel in a hood for 2 h. The carousel was place in a microwave digester (MARS Xpress, CEM Corporation, Matthews, NC, US). The tube was cooled for 12 h, the cap was removed, and the acid was equilibrated for 30 min in the hood. The digested samples were added to each volumetric flask with 50 ml of deionized water and filtered into the ICP sampler tubes with 0.45 µm, 33 mm, PVDF filters. The ICP-MS analyzer (7900 ICP-MS, Agilent, Santa Clara, CA, US) used gas plasma for the determination of calcium, iron, sodium, and potassium.

Sensory Analysis

Prior to determining the level of mashed sweet potato in the frozen dessert formulations, a descriptive sensory test on ice cream formulations was conducted with a semi-trained panel (n=8) in a descriptive room at the MSU Garrison Sensory Laboratory (Department of Food Science, Nutrition, and Health Promotion, Mississippi State, MS, US). The samples were formulated with three different levels of sweet potato (20%, 30%, and 40% by weight) in ice cream samples made from milk and cream. All other variables were adjusted with an ice cream calculator to maintain the same percentage of fat (10%) and sugar (16%) in each sample. The test was performed to determine whether a difference ($p \leq 0.05$) between the treatments existed and which treatment should be used for final products. The non-dairy frozen desserts were formulated based on the prior descriptive evaluation (15 cm line scale). Descriptive sensory tests on frozen desserts made from different types of milk and milk alternatives (milk, almond milk, soy milk) and smoothie made from sweet potato greens were conducted by the same group of panelists with 2 replications. Each attribute was evaluated by the panelist in 15 cm line scales (Appendix A). Interaction between panelists and treatments were analyzed by SAS (SAS version 9.4, SAS Institute, Cary, NC) and the data from 2 panelists were excluded to reduce outliers in the final statistical analysis. Consumer acceptability tests were conducted at the Pontotoc Ridge-Flatwoods Branch Experiment Station (Pontotoc, MS, US) (n=43) and the MSU Garrison Sensory Laboratory (n=101). A 1-9 hedonic scale (Appendix A) was used to rate each attribute: appearance, aroma, flavor, texture, and overall.

Nutrition Estimation Analysis

Nutrition facts of frozen desserts were estimated by a calorie calculator (Tufts University, https://hnrca.tufts.edu/flipbook/resources/restaurant-meal-calculator/). According to the frozen dessert formula (Table 3.2), ingredients were searched from the USDA food composition database and calculated in the software. The weight of milk and almond beverage was converted to volume by density (https://www.aqua-calc.com/) as the nutrition facts were in volume. One hundred g was established as one serving.

Experimental Design and Statistical Analysis

A randomized complete block design was used to evaluate differences ($p \leq 0.5$) with panelists as the blocks in appearance, aroma, flavor, texture, and overall acceptability of sweet potato frozen desserts. Cluster analysis was used for the 101 panelists who participated in the consumer acceptability test at the Sensory Laboratory and they were clustered by dissimilarities of overall linking and preference of the samples using Ward's method of Agglomerative hierarchy clustering (AHC) with XLSTAT (Addinsoft, New York, NY). The number of clusters was determined by comparing the levels on dissimilarity plot. Each cluster was analyzed by SAS (SAS version 9.4, SAS Institute, Cary, NC) and Tukey's HSD test was used to separate the treatment means when difference ($p \leq 0.05$) occurred. For descriptive analysis, a randomized complete black design was used. An interaction plot was used to exclude inconsistent panelists. The remainder descriptive and chemical results were analyzed subjected to ANOVA by SAS with Tukey's HSD to differentiate the treatment means when p-value is 0.05 or smaller.

Experiment II- Sweet Potato Greens and Smoothie

Materials

Coconut water (Vitacoco, New York, NY, US), canned pineapples (Dole, Westlake Village, CA, US), bananas, lemons, and non-fat Greek yogurt (Fage, Johnstown, NY, US) were purchased from Walmart (Starkville, Mississippi). Sweet potato greens (young) were hand-picked in fields at the Pontotoc Ridge-Flatwoods Branch Experiment Station, Pontotoc, Mississippi.

Sample Preparation

Sweet potato greens were washed, blanched for 30 sec in boiling water in a pot (30 cm diameter, 16 cm high, iron pot), with continuous stirring. The greens were drained, immediately cooled in a bowl of ice-cold water 1 min, then the excess moisture was drained. The greens were then packaged in a Ziploc (Johnson & Son, Inc, Racine, WI, US) freezer bags and frozen at -18°C at the Mississippi State University Ammerman-Hernsberger Food Processing Laboratory. Frozen greens were placed in a blender (Ninja Pro BL456, Needham, MA, US) with frozen pineapple, banana, coconut water, lemon juice, and non-fat yogurt (Table 3.3) and blended for 2 min. The sample was prepared for immediate descriptive sensory testing.

Blanching of Sweet Potato Greens

A blanching experiment was conducted to determine the blanching time required to inactivate enzymes. Sweet potato greens were blanched, with continuous stirring, in boiling water for 0, 20, 30, 40, 50, and 60 sec and immediately cooled in cold at 4°C distilled water for 1 min to stop cooking. The samples were cut into quarter inch pieces with scissors and added to test tubes with 5 ml of DI water, 1ml of 0.5% hydrogen peroxide, and 1 ml of 1% guaiaicol reagent (Fisher Scientific, Fair Lawn, New Jersey, US). Catalase and peroxidase were determined by foaming production and red color development, respectively (Güneş & Bayindirli, 1993). A sensory texture (firmness, softness, sliminess) test was conducted by hand, raw and after blanching.

Total Solids and Fat Analysis of Smoothie

Total solids of the smoothie was measured according to AOAC method 925.21 (AOAC, 1999) by adding 10 g of sample in a dried aluminum dish. The sample was dried at 105C in an incubator (ISOtemp oven 200, Model 215F, Fisher Scientific, Hampton, NH, US) for 24 h. Total solids were measured in duplicate. The initial weight of the samples was subtracted from final weight and calculated as:

$$\text{Total Solids (TTS\%)} = 100* \frac{Final\ weight\ (g) - dish\ weight\ (g)}{Initial\ weight\ (g)} \quad (3.3)$$

For crude fat analysis, official AOAC method 905.02 (AOAC, 1999) was used and the materials were purchased from Fisher Scientific. Ten g of frozen dessert sample was weighed with a curved pipet and 2 to 3 drops of phenolphthalein was added to a fat extraction flask as an indicator. One and one-half ml of ammonia hydroxide (NH_4OH), and 10 ml of ethanol were added to each mojonnier flask, and it was shaken 25 times with a lid on. Twenty-five ml of ethyl ether and 25 ml of petroleum ether were added in each flask, and it was shaken for 25 times with lids on after each addition. The samples were centrifuged at 600 rpm for 30 sec. The clear liquid on the top was poured in a pre-weighed aluminum dish, leaving the pink solid sediments in the flasks. The extraction procedure was repeated with 5 ml of ethanol, 25 ml of ethyl ether and 25 ml of petroleum ether, and the flask was shaken after each one was added. The clear liquid in the dishes was evaporated on a hot plate for 15 min. The dishes were vacuum dried (15 in Hg) for 5 min, cooled for 7 min, and weighed. The final weight was subtracted by each dish's initial weight. The approximate total fat content was calculated as:

$$\text{Fat (\%)} = 100* \frac{Final\ weight\ (g) - dish\ (g)}{Initial\ weight\ (g)} \quad (3.4)$$

Proximate Analysis of Frozen Raw and Blanched Greens

Official AOAC methods 990.30 and 934.01 were used for protein and moisture determination, respectively (AOAC, 1999). Fiber and fat were measured by AOCS Ba6A-05 and AOCS Am 5-04 (AOCS, 1997). All the reagents were purchased from Fisher Scientific. To determine minerals, inductively coupled plasma mass spectrometry (ICP-MS) was used for metal analysis. Two g of raw and blanched greens were weighed and transferred to each microwave digestion tube with 3 ml of peroxide and 5 ml of nitric acid (HNO_3). The tube was capped and place in a carousel in a hood for 2 h. The carousel was place in a microwave digester (MARS Xpress, CEM Corporation, Matthews, NC, US). The tube was cooled for 12 h, the cap removed, and the acid equilibrated for 30 min in the hood. The digested greens were added to each volumetric flask with 50 ml of deionized water and filtered into the ICP sampler tubes with 0.45 µm, 33 mm, PVDF filter. The ICP-MS analyzer (7900 ICP-MS, Agilent, Santa Clara, CA, US) used gas plasma for the determination of calcium, iron, sodium, and potassium.

Nutrition Estimation Analysis

Nutrition facts of the smoothie made from frozen blanched sweet potato greens were estimated by a calorie calculator (Tufts University, https://hnrca.tufts.edu/flipbook/resources/restaurant-meal-calculator/). According to the smoothie formula (Table 3.3), ingredients were searched from the USDA food composition database and calculated in the software. Protein, fiber, calcium, potassium, sodium, and estimated carbohydrates from the result of proximate analysis was used as nutrition facts of sweet potato greens (SPL30). One serving was established as the total amount of formula (400g).

Sensory Analysis

Descriptive panels for the smoothie made from frozen sweet potato greens was conducted by a group of semi-trained panelists (n=8) with 2 replications. Appearance, aroma, flavor, texture, and overall acceptability were evaluated by the panelists in 15 cm line scales (Appendix A) to determine the flavor profile of the smoothie (Figure 4.3). The sensory test was performed in the descriptive room at the MSU Garrison Sensory Laboratory.

Table 3.1 Formulation of sweet potato frozen desserts (FD) made from milk and cream with different sweet potato content.

Ingredients	Sweet potato mash added to FD (%)			Content (% by weight)
	20	30	40	
Milk (g)	375	269	160	16-37.5
Heavy cream (g)	270	282	296	27-29.6
Sucrose (g)	150	145	140	14-15
Sweet potato mash (g)	200	300	400	20-40
Stabilizer (g)	4	4	4	0.4
Vanilla Flavor (g)	1	1	1	0.1
Total (g)	1000	1000	1000	100

Table 3.2 Formulation of sweet potato frozen desserts (FD) made with milk and almond soy milk alternatives.

Ingredients	Type of milk or milk alternatives			Content (% by weight)
	Dairy	Almond	Soy	
Milk or replacement (g)	466	455	463	45.5-46.6
Coconut oil (g)	84	95	92	0.84-0.95
Sucrose (g)	145	145	140	14-14.5
Sweet potato mash (g)	300	300	300	30
Stabilizer (g)	4	4	4	0.4
Vanilla Flavor (g)	1	1	1	0.1
Total (g)	1000	1000	1000	100

Table 3.3 Formulation of a sweet potato greens smoothie.

Ingredients	Preparation	Weight (g)	Content (% by weight)
Sweet potato greens (Pontotoc, MS, US)	Frozen and blanched	50	12.5
Pineapple (Dole)	Canned and drained	120	30
Banana (fresh)		50	12.5
Greek Yogurt (Fage, 0% fat)		20	5
Coconut Water (Vita Coco)	Aseptic packaged	157	39.25
Lemon Juice (fresh)	Squeezed	3	0.75
Total		400	100

Table 3.4 Attributes and definitions in descriptive panel of frozen desserts.

Attributes	Definitions
Appearance (color)	The intensity of orange color
Aroma	
Sweet potato	The fundamental odor strength of sweet potato
Vanilla	The fundamental odor strength of vanilla
Flavor	
Sweet	The fundamental taste of sucrose (2% sucrose=2; 5% sucrose= 5)
Sour	The fundamental taste of sensation of lactic acid and citric acid (0.05% citric acid=2; 0.08% citric acid=5; 0.15% citric acid=10)
Astringent	The measure of puckery flavor
Milk	The intensity of dairy milk
Sweet potato	The intensity of sweet potato flavor
Vanilla	The intensity of vanilla flavor
Texture	
Smooth	The possession of a custard-like body with a smooth homogenous texture
Creamy	The possession of creamy feeling without grainy texture
Coarse-icy	The possession of coarse ice texture
Gummy	The possession of gummy texture
Mouth-coating	The measure of mouth coating
Rate of melt in mouth	The measure of melting-rate in mouth

Source: (King, 1994), (Ohmes, Marshall, & Heymann, 1998)

Table 3.5 Attributes and definitions in descriptive panel of greens smoothie.

Attributes	Definitions
Appearance (color)	The intensity of green color
Aroma	
Leafy green	The fundamental odor strength of leafy green (e.g. grass)
Sour	The fundamental odor strength of acidity like lactic acids or citric acids
Banana	The fundamental odor strength of banana
Pineapple	The fundamental odor strength of pineapple
Flavor	
Sweet	The fundamental taste of sucrose (2% sucrose=2; 5% sucrose= 5)
Sour	The fundamental taste of sensation of lactic acid and citric acid (0.05% citric acid=2; 0.08% citric acid=5; 0.15% citric acid=10)
Astringent	The measure of puckery flavor
Leafy green	The intensity of leafy green taste (e.g. grass)
Banana	The intensity of banana flavor
Pineapple	The intensity of pineapple flavor
Yogurt	The intensity of yogurt flavor
Texture	
Smoothness	The possession of a custard-like body with a smooth homogenous texture
Graininess	The mouth-feel of fruit particles or fiber-tissues
Mouth-coating	The measure of mouth coating
Separation	The measure of separation between liquid and solid phases

Source: (Keenan at al 2012)

CHAPTER IV

RESULTS AND DISCUSSION

Experiment I - Frozen Desserts

A. Determination of Maximum Amount of Sweet Potato Mash in Frozen Desserts

The intensity of orange color was greatest ($p \leq 0.05$) for the sample containing 40% (11.1) mashed sweet potato, and the 30% sample (8.6) had more intense orange color than the sample containing 20% ($p \leq 0.05$). The overall intensity of color was similar irrespective of sweet potato mash amount. The overall flavor intensity was stronger with the 30% and 40% mash than the 20% sweet potato mash (Figure 4.1). No differences ($p > 0.05$) existed between treatments for all other sensory descriptions. All samples were rated low for aroma attributes (4.0-5.4), as well as coarse iciness (2.9-3.5) and gummy (4.8-4.8) in texture. Sourness and astringent flavor intensity were low for all treatments (0.6 to 0.8 and 0.9 to 1.2, respectively). According to the results of the descriptive panel in ice creams with difference sweet potato content, the amount of sweet potato added determines the intensity of orange color that came from the natural beta carotene pigment (Takahata, Noda, & Nagata, 1993). As 30% and 40% sweet potato mash added frozen desserts are similar ($p > 0.05$), either treatment could be used for frozen desserts made from milk and milk alternatives. The 30% sweet potato mash amount was chosen for the frozen dessert samples due to the difficulty of incorporation of sweet potato mash into the mixture.

B. Descriptive Panel of Frozen Desserts Made from Milk and Almond and Soy Milk Alternatives

No difference ($p>0.05$) existed among the frozen dessert samples with respect to appearance, aroma, flavor, or texture (Table 4.1).

C. Consumer Acceptability of Frozen Desserts

The appearance and texture of the milk based frozen dessert was preferred over almond and soy milk alternative-based frozen desserts. In aroma, the liking of the milk-based frozen dessert was similar to the soy milk alternative but preferred over the almond milk alternative frozen dessert. Aroma of soy and almond milk alternative samples were similar. The overall acceptability followed the same tendency as aroma with all three samples being slightly liked. The panelists that participated in the field day, rated milk higher ($p\leq0.05$) than almond and soy milk alternatives in appearance (Table 4.3). The samples were similar in the other attributes. The mean for overall acceptability of consumers participating in the field day was 7.1, moderately liked, for all the treatments. The preference among the samples in each attribute of consumer panels that participated at the MSU sensory laboratory (n=101) was identical to total consumer acceptability (table 4.4).

The panelists who participated at the MSU sensory laboratory panel accounted for over 70% of the total consumers. The participants at the field day were sweet potato growers or sweet potato researchers/ extension personnel and the participants at the MSU sensory laboratory were university students or employees. The participants in field day were more knowledgeable about sweet potato whereas the participants at MSU sensory lab were not involved in sweet potato farming or production of sweet potato products.

The mean scores show that those whose occupancy involved with the crop moderately liked the frozen desserts regardless of the type of base used. Their knowledge of sweet potatoes may have contributed as a bias. This is the main reason they were omitted from the Cluster analysis.

D. Cluster Analysis of Consumer Acceptability on Frozen Desserts

Cluster analysis was conducted on the results from consumer panelists at the MSU Sensory Laboratory. The consumers were clustered into 4 groups based on overall acceptability of frozen desserts with a dendrogram. According to the mean scores by clusters (Table 4.6), cluster 1, consisting of 57.4% of the consumer panels, did not have a preference among the three samples. The means for overall acceptability of the group were between 7.1 and 7.4, with all three treatments moderately liked. For cluster 2 (22.8%), the overall acceptability of milk and soy milk alternative samples were similar with a rating of like slightly and preferred over the almond milk alternative sample. These panelists moderately disliked the frozen dessert made from almond milk beverage. Cluster 3, 8% of the consumer panelists, rated all three samples either slightly or moderately disliked (between 3.2 and 4.4) without difference among the samples ($p>0.05$). For cluster 4, 11.9% of the panelists liked milk and almond milk alternative samples moderately. The means for overall acceptability of the frozen dessert made from soy milk alternative was scored differently from the other samples. Cluster 1, 2, and 4 rated the milk based frozen dessert between 6.9 and 7.2 and thus, the treatment was rated slightly liked or greater by the most panelists (92.1%). The soy based frozen dessert was scored 6 or greater by 80.2% of panelists and the almond milk sample by 69.3% of panelists. Both milk and soy milk alternative samples were slightly like or greater by 80.2% of panelists. Milk and almond milk alternative samples were slightly liked or more by 69.3% of panelists. Panelists who liked both almond and soy alternative samples comprised 57.4% of panelists. The frozen desserts contained similar fat contents yet variable protein and sugar content, due to the different compositions of raw materials in the base milk/milk alternative. The different compositions of milk and milk alternatives seemed to have affected the preference of almond milk alternative over milk and soy milk alternative on cluster analysis.

Results different from previous result in that a study on soy and almond milk alternatives reported that consumers preferred almond milk in terms of color, flavor, taste and overall acceptability but rated them similar for mouthfeel (Alozie Yetunde & Udofia, 2015).

E. Chemical/ Proximate Analysis

The pH of the frozen dessert samples did not differ amongst samples and ranged between 6.4 and 7.0 (Table 4.7). The Brix (soluble solids) level of the almond milk alternative sample was 27.3%, lower than milk and soy milk alternative frozen desserts. The fat content of the samples was not different and they are close to the targeted ratio of 10%.

The almond milk alternative based frozen dessert contained the most calcium (0.1%) and the milk based frozen dessert contained the least (0.07%). On the other hand, potassium content was greatest in dairy based dessert and least in almond based-frozen dessert. Iron was not detectable in all samples and sodium was less than 0.1%. The almond milk alternative sample contained 1.14% crude protein, the least among the samples, and approximately 50% of the other samples. Crude carbohydrates were estimated by subtracting crude protein and fat content from total soluble solids, and ranged between 22.3% and 24.3%. The difference between treatments may have been derived from the different nutritional content of each base milk/milk alternative.

Almond milk alternative-based frozen desserts had lower Brix and total solids (TTS). Almond milk alternative was reported to contain protein as low as 0.5% while milk contained 3.3%, about 6.5 times higher (Mäkinen et al., 2016). The almond milk alternative used in this study had 0.4% protein whereas the soy milk alternative had 2.9%, and milk contained 3.8%, thus the difference in TSS and Brix within desserts. The almond milk also contained the least fat and sugar content compared to soy milk and milk (dairy).

Despite the nutritional variability among samples, adding sweet potato mash can greatly increase their nutritional value while replacing the added sugar with a natural sweet flavor from the vegetable. A 30 g portion of sweet potato (baked in skin) contains 288.3 µg of vitamin A RAE (USDA, 2018). A one hundred g serving of frozen dessert samples containing 30 g of sweet potato mash fulfills approximately 50% of the Vitamin A daily recommended intake. The total energy ranged between 168 and 182 Kcal, highest in the frozen dessert made from milk and lowest in dessert made from almond milk alternative (Table 4.11). Frozen desserts in this study were lower in calories, protein, and sugar but prominently higher in vitamins A and C, when compared to standard vanilla ice cream (Appendix A). Frozen desserts contained about 14 times more vitamin A than conventional ice cream due to the addition of 30% of sweet potato mash added in the formula. However, beta-carotene, the form of vitamin A in sweet potato, is susceptible to oxidation, with possible color-fading during storage.

Experiment II - Sweet Potato Greens and Smoothie

A. Blanching and Sensory Texture

The color reaction of peroxidase decreased gradually until 20 sec blanching and was unnoticed after 30 sec blanching. Blanching reduced firmness of the greens and the texture at 30 sec was acceptable (not as firm as raw but not mushy). Blanching for 40 sec or longer resulted in a slimy and overly soft texture (Figure 4.2). This suggests that 30 sec might be the optimum/maximum blanching time for sweet potato greens. Determination of blanching time is necessary to sweet potato greens processing to prevent enzymatic reactions and reduce crystallization of water during freezing.

Some key components of green leafy vegetables are highly susceptible to heat. Spinach and Kale lose various minerals upon heating and/or freezing (Lisiewska et al., 2009). In a study conducted on tropical leafy green vegetables in Africa, blanching significantly decreased antioxidant properties including vitamin C, yet phenols increased in some commodities (Oboh, 2005), probably due to their conversion into more readily available phenolic compounds. Trypsin inhibitors in greens blanched for up to 10 min decreased with blanching time regardless of cultivar (Mosha and Gaga, 1999; Almazan, 1995), however, acceptance of the greens after various blanching times was not reported.

B. Descriptive Panel: Green Smoothie

Green smoothie made from frozen blanched sweet potato greens had a strong green color (12.7) due to the high content of greens in the sample. The overall intensity of aroma was higher than that of flavor and banana was the dominating aroma and flavor. The panelists who evaluated the smoothie stated that it had a more favorable level of sweet flavor, when compared to a commercial green smoothie that was made with kale or spinach. Although the smoothie contained 12.5% of frozen blanched sweet potato greens, the smoothie had low green leafy flavor, which was probably due to the blanching.

C. Chemical/ Proximate Analysis

Frozen, raw sweet potato greens (SPL0) contained slightly more calcium and potassium than frozen greens after blanching for 30 sec (SPL30) (Table 4.10). Iron was not detectable in either sample. Crude protein, fiber, and fat were similar with and without blanching. Moisture from proximate analysis in raw and blanched sweet potato greens were 88.8% and 91%. Crude carbohydrates were estimated by subtracting 100% from moisture, crude protein, and crude fat. Estimated crude carbohydrates were reduced by 33.3% during blanching. Processed/canned fruits or vegetables lose nutritional quality in minerals and vitamins during wet heating processes due to loss of carbohydrates (FAO, 1998). Lisiewska et al. (2009) repeated that both potassium and calcium decreased to 63.8-70.4% in kale after blanching (Lisiewska et al., 2009). Also, spinach lost 17.5% of potassium after blanching. This suggests that minerals in sweet potato greens are held better upon heating and freezing, and thus could be marketed with this advantage, compared to other frozen green products.

The smoothie made from frozen blanched greens contained 0.1% fat and 11.8% total solids. The smoothie might have health benefits since it contains very low fat and abundant vitamins and minerals from sweet potato greens. The smoothie contained 179 Kcal per serving (400g), 5g of protein, and 4g of fiber out of 41g of total carbohydrates (Table 4.12). One serving of the green smoothie fulfilled approximately 50% of the recommended daily value of potassium and 75% of vitamin C.

Table 4.1 Mean scores (n=6) of the quantitative descriptive test[x] on each attribute in frozen dessert samples made with different sources of milk or milk alternatives.

	Type of milk or milk alternative		
Attributes	Dairy	Almond	Soy
Appearance: Orange color	10.8^{a}	9.9^{a}	10.0^{a}
Aroma: Overall intensity	6.2^{a}	6.3^{a}	6.0^{a}
Aroma: Sweet potato	5.7^{a}	5.1^{a}	5.2^{a}
Aroma: Vanilla	2.9^{a}	3.0^{a}	2.9^{a}
Flavor: Overall intensity	9.1^{a}	9.0^{a}	9.4^{a}
Flavor: Sweet	9.9^{a}	9.0^{a}	9.5^{a}
Flavor: Sour	1.1^{a}	0.5^{a}	0.5^{a}
Flavor: Astringent	2.3^{a}	1.9^{a}	2.0^{a}
Flavor: Milk	5.4^{a}	5.0^{a}	4.8^{a}
Flavor: Sweet potato	10.0^{a}	9.7^{a}	9.7^{a}
Flavor: Vanilla	4.7^{a}	4.7^{a}	4.5^{a}
Texture: Smooth	8.8^{a}	7.9^{a}	8.6^{a}
Texture: Creamy	7.7^{a}	7.1^{a}	7.0^{a}
Texture: Coarse icy	5.5^{a}	6.1^{a}	5.2^{a}
Texture: Gummy	4.2^{a}	4.3^{a}	4.0^{a}
Texture: Mouthcoating	6.2^{a}	6.5^{a}	6.0^{a}
Texture: Melting rate in mouth	8.9^{a}	9.0^{a}	8.7^{a}

[x] A 15 cm line scale was used where 0=very weak and 15=very strong regarding each attribute.
a-c: means within each column followed by the same letter do not differ ($p>0.05$).

Table 4.2 Mean scores (n=6) of the quantitative descriptive test[x] on each attribute for a green smoothie made from frozen blanched sweet potato greens.

Attributes	Mean score
Appearance: Green color	12.7
Aroma: Overall intensity	10.5
Aroma: Leafy green	6.9
Aroma: Sour	5.1
Aroma: Banana	9.5
Aroma: Pineapple	6.4
Flavor: Overall intensity	8.6
Flavor: Sweet	6.1
Flavor: Sour	5.9
Flavor: Astringent	5.0
Flavor: Leafy green	6.6
Flavor: Banana	7.8
Flavor: Pineapple	5.9
Flavor: Yogurt	4.2
Texture: Smooth	7.7
Texture: Grainy	4.8
Texture: Mouthcoating	5.0
Texture: Separation	1.4

[x] A 15 cm line scale was used where 0=very weak and 15=very strong regarding each attribute.

Table 4.3 Mean scores for consumer acceptability of frozen desserts (FD) including farmers and MSU consumers (n=144).

Frozen dessert	Score[x] Appearance	Aroma	Flavor	Texture	Overall acceptability
Milk	7.6^{a}	6.3^{a}	6.8^{a}	7.2^{a}	7.0^{a}
Almond milk	6.7^{b}	5.9^{b}	6.5^{a}	6.7^{b}	6.4^{b}
Soy milk	6.9^{b}	6.2^{ab}	6.6^{a}	6.6^{b}	6.6^{ab}

a-b: means within each column followed by the same letter do not differ (p>0.05)
[x] 9 point hedonic scale was used where 1=dislike extremely, 5=neither like nor dislike, and 9=like extremely.

Table 4.4 Mean scores of consumer acceptability on frozen desserts (FD) conducted by sweet potato growers and extension personnel (n=43).

Frozen dessert	Score[x] Appearance	Aroma	Flavor	Texture	Overall acceptability
Milk	7.6^{a}	6.5^{a}	7.0^{a}	7.1^{a}	7.1^{a}
Almond milk	7.1^{a}	6.5^{a}	7.2^{a}	7.3^{a}	7.1^{a}
Soy milk	7.0^{a}	6.4^{a}	6.9^{a}	6.9^{a}	7.1^{a}

a-c: means within each column followed by the same letter do not differ (p>0.05).
[x] 9 point hedonic scale was used where 1=dislike extremely, 5=neither like nor dislike, and 9=like extremely.

Table 4.5 Mean scores of consumer acceptability on frozen desserts (FD) conducted at the MSU sensory laboratory (n=101).

Frozen dessert	Score[x] Appearance	Aroma	Flavor	Texture	Overall acceptability
Dairy milk	7.6^{a}	6.3^{a}	6.8^{a}	7.2^{a}	6.9^{a}
Almond milk	6.5^{b}	5.7^{b}	6.2^{a}	6.4^{b}	6.1^{b}
Soy milk	6.8^{b}	6.1^{a}	6.5^{a}	6.5^{b}	6.5^{ab}

a-b: means within each column followed by the same letter do not differ (p>0.05).
[x] 9 point hedonic scale was used where 1=dislike extremely, 5=neither like nor dislike, and 9=like extremely.

Table 4.6 Mean scores for overall consumer acceptability (n=101) of SP based frozen desserts samples, according to different clusters of consumer segments in the Sensory Lab.

Cluster (number)	Panelist (%)	Score[x] Dairy milk	Almond milk	Soy milk
1 (58)	57.4	7.2^{a}	7.1^{a}	7.4^{a}
2 (23)	22.8	6.9^{a}	3.9^{b}	6.5^{a}
3 (8)	7.9	4.4^{a}	3.5^{a}	3.3^{a}
4 (12)	11.9	7.2^{a}	7.4^{a}	3.8^{b}
percentage of panelists that rated the treatment like slightly or greater		92.1	69.3	80.2

a-b: means within each column followed by the same letter do not differ (p>0.05).
[x] 9 point hedonic scale was used where 1=dislike extremely, 5=neither like nor dislike, and 9=like extremely.

Table 4.7 pH, Brix, total fat content, and total soluble solids (TSS) for frozen dessert (FD) made with 30% sweet potato mash and with dairy milk, almond milk, and soy milk.

Frozen Dessert (FD)	pH	Brix (%)	Fat (%)	TSS (%)
Milk	6.5^{a}	31.2^{a}	9.9^{a}	36.7^{a}
Almond milk	6.9^{a}	27.3^{b}	10^{a}	33.5^{b}
Soy milk	6.9^{a}	30.1^{a}	10^{a}	35.2^{ab}
CV (%)	4.0	7.0	1.0	4.4
SEM	0.11	0.85	0.04	0.64

a-b: means within each column followed by the same letter do not differ ($p>0.05$)
CV: Coefficient of variation
SEM: standard error of the mean
TSS: Total soluble solids

Table 4.8 Chemical analysis of frozen desserts made with milk and almond or soy milk alternative.

Proximate Analysis Component	Milk	Almond milk	Soy milk
Moisture (%)	63.7	67	65.2
Calcium (%)	0.069	0.101	0.088
Iron (%)	ND	ND	ND
Potassium (%)	0.224	0.169	0.189
Sodium (%)	0.044	0.046	0.037
Crude Protein (%)	2.450	1.140	2.220
Crude Fiber (%)	N/A	N/A	N/A
Crude Fat (%)	9.9	10	10
Estimated Carbohydrate (%)	23.9	21.9	22.68

ND: Not Detectable
N/A: Not Available

Table 4.9 Chemical analysis of frozen, raw (SPL0) and frozen, blanched for 30 (SPL30) sec sweet potato greens.

Proximate Analysis Component	SPL0	SPL30
Moisture (%)	88.8	91
Calcium (%)	0.149	0.107
Iron (%)	ND	ND
Potassium (%)	0.446	0.399
Sodium (%)	0.005	0.007
Crude Protein (%)	3.380	3.850
Crude Fiber (%)	1.560	1.470
Crude Fat (%)	0.27	0.24
Estimated Carbohydrate (%)	7.57	5

ND: Not Detectable
N/A: Not Available
SPL0: frozen raw sweet potato leave
SPL30: frozen sweet potato greens blanched for 30 sec

Table 4.10 Estimated nutrition facts (100g) of frozen desserts (FD) made from milk and almond or soy milk alternatives based on USDA food composition database.

Frozen dessert	Milk (Dairy)	Almond milk	Soy milk
Energy (Kcal)	182	168	177
Protein (g)	2	1	2
Total Fat (g)	10	10	10
Saturated Fat (g)	9	9	9
Cholesterol (g)	7	0	0
Carbohydrate (g)	23	21	22
Fiber (g)	1	1	1
Sugar (g)	19	16	17
Sodium (mg)	35	34	29
Calcium (mg)	68	90	68
Potassium (mg)	143	148	199
Vitamin A (IU)	5822	5853	5861
Vitamin C (mg)	6	6	6

Nutrition Calculator, Human Nutrition Research, Tufts University (https://hnrca.tufts.edu/flipbook/resources/restaurant-meal-calculator/)

Table 4.11 Estimated nutrition facts (400 g/serving) of a green smoothie made with frozen blanched sweet potato greens based on proximate analysis and USDA food composition database.

Energy (Kcal)	179
Protein (g)	5
Total Fat (g)	0
Saturated Fat (g)	0
Cholesterol (g)	0
Carbohydrate (g)	41
Fiber (g)	4
Sugar (g)	31
Sodium (mg)	70
Calcium (mg)	135
Potassium (mg)	823
Vitamin A (IU)	92
Vitamin C (mg)	45

Nutrition Calculator, Human Nutrition Research, Tufts University (https://hnrca.tufts.edu/flipbook/resources/restaurant-meal-calculator/)

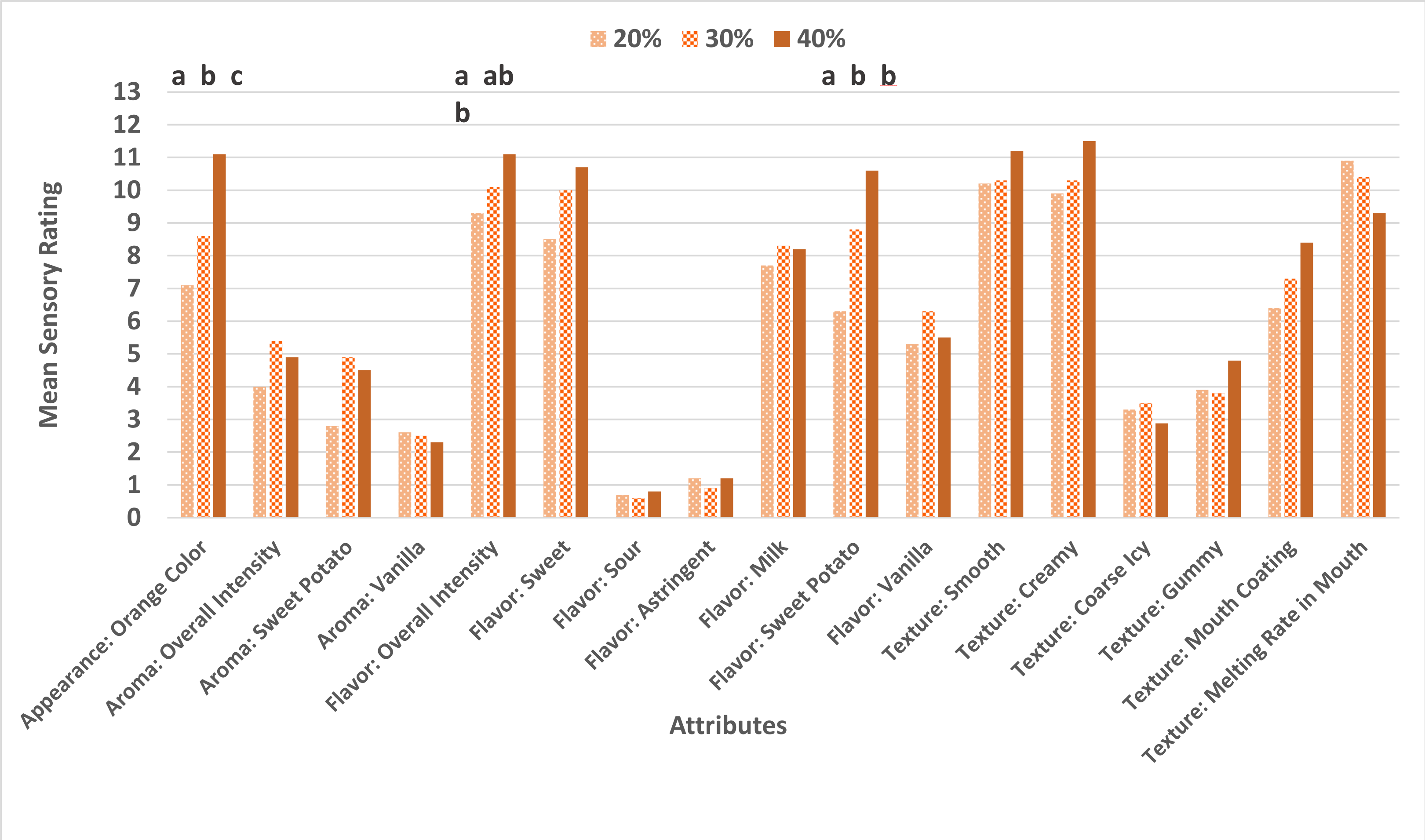

Figure 4.1 Mean scores of descriptive panels on frozen desserts made with 20%, 30%, and 40% of sweet potato mash in each attribute

15 cm line scale was used where 0=very weak and 15=very strong regarding each attribute

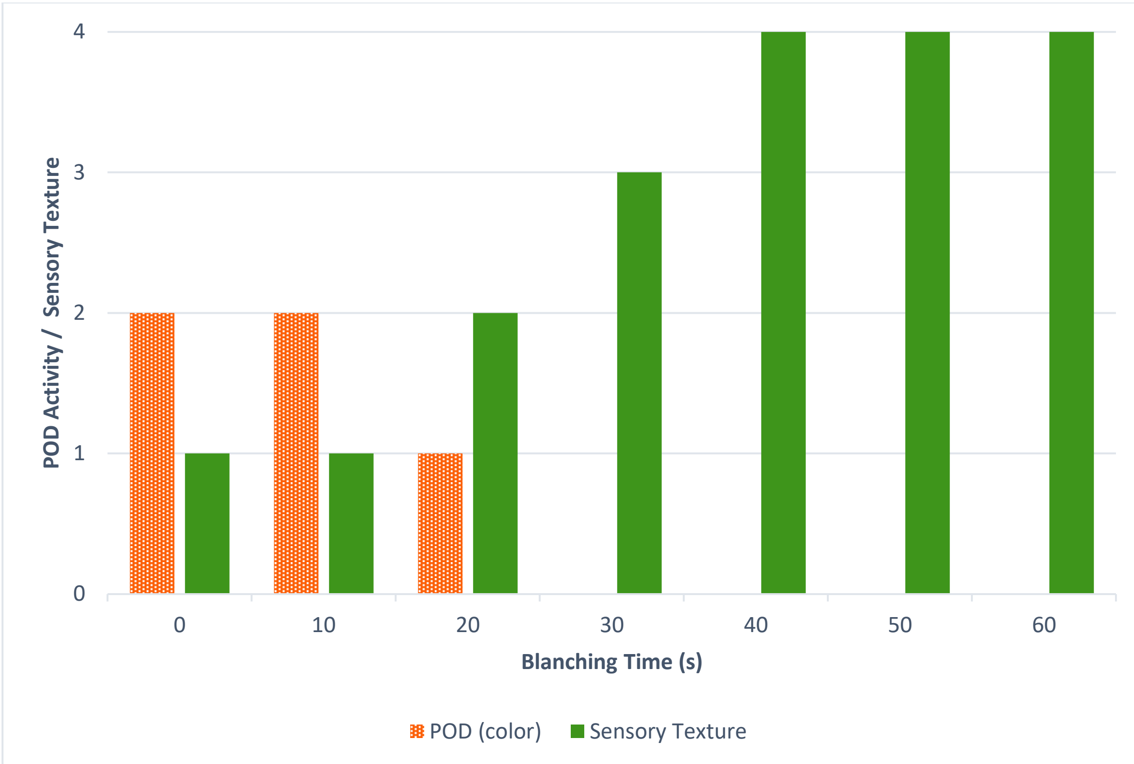

Figure 4.2 Blanching time to inactivate peroxidase and sensory texture evaluation.

POD: Peroxidase
POD color being 2-strong, 1-weak, and 0-negative (clear)
Sensory texture being 1-too hard and raw, 2- firm, 3- soft, and 4- too soft and slimy.

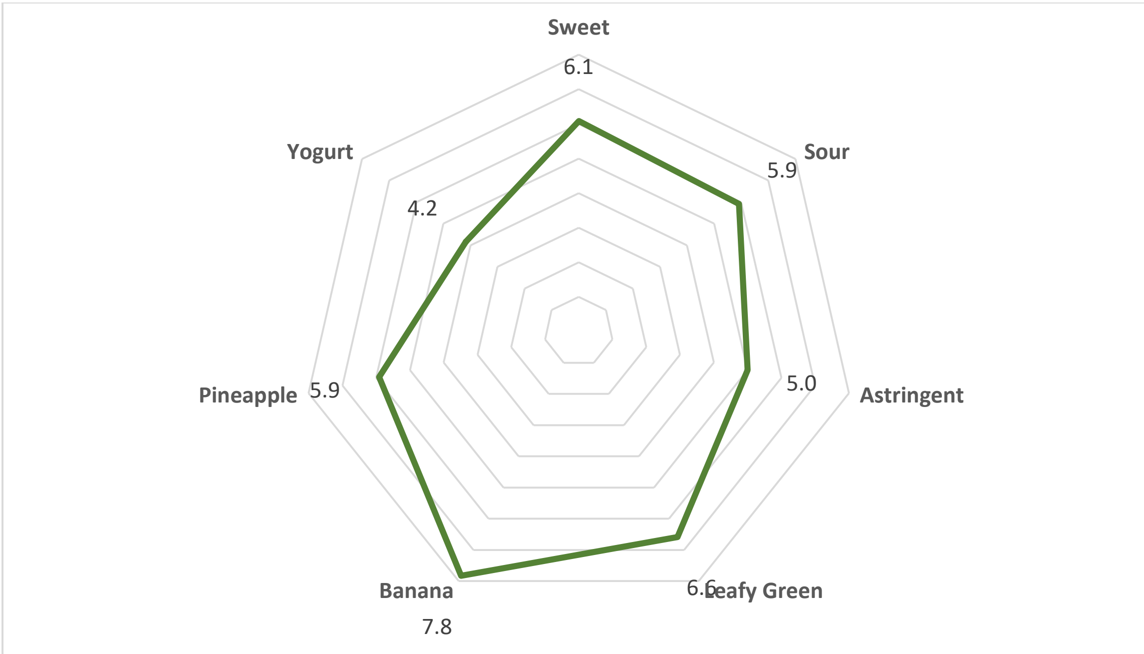

Figure 4.3 Flavor profile of a green smoothie made from sweet potato greens

15 cm line scale was used where 0=very weak and 15=very strong regarding each attribute

CHAPTER V

SUMMARY AND CONCLUSIONS

In this study, it was determined that frozen desserts could contain as high as 40% sweet potato mash but 30% was chosen because of the possible difficulty in incorporating it. Sweet potatoes were baked, pureed and incorporated into a mixture containing coconut oil, sugar, stabilizer, and milk, almond or soy milk alternatives. Sweet potato based-frozen desserts made from dairy milk and almond or soy milk alternatives had similar overall acceptability by consumer panelists. However, the majority of consumers preferred milk-based over the other samples, yet almond and soy milk alternatives were acceptable. To utilize sweet potato greens, the optimum blanching time was determined to be 30 sec, by peroxidase inactivation and sensory texture evaluation. Frozen blanched sweet potato greens were blended into a green smoothie. The green smoothie was evaluated by a descriptive panel, and it was determined that its flavor was well-balanced with favorable texture. This study can contribute to developing new products made from under-utilized sweet potato roots and greens. The frozen desserts can be enjoyed by lactose intolerant, milk protein allergic, and vegan consumers with health benefits from both sweet potato and coconut oil. The green smoothie may be produced for targeting health concerned consumers.

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APPENDIX A

ADDITIONAL TABLES, IRB APPROVAL LETTER, AND DESCRIPTIVE

SENSORY EVALUATION SHEETS

Table A.1 Mean scores (n=6) of the quantitative descriptive test[x] on each attribute in frozen desserts samples made with 20%, 30%, and 40% of sweet potato mash.

Attributes	Sweet potato mash in frozen dessert mix[y] (% by weight) 20	30	40
Appearance: Orange color	7.1^{a}	8.6^{b}	11.1^{c}
Aroma: Overall intensity	4.0^{a}	5.4^{a}	4.9^{a}
Aroma: Sweet potato	2.8^{a}	4.9^{a}	4.5^{a}
Aroma: Vanilla	2.6^{a}	2.5^{a}	2.3^{a}
Flavor: Overall intensity	9.2^{a}	10.1^{ab}	11.1^{b}
Flavor: Sweet	8.5^{a}	10.0^{a}	10.7^{a}
Flavor: Sour	0.7^{a}	0.6^{a}	0.8^{a}
Flavor: Astringent	1.2^{a}	0.9_{a}	1.2^{a}
Flavor: Milk	7.7^{a}	8.3^{a}	8.2^{a}
Flavor: Sweet potato	6.3^{a}	8.8_{b}	10.6^{b}
Flavor: Vanilla	5.3^{a}	6.3^{a}	5.5^{a}
Texture: Smooth	10.2^{a}	10.3^{a}	11.2^{a}
Texture: Creamy	9.8^{a}	10.3^{a}	11.5^{a}
Texture: Coarse icy	3.3^{a}	3.5^{a}	2.9^{a}
Texture: Gummy	3.9^{a}	3.8^{a}	4.8^{a}
Texture: Mouth coating	6.4^{a}	7.3^{a}	8.4^{a}
Texture: Melting rate in mouth	10.9^{a}	10.4^{a}	9.3^{a}

[x]A 15 cm line scale was used where 0=very weak and 15=very strong regarding each attribute.
[y]20%, 30%, 40%: Amount of mashed sweet potato added to the frozen dessert mix
a-c: means within each column followed by the same letter do not differ ($p>0.05$).

Table A.2 Nutrition facts (100g) of vanilla ice cream (standard reference)

Energy (Kcal)	207
Protein (g)	4
Total Fat (g)	11
Saturated Fat (g)	7
Cholesterol (g)	44
Carbohydrate (g)	24
Fiber (g)	1
Sugar (g)	21
Sodium (mg)	80
Calcium (mg)	135
Potassium (mg)	823
Vitamin A (IU)	421
Vitamin C (mg)	1

USDA Food Composition Database (USDA, 2018)

IRB Approval Letter

MISSISSIPPI STATE UNIVERSITY

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P. 662.325.3294

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NOTICE OF DETERMINATION FROM THE HUMAN RESEARCH PROTECTION PROGRAM

DATE:	August 10, 2018
TO:	Juan Silva, PhD, Food Sci Nutrition Hlth Promo, Lurdes Siberio-Perez;Mark Schilling;Stephen Meyers
PROTOCOL TITLE:	Optimization of a new formulation of sweet potato (Ipomoea batatas) based ice cream and frozen desserts made from milk alternatives
PROTOCOL NUMBER:	IRB-18-265
	Approval Date: August 10, 2018 Expiration Date: August 09, 2023

EXEMPTION DETERMINATION

The review of your research study referenced above has been completed. The HRPP had made an Exemption Determination as defined by 45 CFR 46.101(b)6. Based on this determination, and in accordance with Federal Regulations, your research does not require further oversight by the HRPP.

Employing best practices for Exempt studies are strongly encouraged such as adherence to the ethical principles articulated in the Belmont Report, found at www.hhs.gov/ohrp/regulations-and-policy/belmont-report/# as well as the MSU HRPP Operations Manual, found at www.orc.msstate.edu/humansubjects. Additionally, to protect the confidentiality of research participants, we encourage you to destroy private information which can be linked to the identities of individuals as soon as it is reasonable to do so.

Based on this determination, this study has been inactivated in our system. This means that recruitment, enrollment, data collection, and/or data analysis CAN continue, yet personnel and procedural amendments to this study are no longer required. **If at any point, however, the risk to participants increases, you must contact the HRPP immediately. If you are unsure if your proposed change would increase the risk, please call the HRPP office and they can guide you.**

If this research is for a thesis or dissertation, this notification is your official documentation that the HRPP has made this determination.

If you have any questions relating to the protection of human research participants, please contact the HRPP Office at irb@research.msstate.edu. We wish you success in carrying out your research project.

Review Type:	EXEMPT
IRB Number:	IORG0000467

Consumer Acceptance Test Score Sheet for Sweet Potato Frozen Desserts

Samples: Sweet potato frozen desserts **Date: ________**

You have been provided with a tray containing coded frozen dessert samples. Please follow the instructions as indicated:

1. Evaluate each sample starting with the first number listed and continue down the page and until you have evaluated each sample.
2. Rate each sample in each of the categories listed and place a check mark to indicate your choice.
3. Expectorate the sample in the cup provided and rinse with the water provided.
4. Each column will need a check mark if you choose to evaluate all samples**.**
5. Describe each attribute for each of the samples.
6. At the bottom of the page indicate which sample you would buy.

Sample 516	**Appearance**	**Aroma**	**Flavor**	**Texture**	**Overall Acceptability**
9 Like extremely					
8 Like very much					
7 Like moderately					
6 Like slightly					
5 Neither like nor dislike					
4 Dislike slightly					
3 Dislike moderately					
2 Dislike very much					
1 Dislike extremely					

Describe each attribute:
Appearance: ____
Aroma: ____
Flavor: ____
Texture: ____

Sample 733	**Appearance**	**Aroma**	**Flavor**	**Texture**	**Overall Acceptability**
9 Like extremely					
8 Like very much					
7 Like moderately					
6 Like slightly					
5 Neither like nor dislike					
4 Dislike slightly					
3 Dislike moderately					
2 Dislike very much					
1 Dislike extremely					

Describe each attribute:
Appearance: ____
Aroma: ____
Flavor: ____
Texture: ____

Sample 227	**Appearance**	**Aroma**	**Flavor**	**Texture**	**Overall Acceptability**
9 Like extremely					
8 Like very much					
7 Like moderately					
6 Like slightly					
5 Neither like nor dislike					
4 Dislike slightly					
3 Dislike moderately					
2 Dislike very much					
1 Dislike extremely					

Describe each attribute:
Appearance: ____
Aroma: ____
Flavor: ____
Texture: ____

Which one would you buy?

Thank you for your participation.

Descriptive Sensory Evaluation Score Sheet of Sweet Potato Frozen Dessert

Name_________________________________ Date____ /____ /____

APPEARANCE

Color: (The intensity of orange color)

0 White	5	10	15 Orange

Comments:

AROMA

Overall Intensity: (The fundamental odor strength of overall)

0 Not Strong	5	10	15 Very Strong

Comments:

Sweet Potato: (The fundamental odor strength of sweet potato)

0 Not Strong	5	10	15 Very Strong

Comments:

Vanilla: (The fundamental odor strength of vanilla)

0 Not Strong	5	10	15 Very Strong

Comments:

FLAVOR

Overall Intensity: (The total impact of the ice cream and frozen desserts)

0	5	10	15
Not Strong			Very Strong

Comments:

Sweet: (The fundamental taste of sucrose. 2 % sucrose = 2; 5% sucrose= 5)

0	5	10	15
Not Sweet			Very Sweet

Comments:

Sourness: (The fundamental taste sensation of lactic acid and citric acid. 0.05 % citric acid = 2; 0.08% citric acid = 5; 0.15% citric acid = 10)

0	5	10	15
Not Sour			Very Sour

Comments:

Astringency: (The measure of puckery flavor)

0	5	10	15
Not Astringent			Very Astringent

Comments:

Milk: (The fundamental taste of dairy milk)

0	5	10	15
Not Strong			Very Strong

Comments:

Sweet Potato Flavor: (The intensity of sweet potato flavor)

0 No Flavor	5	10	15 Very Strong

Comments:

Vanilla Flavor: (The intensity of vanilla flavor)

0 No Flavor	5	10	15 Very Strong

Comments:

TEXTURE:

Smoothness: (The possession of a custard-like body with a smooth homogenous texture)

0 Not Smooth	5	10	15 Very Smooth

Comments:

Creaminess: (The possession of creamy feeling without grainy texture)

0 Not Creamy	5	10	15 Very Creamy

Comments:

Coarse-Icy: (The possession of coarse ice texture)

0 Not Icy	5	10	15 Very Icy

Comments:

Gummy: (The possession of gummy texture)

0	5	10	15
Not Gummy			Very Gummy

Comments:

Mouth-coating: (The measure of mouth coating)

0	5	10	15
No Mouth-coating			Strong Coating

Comments:

Rate of melt in mouth: (The measure of melting rate in mouth)

0	5	10	15
Not Slow			Very Fast

Comments:

Descriptive Sensory Evaluation Score Sheet of Green Smoothie

Name________________________________ Date____ /____ /____

APPEARANCE

Color: (The intensity of green color)

0 White | 5 | 10 | 15 Green

Comments:

AROMA

Overall Intensity: (The fundamental odor strength of overall)

0 Not Strong | 5 | 10 | 15 Very Strong

Comments:

Leafy vegetable: (The fundamental odor strength of leafy green e.g. grass)

0 Not Strong | 5 | 10 | 15 Very Strong

Comments:

Sourness: (The fundamental odor strength of acidity like lactic acids or citric acids)

0 Not Sour | 5 | 10 | 15 Very Sour

Comments:

Banana: (The fundamental odor strength of fresh banana)

0 5 10 15

No Aroma Very Strong

Comments:

Pineapple: (The fundamental odor strength of fresh pineapple)

0 5 10 15

No Aroma Very Strong

Comments:

<u>FLAVOR:</u>

Overall Intensity: (The total impact of the smoothie)

0 5 10 15

Not Strong Very Strong

Comments:

Sweet: (The fundamental taste of sucrose. 2 % sucrose = 2; 5% sucrose= 5)

0 5 10 15

Not Sweet Very Sweet

Comments:

Sourness: (The fundamental taste sensation of lactic acid and citric acid. 0.05 % citric acid = 2; 0.08% citric acid = 5; 0.15% citric acid = 10)

0 5 10 15

Not Sour Very Sour

Comments:

Astringency: (The measure of puckery flavor)

0	5	10	15
Not Astringent			Very Astringent

Comments:

Leafy Green Flavor: (The intensity of leafy green taste e.g. grass)

0	5	10	15
Not Strong			Very Strong

Comments:

Banana Flavor: (The intensity of banana taste)

0	5	10	15
Not Strong			Very Strong

Comments:

Pineapple Flavor: (The intensity of pineapple taste)

0	5	10	15
No Flavor			Very Strong

Comments:

Yogurt Flavor: (The intensity of yogurt flavor)

0	5	10	15
No Flavor			Very Strong

Comments:

<u>TEXTURE</u>:

Smoothness: (The possession of a custard-like body with a smooth homogenous texture)

0 | 5 | 10 | 15
Not Smooth | | | Very Smooth

Comments:

Graininess: (The mouth-feel of fruit particles or fiber-tissues)

0 | 5 | 10 | 15
Not Grainy | | | Very Grainy

Comments:

Mouth-coating: (The measure of mouth coating)

0 | 5 | 10 | 15
No Mouth-coating | | | Very Strong Mouth-coating

Comments:

Separation: (The measure of separation between liquid and solid phases)

0 | 5 | 10 | 15
No Separation | | | Very Strong Separation

Comments: