Sensory and consumer evaluation of lucuma powder as an ingredient for ice cream in the United States

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Abstract

The growing demand for natural and healthy foods has prompted the use of high-nutrition, low-calorie ingredients in food products. Superfoods consist of a variety of nutrients such as healthy fats, fiber, vitamins, and minerals. Due to the presence of such components, they are proposed to have several health benefits. Lucuma is a subtropical fruit, belonging to Sapotaceae family. It is an ancient fruit cultivated in Andean region of Peru, Chile, and Ecuador. Lucuma fruit is usually commercialized as pulp and/or powdered form. The lucuma powder form has not been studied extensively relative to its sensory characteristics. Therefore, the objectives of this study were 1) to investigate the aroma volatile profiles of lucuma powders from different sources, 2) to examine the sensory characteristics of lucuma powders from different sources when used in a finished product (i.e., ice cream), and 3) to investigate consumer liking of ice creams made with lucuma powders with different sensory profiles and compare them to a caramel ice cream product, considered more mainstream and familiar to the US consumers. Twelve lucuma powder samples from different sources were used to develop their aroma volatile profiles using gas chromatography – olfactometry. The volatile analysis generated 37 aroma active volatiles responsible for 27 different aroma notes. Naturevibe and Healthworks products were the most different products compared to the other manufacturers evaluated in this study. Based on PCA visualization, five lucuma powder samples: Naturevibe, Terrasoul, Healthworks, Herbazest and Superfood by MRM were selected as they differed the most from an aroma profile standpoint to move forward with application into a final product form (i.e., ice cream). Six highly trained descriptive sensory panelists developed a sensory lexicon to describe the sensory properties of lucuma ice cream, consisting of 31 attributes including appearance, aroma, flavor,

aftertaste, and texture. Analysis of Variance (ANOVA) results for descriptive analysis showed that the lucuma ice cream samples were perceived to be mostly similar to each other and slightly different than the caramel ice cream. Only five attributes: color intensity (appearance), caramelized (aroma), brown sweet (flavor), chalkiness (texture) and grainy (texture) were found to be statistically different ($p<0.05$). A central location consumer test was performed using untrained panelists who were frequent ice cream users. Results showed that lucuma and caramel ice creams were perceived to be different by consumers, but the margin was small. This study confirms that variability exists between lucuma powders from different sources and helps understand the consumer perception towards lucuma ice cream, which shows that it may have a competitive opportunity in the US market. More than half of the consumers (57%) responded that they would definitely or probably buy lucuma ice cream, if available on shelves, after tasting and looking at a product concept. Further research can explore the sources of variability and its effects on products containing lucuma powder as an ingredient, and the study of consumer perception of lucuma powder applied into other finished products such as yogurts, smoothies, and baked goods.

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Chapter 1 - Literature Review

Introduction

The growing demand for natural and healthy foods has prompted the use of high-nutrition, low-calorie ingredients in food products. These food products are becoming a trend amongst consumers. There are several reasons behind this shift shown by the consumers. With the rapid increase of easily accessible options for high-calorie, low-nutrition foods, the rates of obesity are on the rise (Kahler, 2020). Food manufacturers are finding innovative ways to respond to consumer demands. Recent trends in the food industry have shown the diversion toward the natural, plant based as well as healthier products. Consumers intend to buy healthy products but do not like to change their eating habits; therefore, marketers have been riding the wave of increasing health interest and have recognized the considerable potential of adding the functional ingredients to regular products (Bech-Larsen and Grunert, 2003).

Superfood is a marketing term used for natural foods that are supposed to be beneficial for human health because they are rich in one or more nutrients (Mukta et al., 2017). The superfoods can consist of a variety of nutrients such as healthy fats, fiber, vitamins and minerals. Due to the presence of such components, they are proposed to have several health benefits. The Oxford English Dictionary characterizes superfood as food that is “considered particularly nutritious or in any case helpful to human wellbeing and prosperity.” Therefore, the term superfood is considered to be an umbrella term for the description of foods that, in addition to their typical nutrition content, offer health benefits and/or properties of disease prevention (Lunn, 2006). Superfoods as ingredients are considered rich in components believed to reduce the onset of diseases such as cancer, diabetes, heart disease etc. and can be considered both a food and a medicine as they have elements of both (Wolfe, 2009).

Lucuma

Lucuma (Pouteria Lúcuma) is a subtropical fruit, belonging to Sapotaceae family. It is an ancient fruit cultivated in Andean region of Peru, Chile and Ecuador, Peru being the largest producer at 88% of worldwide production (Aguilar, 2015). This fruit is also known as the "Gold of the Incas" and was used by Inca civilization as one of the main ingredients of their diet. It is cultivated from 1500 to 3000 meters above the sea level, with a temperature range of 8 to 27 degrees Celsius and a relative humidity of 80 – 90% (Inga et al., 2019). Native populations of Andean region have long cultivated the fruit to be used for diet as well as medicinal purposes (Fuentealba et al., 2016). Lucuma is an ovoid to elliptical shaped fruit that is 7.5 to 10 centimeters in size. It has thin skin, and the color of the skin varies from green to yellow depending on ripeness of the fruit whereas the flesh of the fruit is dry and starchy with orange to yellow color and pumpkin-like sweet flavor (Yahia and Gutierrez-Orozco, 2011). The fruit can take up to 15 – 16 months to reach harvest maturity (Fuentealba et al., 2016) and the common index used for maturity is change in skin color alongside the amount of soluble solids due to ripeness of fruit. The skin color changes from green to yellow whereas for pulp, the color can vary from green to yellowish green (Lizana, 1980). There are two main types of lucuma depending upon the pulp of the fruits: lucuma-seda and lucuma-palo. These have soft pulp and hard pulp at maturity respectively. The former is consumed fresh whereas the latter is typically utilized in its processed form (Gomez-Maqueo et al., 2020).

As far as the handling of lucuma is concerned, there are several measures that need to be followed carefully. The soft texture and thin skin of the lucuma fruit makes it prone to physical damage (Yahia and Gutierrez-Orozco, 2011). Because of the sensitivity of the fruit to postharvest water loss, adequate storage becomes more significant. According to Sandoval

(1997), the fruit is highly sensitive to postharvest water loss and does not ripen uniformly after longer storage duration. The quality of the fruit remains intact for up to seven days if stored at 7 degrees Celsius and can be kept for up to 14 days at temperature range of 13 to 18 degrees Celsius before it shows signs of decay (Sandoval, 1997).

Since the exotic Peruvian fruit is highly sensitive and susceptible to physical injury, it is important to preserve the product without compromising the nutritional value significantly (Sharma et al., 2018). Therefore, the lucuma fruit is usually commercialized as pulp and/or powdered form. Usually, the ripe fruits are dehydrated and milled into flour to extend storage duration. To produce pulp, the fruit is washed, disinfected, peeled and seeded. Then, the pulp is ground, vacuum-packed and frozen at -25 degrees Celsius to make the pulp stable for two years. Similarly, the lucuma flour or powder is produced from dehydrated lucuma fruit after it is dried at 60 degrees Celsius through hot air tunnels (Yahia and Gutierrez-Orozco, 2011). According to Clevidence et al (1999), commercial food processing does not affect the bioavailability of carotenoids. Thermal processing of spinach and carrot did not affect the bioavailability of beta-carotene (Rock et al., 1998; Clevidence et al., 1999). Processing of lucuma fruit into pulp or powdered form may or may not affect the nutritional value and quality of the product, but it can affect the sensory properties. Therefore, one of the objectives of the research is to investigate the change in sensory profile of powdered form of lucuma. Lucuma powders from various sources will be used to account for the variability.

Health and Nutritional Aspects

Lucuma fruit has promising health benefits and it can be eaten raw or processed. Processed forms of lucuma can be used as an ingredient in a variety of food products such as ice creams, baked consumer goods, flavored beverages etc. As mentioned above, the food industry has shifted the focus towards the utilization of natural ingredients to create clean label food products. The consumer demand for healthy foods has led to the use of dried foods as a natural sweetener, thickener, humectant as well as functional ingredients. Lucuma fruit powder has also been used as an ingredient in the production of baby foods, pies, smoothies, chocolate and yogurt (Banasiak, 2003; Dini, 2011). Lucuma flavored ice cream is popular in Peru and Chile defeating the traditional vanilla and chocolate flavored ice creams because of its sweet taste, caramel-like and maple-like flavor and aroma (Yahia and Gutierrez-Orozco, 2011). Sugars have proved to be a major culprit when it comes to weight gain for human body, which can lead to further health problems such as obesity, diabetes, cardiovascular health problems etc. Lucuma can be considered as a natural alternative to sweeteners because it has low glycemic index which provides additional health benefits alongside good taste. It has low sugar concentration even though it tastes sweet when added to the food products. Therefore, it can be beneficial to consume lucuma (raw or processed). Silva et al (2009) suggested that lucuma extracts can behave as alpha-glucosidase inhibitors producing hypoglycemic effect that may help in managing diabetes in patients.

Lucuma fruit is a good source of dietary fiber (Glorio et al., 2008). This fruit is considered an excellent source of fiber. Previous research suggested that the fiber composition in the fruit or pulp varies from 1.1g per 100g of fruit (Yahia and Gutierrez-Orozco, 2011) to 10.2g per 100g of fruit pulp (MINSA, 2017) as shown in Table 1.1. Fiber is an important part of diet that can lower the risk of diverticular diseases by preventing intestinal blockages. High fiber diet is also associated with reducing the risk of occurrence of obesity and metabolic syndrome. According to Brizzolari et al. (2019), fruits belonging to Sapotaceae family are a rich source of anti-inflammatory polyphenols and antioxidant compounds. Another study suggested that lucuma extracts have catechin and epicatechin that may contribute to the antioxidant capacity (Ma, 2004). Taiti et al. (2017) and Dini (2011) also proposed that because of having flavonoid compounds as well as high phenolic contents, lucuma can be treated as an excellent nutraceutical ingredient for food preparations. Since flavonoids carry antioxidant activity, they are linked to prevent the onset of diseases such as coronary heart disease, Parkinson's disease and cancer (Kumar and Pandey, 2013; Ribas-Agusti et al., 2018). Antioxidants inhibit oxidation process by safely interacting with free radicals before they could cause damage to our body (Lobo et al., 2010). Furthermore, lucuma consists of high concentration of beta-carotene, niacin and iron, so it is recommended for consumption specially in children for their physical development (Durakova et al., 2019).

Table 1.1.

Nutritional Information of Lucuma Fruit/Pulp (Per 100g of Fruit/Pulp).

Constituent	Yahia & Gutierrez-Orozco (2011)	MINSA (2017)	Duarte & Paull (2015)
Water	62g	61.7g	72.3g
Protein	2.3g	2.1g	1.5g
Carbohydrates	33.2g	34.9g	25g
Fat	0.2g	0.2g	0.5g
Fiber	1.1g	10.2g	1.3g
Calcium	16mg	16mg	16mg
Phosphorus	26mg	26mg	26mg
Vitamin C	5.4mg	0.77mg	2.2mg

Note. Source: Maza-De la Quintana and Paucar-Menacho (2020)

Ice Cream

Ice cream is an incredibly popular dessert in the world. It consists of air bubbles, fat and ice crystals diffused into a mix of sugars, proteins and stabilizers etc. (Clarke, 2004). Typically, the main ingredients that make up an ice cream recipe are milk and sugar. But there is another ingredient, air, which is responsible for 30 – 50% of the total volume of the ice cream. The air is incorporated into the mix while preparing the ice cream and it contributes to the flavor as well as texture of the ice cream. Various flavors of ice cream cater to different sections of the population around the world. The United States consumers continue to hold a significant market share in the ice cream industry.

However, with the growing health concerns among consumers, the demand for healthy alternatives in such products has been increasing. The increased interest in adding nutritional value to the food and healthy eating patterns has led consumers to incline towards the healthier food products (Grunert, 2006). Industry manufacturers have been trying to respond to new healthier lifestyle consumer needs, but these are constantly evolving. It is important to recognize the determining factors for healthier eating habits, and to identify the market segments that are more interested in health benefit claims of the products (Chrysochou et al., 2010; Conner et al., 2002, Povey et al., 2000). Some studies have suggested that consumers may perceive enrichment of healthy foods less satisfying than that of non-healthy foods (Bech-Larsen and Grunert, 2003; Krutulyte et al., 2011, Lahteenmaki, 2013).

The process of making changes for healthier options to ice cream formulations proves to be a challenging task as it affects the overall sensory properties of the product. A proper understanding of how consumers perceive food products is necessary for different aspects of new product development such as reformulation, quality control and marketing (Ares, 2015; Fonseca et al., 2016; Meilgaard et al., 1999). New varieties of ice cream catering to the functional and dietary requirements of the consumers are becoming popular. There has been constant demand for healthier and natural foods with functional foods or ingredients for obesity control, good cardiovascular and intestinal tract health, hence, the development of several functional ice cream formulations including ingredients such as probiotics, prebiotics, dietary fibers etc. (Soukoulis and Tzia, 2010). There are healthier options available for the consumers on the shelves now as the manufactures are responding to current consumer trends. Evstigneeva et al. (2020) reported that a low-calorie ice cream with a special ingredient (L-carnitine: a diet supplement known as a fat burner) was developed for people dealing with overweight issues. Use of amaranth was proposed in ice cream formulations (Yakovleva, 2012) because of its nutritional value that provides several health benefits such as reducing inflammation and cholesterol levels. However, there is an expectation from the consumer perspective that conventional foods should only be replaced by foods or ingredients perceived as healthy, which is paramount in determining consumer acceptance of such products (Bech-Larsen et al., 2001; Silva et al., 2016). Hoefkens et al. (2011) also reported that consumers perceive nutritional value as important for the selection of various foods and that more so for qualifying nutrients (fiber, vitamins and minerals) than disqualifying nutrients (energy, fat, sugar, salt).

As mentioned above, lucuma fruit provides high nutritional value as it has high dietary fiber concentration and antioxidant properties. It tastes sweet but has low glycemic index, which can provide for an excellent functional ingredient for various food products such as ice cream, smoothies, yogurt, cakes, cookies etc. Typically, lucuma powder or frozen pulp are used as an ingredient in the food products. Since lucuma is native to Peru, lucuma ice cream is extremely popular in the country. It regularly outsells strawberry as well as chocolate ice creams and can be found throughout Peru including some fast-food chains, and the flavor can be described as sweet, pleasant, caramel-like and maple-like. Unfortunately, lucuma ice cream is not well-known outside of South America. Lucuma powder can be considered as a healthy addition to ice creams that can provide excellent taste and numerous health benefits.

Gas Chromatography - Olfactometry

Flavor and aroma play an important role in the success or failure of food products in the consumer market. The aroma and flavor profiles of a particular food are caused by numerous volatile and semi volatile compounds present in the products at various concentrations. These compounds are responsible for the release various odors from the foods. There are several methods to quantify the volatiles but Gas Chromatography – Olfactometry (GC-O) is one of the most used methods (Friedrich and Acree, 1998). Gas Chromatography – Olfactometry can be defined as the technique used to detect and evaluate the volatile profile of products using instrumental and human assessors which development has been paramount in understanding the separation, identification, and quantification of the compounds (Delahunty et al., 2006). Gas Chromatography – Olfactometry combines the information supplied by chemical characterization and by odor perception. It utilizes a gas chromatography – mass spectrometry (GC-MS) system equipped with an olfactory detection port. Main components of the set up are an injector, a column, and a detector. An injector port is used to inject samples into the system. The sample gets separated into individual components in the column whereas the detector is where the concentration of the components is determined. Additionally, GC-O consists of a detection port that is a cone shaped outlet where the trained human assessor can smell the volatiles and provide the information regarding the odor released from the volatile.

According to Zellner et al. (2008), the sensation of a certain odor is triggered by complex mixture of volatile compounds, and GC-O enables the evaluation of odor-active volatiles in a complex mixture based on their correlations with chromatographic peaks of interest. Various compounds with identical structures can smell different and the opposite is also true, where compounds with different structures can smell similarly (Delahunty et al., 2006). Volatile profiles are closely related to the isolation procedure so sample preparation is a very important step. The isolated part or amount of sample should represent the entire sample in order to achieve the intended purpose. There are several sample preparation methods such as solvent extraction, steam distillation, solvent assisted flavor evaporation, headspace techniques, solid phase micro-extraction (SPME) etc. (Zellner et al., 2008). SPME is a widely used technique for the purpose of sample preparation in a variety of applications including food analysis. The technique uses a fused-silica fiber coated on the outside to extract the volatile and semi-volatile compounds from the sample (Kataoka et al., 2000).

The volatile composition of the powdered form of lucuma as a raw ingredient is a key feature that can determine the consumer acceptance of the food products having lucuma powder on the ingredient label. Taiti et al. (2017) performed an instrumental analysis to assess the volatile organic compound profile of the lucuma fruit. There have been some research studies including the chemical characterization of odor-active volatile compounds of lucuma fruit during ripening (Inga et al., 2019) and the sorption characteristics of lucuma powder (Durakova et al., 2019). The research shows that lucuma comprises of a complex volatile profile responsible for its authentic aroma, although there is limited information available on the topic.

Sensory Analysis

Sensory evaluation can be defined as a science that measures, analyzes and interprets the reactions of the panelists to various products as perceived by their senses (Stone and Sidel, 2004). It comprises of a set of techniques to accurately measure the human responses to foods minimizing the other information that can influence consumer perception (Lawless and Heymann, 2010). Therefore, it involves measurement and evaluation of sensory characteristics of the foods as well as non-food materials. Additionally, it is essential to analyze and interpret the results accurately to make appropriate decisions regarding various sectors of the industry such as product development, marketing and quality assurance (Stone and Sidel, 2004). Sensory data is useful to understand product attributes as well as consumer perception of the product that further helps in making product related decisions. However, it is important to select an appropriate testing method. A good sensory test minimizes the errors in measurement and focuses on conclusions and decisions (Lawless and Heymann, 2010).

Sensory evaluation data consists of human perceptions and their responses. These perceptions can vary and are affected by psychological and physiological factors (Kemp et al, 2011). The sensory test methods should be designed considering the above-mentioned factors to reduce the bias (Kemp et al, 2011). It is important to ensure that the adequate number of participants perform product evaluation in replications to reduce the variability and produce concrete results. Furthermore, objective of the sensory studies should be clearly defined, and questions asked to the consumers should support the objective. It is essential to understand the objectives as it helps determine the test method, experimental design as well as the statistical analysis required to successfully complete the project (Kemp et al, 2011).

Sensory analysis can be divided into two main categories based on the goals and objectives of a study: analytic and affective methods. The analytic methods consist of two sub-categories named discrimination testing and descriptive analysis whereas the affective methods involve consumer testing (Lawless and Heymann, 2010).

Discrimination testing are employed to determine if a difference or similarity exists between two or more samples (Kemp et al, 2011). There are several discrimination test methods such as triangle test, dual comparison, paired comparison, tetrad, etc. (Stone and Sidel, 2004). The respondents are asked to identify the samples that are different or similar based on the type of test method employed. Manufacturers can utilize discrimination testing when they reformulate the product due to reasons such as change of ingredients, regulations, or pricing. The idea behind testing would be that not enough participants should be able to detect the difference (Lawless and Heymann, 2010).

Descriptive analysis involves describing the sensory characteristics, identifying the sensory attributes and assigning the intensity ratings to those attributes using highly trained assessors. It is a methodology that provides a quantitative description of the products based on the perceptions from a group of qualified subjects (Stone and Sidel, 2004). This technique allows sensory professionals to obtain sensory profiles of the products including underlying ingredient and process variables to determine, when combined with affective testing, which sensory attributes are important to product acceptance (Lawless and Heymann, 2010). Descriptive analysis can provide information on how the product differs from the market competitors. Therefore, it can be used at different stages such as product development, quality assurance as well as shelf-life testing. The more commonly used descriptive techniques are flavor profile, quantitative descriptive analysis (QDA), texture profile, and spectrum method (Lawless and

Heymann, 2010). The descriptive analysis technique uses highly trained panelists who evaluate the product for various attribute categories such as appearance, aroma, flavor, texture, aftertaste etc. The panelists are encouraged to use specific and singular sensory terms to describe product attributes and refrain from using consumer terms, which can be more ambiguous and less actionable. Different descriptive techniques use different scales with a common focus on the objective recognition and quantification of the principal characteristics of the product.

Affective methods are performed to assess consumers' preference or acceptance regarding a particular product, concept, or specific product characteristic (Meilgaard et al., 2016). Acceptance tests measure the degree to which a product is liked or disliked and allows the generation of data that can be compared across studies whereas preference tests produce ordinal data that permits identification of sample preference within the sample set. Affective tests are different from descriptive testing in that these are performed using the frequent users of the product under examination i.e., untrained panelists. Therefore, it is important to ask the right question in a simplified manner so the respondents can understand and answer accordingly. The questions can also help explore the rationale behind the consumer liking or disliking of the product. Commonly used scales in consumer testing to assess consumer liking and product diagnostic are the 9-point hedonic scale, a widely used scale that measures liking going from 1 "dislike extremely" to 9 "like extremely" and the 5-point just-about-right scale. The 9-point hedonic scale allows participants to rate their liking or disliking towards various attributes the product whereas the 5-point just-about-right scale is used to compute the penalties from the respondents as to what modifications can be performed to increase consumer liking. The 9-point hedonic scale is easily understood by all sections of consumers with minimal instructions and results have proven to be remarkably stable (Stone and Sidel, 2004).

Central Location Test (CLT) and Home Use Test (HUT) are two common techniques used to perform quantitative consumer testing. As the names suggest, central location tests are performed at a location arranged by the sensory professionals whereas in home use tests, participants are asked to use the product at their homes. While the central location tests are performed under controlled environment, home use tests typically take place under uncontrolled conditions. According to Lawless and Heymann (2010), the home use tests provide more realistic information as the consumers get to use products as they would, under normal circumstances over a pre-determined period. However, central location tests are more cost-effective, and results are obtained in lesser time than home use tests. Online survey is another technique to gather information about consumer expectations as well as consumer satisfaction regarding various products.

Consumer testing also includes qualitative testing. This technique involves conducting focus groups, one-on-one interviews, and group discussions to gain in-depth understanding of consumer needs. One-on-one interview is the most flexible as it allows the interviewer to include a variety of topics in the questionnaire, but the length of interview should be carefully considered (Lawless and Heymann, 2010).

Furthermore, consumer research encompasses a rather interesting approach to generate deeper consumer understanding. This approach is called attitudinal consumer research. There are several ways to assess market segmentation such as geographic, demographic, behavioral and through psychographics. Psychographics can be defined as the study of consumer personality traits to understand and predict patterns in consumer behavior. Various scales in the form of questionnaires have been developed to achieve the purpose such as likert scale, dietary restraint scale, food neophobia scale etc.

The Food Neophobia Scale (FNS) is a psychometric tool developed by Pliner and Hobden (1992) to measure food neophobia where respondents indicate their agreement or disagreement with 10 statements about foods or eating situations (Ritchey et al., 2003). Food neophobia can be defined as reluctance to eat unfamiliar foods or food products (Loewen and Pliner, 2000). The higher the score, the greater the individual is neophobic toward new or novel foods (Pliner and Hobden, 1992). Stratton et al (2015) explored the relationship between food neophobia and factors associated with functional food consumption in older adults. Similarly, it was studied how food neophobia can contribute to nutritional risks in older adults (Soucier et al., 2019). According to Rubio et al (2008), exposure to diverse foods at early age is negatively correlated to food neophobia, which indicates that culture is a major factor when studying the phenomenon. Evidence suggests that lower intake of foods such as vegetables, fruits, chicken and cheese can be linked to food neophobia (Cooke et al., 2006; Galloway et al., 2003; Soucier et al., 2019).

Associations Between Sensory and Instrumental Analysis

Descriptive sensory techniques involve evaluation of the foods and materials using highly trained panelists. They identify as well as quantify the product attributes. On the other hand, instrumental analysis techniques such as gas chromatography – olfactometry can prove to be crucial in profiling the products. The association between sensory and instrumental analysis has been studied to draw useful conclusions and establish relationship between aroma attributes and volatile composition (Chambers and Koppel, 2013). The aroma attributes significantly affect the overall quality of the product. Research conducted thus far suggests that sensory and instrumental techniques can complement each other to provide useful information that could increase the understanding of product attributes (Lawless and Heymann, 2010). The volatile composition of various products has been evaluated in relation to the sensory profile such as sorghum grain (Vasquez-Araujo et al., 2011), coffee (Velasquez et al., 2019) and pet foods (Koppel et al., 2014). There is no published literature regarding the associations between volatile profile of lucuma powder as a raw ingredient and sensory profile when used in finished product such as ice cream.

Research Objectives

Consumer demand for healthy foods is on the rise as they add nutritional value to the diet, which in turn provides numerous health benefits. Lucuma is considered a superfood as it comprises of variety of nutrients such as healthy fats, dietary fiber, vitamins and minerals. It tastes sweet but has low glycemic index providing additional benefits. Since the information available regarding the lucuma powder as a raw ingredient is limited, it provides for an opportunity to explore the product further.

Objective 1. To investigate the aroma volatile profiles of lucuma powder from different sources. Gas chromatography – olfactometry using trained panelists was performed to achieve the purpose.

Objective 1A. Select five lucuma powder samples that differ the most from an aroma profile standpoint to move forward with application into a final product form (i.e., ice cream).

Objective 2. To investigate the sensory characteristics of lucuma powder from different sources when used in a finished product (i.e., ice cream). Descriptive sensory analysis was conducted using highly trained panelists to describe the sensory characteristics of lucuma ice cream.

Objective 2A. Establish the associations between sensory characteristics of the final product and instrumental analysis of the powder form to understand how the raw ingredient (lucuma powder) from different sources translates into the sensory properties of finished products (i.e., ice cream).

Objective 3. To investigate consumer liking of ice creams made with Lucuma powder with different sensory profiles (purchased from different sources) and compare them to a Caramel ice cream product, considered more mainstream and more familiar to consumers in the

United States. A central location test was performed using untrained panelists who were frequent ice cream consumers.

Objective 3A. Understand how Lucuma ice cream compares to a more mainstream ice cream flavor that is more familiar to US consumers.

Objective 3B. Assess food neophobia to segment US consumers and understand how the overall liking of these segments differ for ice cream samples. A 7-point likert scale consisting of 10 statements was utilized to understand consumers' attitude towards unfamiliar foods and food products.

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Chapter 2 - Volatile and Aroma Aspects of Different Lucuma Powder

Abstract

The objective of this study was to investigate aroma volatile profiles of lucuma powder samples from different sources. A total of 12 lucuma powder samples produced by different manufacturers were used. The goal was to incorporate variability present in different commercial samples. Gas chromatography – olfactometry using two trained panelists from the Center for Sensory Analysis and Consumer Behavior (Manhattan, Kansas) was conducted to achieve the objective. An attribute list with their corresponding reference materials was developed after an orientation session. Then, all the samples were evaluated for their volatile composition and aroma characters. The volatile analysis of the lucuma powder samples generated 37 aroma active volatiles responsible for 27 different aroma notes. Key aroma active compounds include Benzyl nitrile, 1-Hexanol, 2,3-Dimethyl-5-ethylpyrazine, Benzaldehyde, Butanal-3-methyl and Hexanal. Main aroma attributes in all the samples were buttery, sweet, caramelized, waxy, green, nutty, cucumber and baked potato. Other aroma notes such as mushroom, brown sweet, grain, plastic and burnt were also detected. Principal Component Analysis (PCA) shows the separation of the lucuma powder samples based on their volatile composition. Naturevibe and Healthworks products were the most different products compared to the other manufacturers evaluated in this study. This is because they had different concentrations of volatiles such as acetic acid methyl ester, benzene isothiocyanate, benzyl nitrile, hexanal, 3-methyl butanal and 2-methyl butanal that imparted aroma notes such as buttery, brown sweet, chemical, cucumber, green, burnt and leather. This study confirms the variability of lucuma powders from different sources which may affect the final product. Five samples: Naturevibe, Healthworks, Terrasoul, Herbazest and

Superfood by MRM were selected to move forward with their application into the ice cream product. Further research is needed to understand the sources of variability and the effect this has on final products that use lucuma powder as an ingredient.

Introduction

Lucuma is a subtropical fruit, belonging to Sapotaceae family. It is an ancient fruit cultivated in Andean region of Peru, Chile and Ecuador, Peru being the largest producer at 88% of worldwide production (Aguilar, 2015). This fruit is also known as the “Gold of the Incas” and was used by Inca civilization as one of the main ingredients of their diet. It is cultivated from 1500 to 3000 meters above the sea level, with a temperature range of 8 to 27 degrees Celsius and a relative humidity of 80 – 90% (Inga et al., 2019). Native populations of the Andean region have long cultivated the fruit to be used for diet as well as medicinal purposes (Fuentealba et al., 2016). Lucuma is an ovoid to elliptical shaped fruit that is 7.5 to 10 centimeters in size. It has thin skin, and the color of the skin varies from green to yellow depending on ripeness of the fruit whereas the flesh of the fruit is dry and starchy with orange to yellow color and pumpkin-like sweet flavor (Yahia and Gutierrez-Orozco, 2011). The fruit can take up to 15 – 16 months to reach harvest maturity (Fuentealba et al., 2016) and the common index used for maturity is change in skin color alongside the amount of soluble solids due to ripeness of fruit. The skin color changes from green to yellow whereas pulp color can vary from green to yellowish green (Lizana, 1980). There are two main types of lucuma depending upon the pulp of the fruits: lucuma-seda and lucuma-palo. These have soft pulp and hard pulp at maturity respectively. The former is consumed fresh whereas the latter is typically utilized in its processed form (Gomez-Maqueo et al., 2020).

There is an increased demand of nutritional foods with health benefits in the consumer market. There are several substitutes available to replace the conventional ingredients in the food products. Lucuma, a Peruvian fruit, is considered as a superfood that can potentially be used in its powdered form as a natural, healthy and plant-based ingredient in various food products such as ice cream, smoothies, cakes etc. Consumers pay attention to the product quality, dietary value and other sensory characteristics (Taiti et al., 2017). The aroma of the lucuma powder is an essential parameter in assessing its quality. There are several volatile compounds that are responsible for various odors released from the lucuma powder. Baietto and Wilson (2015) reported that different fruits have different volatile composition that contributes to distinguishing odors. The chemical composition of a product comprises of numerous compounds but not all are responsible for the odors released. It is also important to consider that a particular volatile compound can be perceived differently while evaluating different products. The compounds that produce enough volatiles for a human assessor to detect the presence of an odor are called aroma active compounds (Mahattanatawee et al., 2005; Brattoli et al., 2013). The use of volatile analysis is one way to quantify and monitor sensory characteristics of lucuma powder that can affect the overall quality of the powder as a raw ingredient.

Gas chromatography – Olfactometry (GC-O) has been extensively used in research pertaining to volatile and aroma aspects of various products. The technique when coupled with Gas Chromatography – Mass Spectrometer (GC-MS) is used to detect, identify and quantify the volatile compounds and the corresponding odors released. Several methods are available to isolate and concentrate volatile compounds from the product matrix such as solid phase microextraction (SPME), aroma extract dilution analysis (AEDA), steam distillation etc. (Di Donfrencesco et al., 2012; Chambers and Koppel, 2013). GC-O allows for the determination of individual contribution of volatile compounds present in the products (Venkateshwarlu et al., 2004). However, the concentration and the overall chemical composition of a particular product may influence the odor release and eventually, aroma perception (Chambers and Koppel, 2013).

Various food processing measures may influence quality of foods and food products. For example, milling can cause removal of micronutrients such as minerals during processing. Therefore, food industry has widely applied the use of instrumental analysis to meet the needs of quality control. Obtaining the instrumental data is usually more efficient, reproducible and cost-effective. Therefore, GC-MS is an example of popular instrumental analysis for volatiles. The addition of sniffing port to the instrument helps human assessors detect the aroma corresponding to specific volatiles. Several research studies have been conducted for analyzing volatile profiles using GC-O for a wide range of products such as chocolates (Afoakwa et al., 2009), soymilks (Xia et al., 2015) and coffee (Bhumiratana et al., 2011) etc. Limited information is available regarding the use of GC-O to determine the volatile profile of lucuma fruit whereas no published literature is available for lucuma powder. Inga et al (2019) investigated the chemical characterization of odor-active compounds of lucuma fruit during ripening process.

The objective of the study was to investigate the aroma active volatile profiles of lucuma powder from different sources. The goal of adding different manufacture sources was to incorporate processing variability. Another objective of the research was to select five lucuma powder samples that differ the most from volatile and aroma standpoint to move forward with descriptive testing of a final lucuma flavored product (i.e., ice cream). Gas chromatography – olfactometry was used to achieve the purpose.

Materials and Methods

Samples

Twelve commercial lucuma powder samples from 11 different manufacturers (Table 2.1) were used in the study. All the samples were purchased online from amazon website except for two samples that were purchased from a market in Peru and brought to the United States. Samples bought online were available in packages with different quantities. Therefore, two to three packages of each product sample were purchased. For each manufacturer, the powder from different packages was mixed into single Food Saver vacuum bags and sealed using Food Saver Heat-Seal Vacuum Sealing System (Sunbeam Products Inc., Boca Raton, FL, USA). All the samples were then stored in a freezer at -18 ^{0}C

Table 2.1.

Lucuma Powder Samples Used in Volatile Analysis.

Sample or Brand name	Total Amount (g)	Purchased	Manufacturer/Distributor	Location
Alvitox	693	Amazon.com	Alvitox	Lake Forest, CA
Bio-Aurora	225	Peru	Bio-Aurora	Peru
Earthtone	1377	Amazon.com	Earthtone Foods	Middletown, NY
Ecoandino (Online)	994	Amazon.com	Ecoandino SAC	Concepción, Peru
Ecoandino (Market)	225	Peru	Ecoandino SAC	Concepción, Peru
Health Force	717	Amazon.com	Excelsior Alchemy	Tempe, AZ
Healthworks	1386	Amazon.com	Healthworks	Scottsdale, AZ
Herbazest	917	Amazon.com	Herbazest Inc.	Orlando, FL
Naturevibe	1338	Amazon.com	Naturevibe Botanicals	Rahway, NJ
Navitas	910	Amazon.com	Navitas Organics	Novato, CA
Superfoods by MRM	973	Amazon.com	MRM	Oceanside, CA
Terrasoul	1357	Amazon.com	Terrasoul Superfoods, LLC.	Fort Worth, TX

Gas Chromatography – Olfactometry Analysis

Volatile compounds were extracted using solid phase microextraction (SPME) with 50/30 micrometer divinylbenzene/ carboxen/ polydimethylsiloxane fiber (Supelco Analytical, Bellefonte, PA, USA) to characterize aroma and volatile profiles of lucuma powder samples from various sources. An amount of 0.5g of the sample was transferred into 10ml screw-cap vial (Supelco Analytical, Bellefonte, PA, USA) equipped with a polytetrafluoroethylene/silicone septum (Supelco Analytical, Bellefonte, PA, USA). The fiber was cleaned by inserting the fiber in the auxiliary injection port at 150 0C for 5 minutes before and after each run. Samples were incubated at 40 0C for 1 minute at 250 rpm using the autosampler. SPME fiber was inserted into the vial and exposed to the headspace at 40 0C for 1 minute for volatile extraction. The fiber was then removed from the vial. The volatile compounds were desorbed into the gas chromatograph – mass spectrometer (Shimadzu Corporation, Kyoyo, Japan) using a spitless injector for 1 minute at 240 0C. Helium gas was used as a carrier. The compounds were separated on an SH-Rxi-5Sil MS column (Shimadzu, Kyoto, Japan; 30m long, 25mm diameter and 0.25 micrometer thickness). The working conditions included ramping the initial temperature of 40 0C to 130 0C with the rate of 10 0C per minute. Then, the temperature was increased to 150 0C with 5 0C per minute rate followed up by 14 0C per minute increase to take it to 200 0C. Mass spectrometry was performed using electron-impact ionization at 70 eV (200 0C). The 16.57-minute run time was recorded in full scan mode (35-350 m/z mass range). All samples were analyzed in three replicates by two trained panelists, thereby producing six chromatograms for each lucuma powder sample.

Gas Chromatography – Olfactometry combines the information supplied by chemical characterization and by odor perception. It utilizes a gas chromatography – mass spectrometry (GC-MS) system equipped with an olfactory detection port. Main components of the set up are an injector, a column, and a detector. An injector port is used to inject samples into the system. The sample gets separated into individual components in the column whereas the detector is where the concentration of the components is determined. Additionally, GC-O consists of a detection port that is a cone shaped outlet where the trained human assessor can smell the volatiles and provide the information regarding the odor released from the volatile.

The study was performed by two trained panelists (one male and one female) from the Sensory and Consumer Research Center (SCRC, Manhattan, KS, USA). Initial attribute list was generated where each panelist evaluated four randomly selected lucuma powder samples. Attribute list consisted of 15 attributes (buttery, hay-like, green, grain, baked potato, sweet/fruity, caramelized, cucumber, waxy, burnt, sweet, eucalyptus, mushroom, nutty and chemical). An orientation session was conducted after the development of initial lexicon to discuss the attribute definitions as well as reference materials. The final attribute list was prepared after the modifications as per the orientation session discussions (Table 2.2).

Table 2.2.

Attribute List, Reference Materials and Their Preparation.

Number	Aroma attribute	Reference*	Preparation
1	Buttery	Kroger imitation butter flavor	Dip an orlandi perfumer strip in the compound to the second marking line and place the strip (marking line up) in a glass tube with screw cap
2	Hay-like	Dry parsley flakes	Serve 1/2 teaspoon parsley flakes in a glass tube with screw cap
3	Green	Trans-2-hexen-1-ol	Dip an orlandi perfumer strip in the compound to the second marking line and place the strip (marking line up) in a glass tube with screw cap
4	Grain	Cereal mix	Mix 1 cup each of General Mills rice chex, General Mills wheaties and Quaker quick oats. Pulse blend inro small particles. Place 1 teaspoon in glass tube with screw cap

5	Baked potato	Methylthiopropanaldehyde	Dip an orlandi perfumer strip in the compound to the second marking line and place the strip (marking line up) in a glass tube with screw cap
6	Sweet/fruity	Benzaldehyde	Dip an orlandi perfumer strip in the compound to the second marking line and place the strip (marking line up) in a glass tube with screw cap
7	Caramelized	Werther's original caramel candy	Crush one candy. Place in glass tube with screw cap
8	Cucumber	Cucumber water	Weigh 50g store bought conventional cucumber, peel, rinse, chop and add 300ml water. Blend for 1 minute and let it sit for 15 minutes. Filter and serve 1 teaspoon in glass tube with screw cap
9	Waxy	2-nonanal	Dip an orlandi perfumer strip in the compound to the second marking line and place the strip (marking line up) in a glass tube with screw cap
10	Burnt	Benzyl disulfide	Dip an orlandi perfumer strip in the compound to the second marking line and place the strip (marking line up) in a glass tube with screw cap
11	Sweet/fruity	Fisher scientific vanillin	Mix 2g Fisher Scientific Vanillin in 250ml water. Place 1 teaspoon in glass tube with screw cap
12	Eucalyptus	Aura cacia eucalyptus essential oil	Dip an orlandi perfumer strip in the compound to the second marking line and place the strip (marking line up) in a glass tube with screw cap
13	Mushroom	3-octanol	Dip an orlandi perfumer strip in the compound to the second marking line and place the strip (marking line up) in a glass tube with screw cap
14	Nutty	Chopped walnuts	Chop Diamond walnuts. Place 1 teaspoon in glass tube with screw cap

15	Chemical	Clorox bleach	Mix 1 drop of clorox bleach in 200ml water. Place 1 teaspoon in glass tube with screw cap

Note. Chemical references were obtained from Sigma Aldrich (St. Louis, MO, USA)

Data Analysis

After completing the evaluation for all the samples, Shimadzu GC-MS PostRun software outputs were obtained, and data was cleaned. Only the volatiles that appeared in at least four out of six replicates were considered for further analysis. Additionally, the volatiles with retention times that did not match with the other replicates were eliminated. Furthermore, silyls and siloxanes were removed from the data set as these can be present because of the column coating (Nielsen, 2010). Averages of area percentages of the remaining volatile compounds were determined. Principal Component Analysis (PCA) was performed in order to visually demonstrate the data using XLStat statistical software (Addinsoft, MS Excel, NY, USA).

Results and Discussion

Different lucuma powder samples contained various compounds at different concentrations that contributed to their unique aromas. The volatile analysis of 12 lucuma powder samples from different sources generated 37 aroma active compounds that were responsible for the release of various odors (Table 2.3). The panelists identified 27 different aromas. Main aroma attributes in all the samples were buttery, sweet, caramelized, waxy, green, nutty, and cucumber. Other aroma notes such as mushroom, brown sweet, grain, plastic and burnt were also detected.

Table 2.3.

Aroma Active Compounds and Their Respective Odor Descriptors

Number	Volatile compounds	Odor descriptors
C1	alpha-Campholenal	Burnt, hay-like
C2	3-methyl-1-Butanol, acetate	Grain, nutty
C3	1-Hexanol	Grain, nutty
C4	1-Octen-3-ol	Mushroom
C5	2-Nonenal, (E)-	Leather
C6	2-Penten-1-ol, acetate, (Z)-	Musty/dusty, burnt
C7	2,3-Butanedione	Buttery
C8	2,3-Dimethyl-5-ethylpyrazine	Leather
C9	3,5-Octadien-2-one	Musty/dusty, caramelized
C10	6-methyl-5-Hepten-2-one	Musty/dusty, mushroom
C11	6,10-dimethyl-5,9-Undecadien-2-one	Brown sweet, sweet, grain
C12	Acetaldehyde	Alcohol, sour
C13	Acetic acid	Sour
C14	Acetic acid ethenyl ester	Brown sweet
C15	Acetic acid, methyl ester	Sweet
C16	Benzaldehyde	Mushroom, plastic
C17	2,4-dimethyl-Benzaldehyde	Nutty
C18	Benzyl isothiocyante	Chemical
C19	Benzeneacetaldehyde	Sweet, caramelized
C20	Ethyl benzoate	Spicy
C21	Benzyl alcohol	Sweet, caramelized
C22	Benzyl nitrile	Cucumber
C23	2-ethyl-3-methyl-Butanal	Burnt, musty/dusty
C24	2-methyl-Butanal	Burnt, musty/dusty
C25	3-methyl-Butanal	Grain, chemical, leather
C26	3-methyl-Butanoic acid	Sweet, fruity
C27	Decanal	Waxy, plastic, leather, burnt
C28	Decanoic acid, methyl ester	Burnt, waxy
C29	endo-Borneol	Nutty, spicy
C30	Eucalyptol	Eucalyptus
C31	Furfural	Musty/dusty, plastic
C32	Hexanal	Green

C33	Nonanal	Sweet, burnt, waxy
C34	Nonanoic acid	Leather
C35	Octanoic acid	Waxy, plastic, leather
C36	2-methyl-Propanal	Buttery, sweet, grain
C37	2,6-diethyl-Pyrazine	Caramelized, nutty

Benzyl nitrile compound was detected in all lucuma powder samples. Naturevibe sample showed the highest area percentage for benzyl nitrile, which was associated with cucumber aroma notes. Previous research associated this compound with pickled and pungent odors (Zhou et al. 2019). Compounds such as hexanal and nonanal were also detected in the instrumental analysis. Hexanal was present in most of the samples with highest area percentages for Earthtone and Superfoods by MRM samples. The panelists associated Hexanal with green aroma notes. Previous research also associated hexanal with green and grassy odors (Inga et al., 2019; Xia et al., 2015; Omur-Ozbek, 2008). On the other hand, nonanal was detected in half of samples but was missing in the other half. In this study, nonanal was associated with sweet, burnt, and waxy aroma notes whereas Xia et al. (2015) associated it to peanut and almond notes. The difference in aroma notes could be influenced by the product tested as well as concentration of the compound in that product.

Additionally, 2-methylbutanal, 3-methylbutanal and 2-ethyl-3-methylbutanal were observed to be consistently present across lucuma powder samples. Burnt and musty/dusty aroma notes were assigned to 2-methylbutanal and 2-ethyl-3-methylbutanal. The concentration of the compound also affects the perceived odor. It has been reported that 2-methylbutanal can have sharp notes at higher concentrations whereas roasted cocoa aroma when present in lower concentrations (Aprotosoaie et al., 2016). 3-methylbutanal was perceived as grain, chemical and leather aroma. However, all the compounds were occasionally assigned additional descriptors such as putrid and plastic. Putrid can be described as an unpleasant odor and is common in sulfur compound groups (Owusu et al., 2012).

Mushroom aroma is often associated with 1-octen-3-ol (Deibler and Delwiche, 2004). Therefore, the results for mushroom aroma in this study align well with the previous research as it shows 1-octen-3-ol to be associated with mushroom odor. However, it also shows Benzaldehyde to be associated with mushroom and plastic odors which is contrasting to its usual associations with almond and cherry aroma (Legua et al., 2017). It was present in four samples: Healthforce, Healthworks, Bio-Aurora and Naturevibe, although in low concentrations. Benzeneacetaldehyde was another compound responsible for sweet and caramelized aroma in five out of 12 samples. Chen et al. (2019) described benzeneacetaldehyde odor as sweet and fruity. Similarly, benzyl alcohol, which was present only in Earthtone sample with low area percentage produced sweet and caramelized aromas. Other benzene compounds including 2,4-dimethyl benzaldehyde, ethyl benzoate and benzyl isothiocyanate were also detected. 2,4-dimethyl benzaldehyde and ethyl benzoate were associated with nutty and spicy aromas. However, these compounds were found to be at low concentrations. Ethyl benzoate was perceived in the Naturevibe sample only. Benzyl isothiocyanate was present in the Naturevibe sample at higher concentration responsible for the release of chemical aroma notes.

Acetic acid and its esters such as acetic acid methyl ester and acetic acid ethenyl ester were found to be responsible for buttery, brown sweet, sweet, and sour aroma notes. These compounds were present in several lucuma powder samples. Acetic acid and its methyl ester were found in Superfood by MRM and Naturevibe samples respectively. However, acetic acid ethenyl ester was spread across five lucuma powder samples with similar concentrations. Also, acetaldehyde was found to be responsible for alcohol and sour aroma in Terrasoul sample.

The leather aroma has been observed in several samples. The results indicate that there are several sources for the release of leather aroma including 2,3-dimethyl-5-ethylpyrazine. On the other hand, 2,6-diethyl pyrazine was associated with caramelized and nutty odor notes which aligns well with the previous research on pyrazine aroma associations. Pyrazines may form via the Maillard reaction (Morgan, 1976; Liardon et al., 1982; Griffith and Hammond et al., 1989; Qian and Reineccius, 2002) and are usually associated with nutty and roasted aroma (Qian and Reineccius, 2002). The pyrazine compounds were also assigned other aroma descriptors such as burnt, smoke and plastic. Apart from pyrazine, compounds such as 2-nonenal (E) and nonanoic acid were associated with leather aroma.

Musty/dusty and burnt aroma descriptors were used when ketones such as 3,5-octadien-2-one and 6-methyl-5-hepten-2-one were being perceived through the sniffing port. Notes of caramelized were also associated with 3,5-octandien-2-one. Similarly, mushroom aroma notes were associated with 6-methyl-5-hepten-2-one. Additionally, 2-penten-1-ol, acetate was also responsible for musty/dusty and burnt aroma notes whereas alpha-campholenal contributed to the release of burnt and hay-like odor notes. 6,10-dimethyl-5,9-undecadien-2-one compound was also detected by the panelists and was associated with brown sweet, sweet and grain aroma notes. This compound was detected in low concentrations in five out of 12 samples. On the other hand, 2,3-butanedione was perceived in Terrasoul sample only responsible for buttery aroma, which is in line with literature (Toledo et al., 2016). Inga et al (2019) described 2,3-butandione as sweet, buttery and lucuma-like.

Compounds such as decanal and octanoic acid were detected in the lucuma powder samples. Decanal was mainly associated with a variety of aroma descriptors such as waxy, plastic, leather and burnt. Similarly, octanoic acid was also perceived as waxy, plastic and leather. 1-Hexanol was found to be responsible for grain and nutty aromas in seven of the samples, although it was present in lower concentrations. Furfural was associated with musty/dusty and plastic whereas endo-burneol was perceived as nutty and spicy. Eucalyptol was also detected, although in only one sample responsible for eucalyptus aroma notes.

Table 2.4.

Aroma Active Compounds Mean Area Percentages in Lucuma Powder Samples.

			Aroma active compounds mean area percentage and their standard deviation									
KI Calculated	KI Referenced	Aroma active compounds	Healthforce	Ecoandino (M)	Bio-Aurora	Naturevibe	Earthtone	Terrasoul	Herbazest	Superfood MRM	Ecoandino (O)	Hea
1144.78	1130	alpha-Campholenal	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.04 ± 0.04	n/a	
868.17	867	3-methyl-1-Butanol, acetate	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.43 ± 0.06	
945.20	869	1-Hexanol	0.24 ± 0.03	n/a	n/a	0.13 ± 0.02	n/a	0.15 ± 0.08	0.12 ± 0.07	n/a	n/a	0.1
967.08	964	1-Octen-3-ol	n/a	n/a	n/a	n/a	0.19 ± 0.03	n/a	n/a	n/a	n/a	
1189.88	1162	2-Nonenal, (E)-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.1
844.26	897	2-Penten-1-ol, acetate, (Z)-	n/a	n/a	0.4 ± 0.09	n/a	n/a	0.04 ± 0.04	n/a	n/a	n/a	
n/a	623	2,3-Butanedione	n/a	n/a	n/a	n/a	n/a	3.83 ± 3.02	n/a	n/a	n/a	
1041.01	1068	2,3-Dimethyl-5-ethylpyrazine	n/a	0.6 ± 0.05	n/a	1.12 ± 0.07	n/a	0.28 ± 0.07	0.33 ± 0.02	n/a	0.68 ± 0.12	0.3
1031.09	1052	3,5-Octadien-2-one	0.66 ± 0.13	n/a	0.98 ± 0.19	0.77 ± 0.09	1.11 ± 0.15	n/a	n/a	n/a	n/a	0.4

974.11	986	6-methyl-5-Hepten-2-one	n/a	1.25 ± 0.46	n/a	0.6 ± 0.11	0.74 ± 0.14	n/a	0.97 ± 0.23	0.97 ± 0.73	1.6 ± 0.09	
1440.43	1456	6,10-dimethyl-5,9-Undecadien-2-one	n/a	n/a	0.57 ± 0.53	0.38 ± 0.03	0.36 ± 0.03	0.2 ± 0.07	n/a	n/a	0.34 ± 0.07	
n/a	400	Acetaldehyde	n/a	n/a	n/a	n/a	n/a	3.56 ± 1.77	n/a	n/a	n/a	
n/a	625	Acetic acid	n/a	n/a	n/a	n/a	n/a	n/a	n/a	6.41 ± 3.09	n/a	
n/a	560	Acetic acid ethenyl ester	n/a	n/a	n/a	n/a	3.72 ± 0.50	n/a	4.18 ± 1.04	n/a	3.2 ± 0.50	3.7
n/a	522	Acetic acid, methyl ester	n/a	n/a	n/a	6.95 ± 0.62	n/a	n/a	n/a	n/a	n/a	
949.84	936	Benzaldehyde	0.71 ± 0.19	n/a	1.88 ± 0.76	2.7 ± 0.24	n/a	n/a	n/a	n/a	n/a	1.0
1142.34	1180	2,4-dimethyl Benzaldehyde -	n/a	n/a	0.18 ± 0.02	n/a	0.09 ± 0.07	n/a	n/a	n/a	n/a	
1313.96	1361	Benzene isothiocyanate	n/a	n/a	n/a	7.66 ± 4.42	0.42 ± 0.09	n/a	n/a	n/a	n/a	
1069.31	1044	Benzeneacetaldehyde	0.23 ± 0.04	0.15 ± 0.04	n/a	n/a	0.29 ± 0.02	0.37 ± 0.04	n/a	n/a	n/a	0.2
1139.65	1171	Ethyl benzoate	n/a	n/a	n/a	0.08 ± 0.06	n/a	n/a	n/a	n/a	n/a	
994.21	1005	Benzyl alcohol	n/a	n/a	n/a	n/a	0.94 ± 0.20	n/a	n/a	n/a	n/a	
1151.23	1135	Benzyl nitrile	2.19 ± 0.22	1.21 ± 0.12	0.91 ± 0.37	5.6 ± 0.35	1.69 ± 0.12	1.11 ± 0.18	1.26 ± 0.13	1.39 ± 0.10	0.68 ± 0.05	1.3

838.64	N/A	2-ethyl-3-methylbutanal	n/a	n/a	n/a	n/a	0.35 ± 0.03	n/a	n/a	n/a	0.36 ± 0.08	
n/a	663	2-methyl butanal	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	8.6
n/a	652	3-methylbutanal	5.07 ± 0.84	n/a	n/a	n/a	3.15 ± 0.34	5.28 ± 1.06	n/a	2.35 ± 0.98	n/a	5.8
n/a	867	3-methylbutanoic acid	n/a	n/a	n/a	0.47 ± 0.12	n/a	n/a	n/a	n/a	n/a	
1204.85	1203	Decanal	n/a	0.14 ± 0.01	n/a	0.32 ± 0.05	0.44 ± 0.04	0.19 ± 0.04	n/a	0.28 ± 0.09	n/a	
1309.58	1326	Decanoic acid, methyl ester	n/a	n/a	n/a	n/a	0.06 ± 0.01	n/a	n/a	n/a	n/a	
1171.39	1169	endo-Borneol	n/a	0.18 ± 0.02	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
1043.55	1035	Eucalyptol	n/a	1.02 ± 0.30	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
n/a	831	Furfural	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.5
805.84	802	Hexanal	n/a	3.24 ± 0.65	1.16 ± 0.29	2.21 ± 0.30	5.47 ± 0.45	2.67 ± 0.69	n/a	5.23 ± 1.24	1.91 ± 0.37	5.0
1124.24	1101	Nonanal	n/a	n/a	n/a	n/a	2.95 ± 0.67	1.38 ± 0.26	3.29 ± 0.61	2.9 ± 0.76	2.96 ± 0.62	
1189.76	1283	Nonanoic acid	0.20 ± 0.05	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
1157.11	1192	Octanoic acid	n/a	n/a	0.37 ± 0.18	0.43 ± 0.09	n/a	n/a	n/a	n/a	n/a	
n/a	556	2-methylpropanal	3.03 ± 0.40	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

1035.09	1057	2,6-diethyl Pyrazine,	n/a	0.23 ± 0.06	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Note. Ecoandino (M): Sample bought from market in Peru; Ecoandino (O): Sample bought online; Kovats retention index compared using the National Institute of Standards and Technology (NIST) library of compounds; n/a: Not applicable.

Principal Component Analysis

Principal Component Analysis (PCA) was used to visualize the aroma active compounds and aroma profiles of lucuma powder samples (Figure 2.1). PCA graph shows the separation of the lucuma powder samples based on their volatile composition. First two principal components explained 53.51% (32.12% and 21.39%, respectively) of the variability in the data. The differentiating aroma active compounds on the first component were 2,3-dimethyl-5-ethylpyrazine (C8), acetic acid methyl ester (C15), benzaldehyde (C16), benzyl isothiocyanate (C18), benzeneacetaldehyde (C19), ethyl benzoate (C20), benzyl nitrile (C22), 3-methyl butanoic acid (C26) and octanoic acid (C35).

Healthworks and Naturevibe samples were shown to have more differentiating profiles than the rest of the samples. Healthworks was positively correlated with aldehydes such as 2-methyl butanal (C24) (burnt, musty/dusty), 3-methyl butanal (C25) (grain, chemical), hexanal (32) (green) and furfural (C31) (musty/dusty) whereas Naturevibe was majorly associated with benzyl isothiocyanate (C18) (spicy, nutty), acetic acid methyl ester (C15) (buttery, brown sweet), benzyl nitril (C22) (cucumber), benzaldehyde (C16) (mushroom, plastic). Both samples are placed in two different quadrants (upper quadrants) on the graph, thereby, suggesting that the samples are not correlated with each other (Figure 1).

Alvitox, Earthtone and Terrasoul samples were shown to be clustered together with aroma active compounds such as benzeneacetaldehyde (C19), 2-nonenal (E)- (C5), 1-hexanol (C3) and acetic acid methyl ester (C15). Therefore, these samples seem to possess sweet, caramelized, brown sweet and grainy aroma. Similarly, Healthforce, Navitas, Superfood by MRM were positively correlated with 2-methyl propanal (C36), nonanoic acid (C34), acetic acid

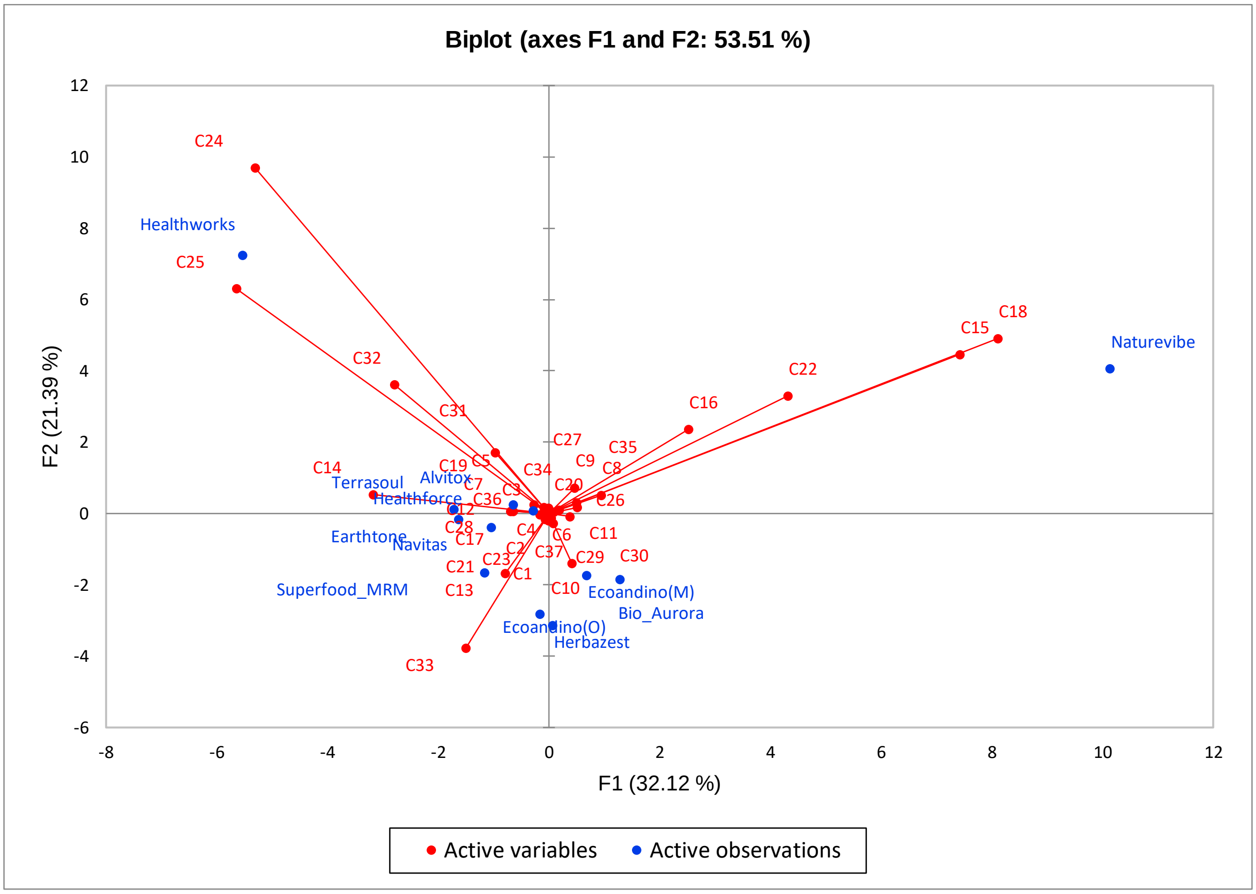
(C13) and 2-ethyl-3-methylbutanal (C23), thereby, associating with buttery, plastic, sweet and burnt aroma notes.

Furthermore, Herbazest and Ecoandino (online) were clustered together on the PCA map showing their correlation with compounds such as eucalyptol (C30) and endo-burneol (C29) that were responsible for nutty, spicy and eucalyptus aroma notes. They were also associated with 2-penten-1-ol, acetate (C6) which released burnt and musty/dusty odor. Bio-Aurora and Ecoandino (M) were other samples that showed distinguishing profile and was placed on the bottom right quadrant of the PCA graph. It shows positive correlation with 6-methyl-5-hepten-2-one (C10) (mushroom, plastic), and 6,10-dimethyl-5,9-undecadien-2-one (C11) (brown sweet, sweet). It should be noted that even though market and online Ecoandino samples were positively correlated on the PCA map, they showed differences in aroma active volatile composition. Therefore, the aging of the sample may affect the volatile composition of the lucuma powder, but further research will be needed to validate the hypothesis and assess the specific changes that occur in the product's aroma.

As mentioned above, Naturevibe and Healthworks showed distinguishing aroma active volatile composition (Figure 2.1). These two samples were selected for their application into the final product (i.e., ice cream). Additionally, Terrasoul, Herbazest and Superfood by MRM samples were selected based on the differences in their aroma active volatile composition as shown by principal component analysis.

Figure 2.1.

Principal Components Analysis of Aroma Active Volatile Profile of Lucuma Powder Samples



Note. Refer to table 2.3 for compound codes starting with letter C.

Study Limitations

This study pertains to different commercial sources of lucuma powder samples. Further research can be performed including the original source of the lucuma powder i.e., lucuma fruit. Since, previous research shows that ripening of the fruit affects the volatile composition of the fruit (Inga et al., 2019), it will be interesting to study whether it translates into the powdered form of lucuma. Moreover, there may be scope for adjustments in the methodology to enhance the flow of compounds to further improve the accuracy.

Conclusions

Lucuma powder aroma active composition has not been studied extensively and limited information is available on the topic. Therefore, aroma volatile profiles of 12 lucuma powder samples from different manufacturing sources were investigated. A total of 38 aroma active volatiles responsible for 28 different aroma notes were detected the lucuma powders evaluated. Benzyl nitrile was detected in all the samples. Other key aroma active compounds include 1-Hexanol, 2,3-Dimethyl-5-ethylpyrazine, Benzaldehyde, Butanal-3-methyl and Hexanal. Main aroma attributes in all the samples were buttery, sweet, caramelized, waxy, green, nutty, and cucumber. Other aroma notes such as mushroom, brown sweet, grain, plastic and burnt were also detected. The compounds that were most differentiating among products from different manufacturing sources were acetic acid methyl ester, oxime methoxy phenyl, nonanal, hexanal and benzene compounds such as benzaldehyde, benzyl isothiocyanate and benzyl nitrile. PCA visualization confirms that lucuma powder products purchased from different sources will have somewhat different aroma volatile composition. This will affect the aroma profile of the product and may result in final products of varying qualities. Five samples: Naturevibe, Healthworks, Terrasoul, Herbazest and Superfood by MRM were selected to move forward with their application into the ice cream product. Further research is needed to more specifically understand the most important sources of variability and the effects these may have on final products that use lucuma powder as an ingredient.

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Chapter 3 - Descriptive Analysis of Lucuma Ice Cream and the Association of Sensory Characteristics with Volatile Profiles of the Raw Ingredient

Abstract

Six ice cream products were prepared including five lucuma flavored products (base Lucuma powders procured from different commercial sources and selected based on the aroma volatile composition of the raw lucuma powder), and a caramel flavor ice cream, a more familiar product for the U.S. market. The objective of the research was to investigate the sensory characteristics of lucuma ice cream by developing a lexicon to describe the sensory characteristics of lucuma ice cream, and to establish the associations between sensory characteristics of the final product and instrumental analysis of the powder form to understand how the raw ingredient (lucuma powder) from different sources translates into the sensory properties of the finished product (i.e., ice cream). Descriptive analysis was conducted using six highly trained panelists. All the samples were evaluated for 31 attributes including appearance, aroma, flavor, aftertaste, and texture. Analysis of Variance (ANOVA) results for descriptive analysis showed that the lucuma powder samples were perceived to be mostly similar to each other and slightly different than the caramel ice cream. Samples were found to be not statistically significantly different ($p>0.05$) for most of the attributes. Only five attributes: color intensity (appearance), caramelized (aroma), brown sweet (flavor), chalkiness (texture) and grainy (texture) were found to be statistically different ($p<0.05$). Partial Least Square regression was used to draw associations between instrumental and sensory data. Benzeneacetaldehyde, hexanal, furfural, 2,3-dimethyl-5-ethylpyrazine and benzyl nitrile were the key compounds separating the

lucuma samples on PLS-R map along with descriptive aroma attributes such as brown sweet, caramelized (Terrasoul), sour aromatics (Healthworks) and vanilla (Naturevibe). This information helps better understand the sensory properties of lucuma ice cream and its raw ingredient (lucuma powder) and provide a starting point to explore the usage of lucuma powder into other finished products such as smoothies and baked goods.

Introduction

The growing demand for natural and healthy foods has prompted the use of high-nutrition, low-calorie ingredients in food products. These food products are becoming a trend amongst consumers. There are several reasons behind this shift shown by consumers. With the rapid increase of easily accessible options for high-calorie, low-nutrition foods, the rates of obesity are on the rise (Kahler, 2020). Food manufacturers are finding innovative ways to respond to consumer demands. Recent trends in the food industry have shown the diversion toward the natural, plant based as well as healthier products. Consumers intend to buy healthy products but do not like to change their eating habits; therefore, marketers have been riding the wave of increasing health interest and have recognized the considerable potential of adding the functional ingredients to regular products (Bech-Larsen and Grunert, 2003).

Superfoods as ingredients are considered rich in components believed to reduce the onset of diseases such as cancer, diabetes, heart disease etc. and can be considered both a food and a medicine as they have elements of both (Wolfe, 2009). Lucuma fruit has promising health benefits and it can be eaten raw or processed. Processed forms of lucuma can be used as an ingredient in a variety of food products such as ice creams, baked consumer goods, flavored beverages etc. Lucuma flavored ice cream is popular in Peru and Chile defeating the traditional vanilla and chocolate flavored ice creams because of its sweet taste, caramel-like and maple-like flavor and aroma (Yahia and Gutierrez-Orozco, 2011). Sugars have proved to be a major culprit when it comes to weight gain for human body, which can lead to further health problems such as obesity, diabetes, cardiovascular health problems etc. Lucuma can be considered as a natural alternative to sweeteners because it has low glycemic index which provides additional health benefits alongside good taste. It has low sugar concentration even though it tastes sweet when added to food products. Pinto et al. (2009) suggested that lucuma extracts can behave as alpha-glucosidase inhibitors producing hypoglycemic effect that may help in managing diabetes in patients.

Descriptive sensory analysis is a tool to evaluate products for their sensory characteristics. It involves identifying the sensory attributes and assigning the intensity ratings to those attributes using highly trained assessors. The descriptive analysis technique uses highly trained panelists who evaluate the product for various attribute categories such as appearance, aroma, flavor, texture, aftertaste etc. Several studies including ice cream have incorporated the use of descriptive sensory analysis. Roland et al. 1999 conducted a descriptive sensory study focusing on effects of fat content on sensory properties of ice cream was conducted. Another study examining the sensory profile of low-calorie symbiotic and probiotic chocolate ice cream used this technique (Peres et al., 2018). The panelists are encouraged to use specific sensory terms to describe product attributes and refrain from using more general and sometimes ambiguous consumer terms. Different descriptive techniques use different scales with a common focus on recognizing and quantifying the principal characteristics of the product. Thompson et al. (2009) studied sensory differences among the ice cream produced in US and Italy. Kalicka et al. 2019 examined the sensory characteristics of ice cream sweetened with polyols. However, there is no information available on how the use of lucuma powder in an ice cream formulation affects its sensory properties.

Another technique to assess the aroma profile of a product is to detect and quantify its aroma volatile composition. The volatile composition and descriptive sensory techniques can be combined to understand the products better (Lawless and Heymann, 2010). By examining the volatile composition and combining with the most important sensory attributes of a product, researchers can identify the key compounds responsible for the aroma of products and use them as indicators for variations in raw materials, processing methods, formulation modification and ingredient replacement. The association between sensory and instrumental analysis has been studied to draw useful conclusions and establish relationship between aroma attributes and volatile composition (Chambers and Koppel, 2013).

The objective of this research was to investigate the sensory characteristics of lucuma ice cream samples and to establish the associations between sensory characteristics of the final product and instrumental analysis of the powder form to understand how the raw ingredient (lucuma powder) from different sources vary, and how it translates into the sensory properties of a finished product (i.e., ice cream).

Materials and Methods

Samples

Five lucuma powder samples were selected using volatile analysis to conduct descriptive sensory analysis of the finished product (ice cream) alongside a mainstream and more familiar ice cream product (i.e., caramel ice cream). The five selected lucuma powder products selected for this study had different aroma volatile compositions. These were Naturevibe, Terrasoul, Healthworks, Herbazest and Superfood by MRM. Ice cream products were prepared using a standard base recipe at Dairy Plant, Kansas State University (Manhattan, Kansas, USA). The recipe consisted of cream, milk, non-fat dry milk (NFDM), sugar, corn sugar, and stabilizer (icepro2004)**.** All the ingredients except cream were mixed and heated to 38 ^{0}C. Then, cream was added to the mixture and was pasteurized at 74 ^{0}C. Mixture was held at 74^{0}C for 30 minutes followed by cooling it down to 60 ^{0}C. Then, the mixture was homogenized at 8274 kPa (1200 psi) pressure. After the homogenization, the mixture was cooled down to 10 ^{0}C. It was then placed into a holding tank (Creamery Package Manufacturing Company, Lake Mills, WI) for 24 hours. Five percent each of lucuma powders and caramel were added to the base mixture as flavoring agents. Samples were prepared using batch freezer (Emery Thompson Machine and Supply Co., Bronx, NY). Batch freezer is an equipment used for commercial production of frozen desserts such as ice cream and gelato. Final ice cream product consisted of approximately 12-13% of fat (by weight) and approximately 11% total solids. Ice cream was transferred into half gallon plastic containers and stored in blast freezer overnight. Then, all the samples were transferred to walk-in freezer at -18 ^{0}C. The ice cream samples were moved to a commercial ice cream freezer (Excellence Industries, Tampa, FL) set at -12 ^{0}C two hours prior to testing. One scoop (approximately two ounces) of the ice cream were served in triplicates to the panelists in four-ounce Styrofoam cups labeled with random three-digit codes.

Descriptive Sensory Analysis

Six highly trained panelists from Sensory and Consumer Research Center, Kansas State University (Manhattan, KS), participated in the descriptive analysis. All the panelists had received minimum of 120 hours of descriptive sensory analysis training and had at least 1000 hours of experience in evaluating a variety of products prior to completing this panel, including ice creams. First two days of the panel consisted of 90-minute orientation sessions. The orientation sessions were held to familiarize the panelists with the ice cream samples that they would be evaluating. Based on literature research, an initial list of attributes was provided to the panelists in the orientation sessions. The list of attributes included appearance, aroma, flavor, texture, and aftertaste. Panelists were instructed to add or remove attributes as per their perception i.e., if a new attribute was perceived, the panel would discuss and if agreed, the attribute would be added to the list. Panelists discussed various characteristics including aroma attributes such as cooked, dairy-fat, and green, but were eventually removed from the list. Certain flavor attributes such as nutty, woody, floral and oily were also eliminated by the end of second day of orientation. A lexicon of 31 attributes was used to describe and characterize the lucuma ice cream products. Each attribute was clearly defined and was assigned a reference standard shown in table 3.1. Final list of attributes included appearance (two attributes), aroma (six attributes), flavor (nine attributes), aftertaste (6 attributes) and texture (eight attributes). Then, the panel evaluated all the samples in triplicates over four 90-minute evaluation sessions. A 0-15 scale with 0.5 increments was used for intensity quantification of the attributes. Deionized water, crackers and hot towels were used as palate and nasal passage cleansers.

Instrumental Analysis

Volatile compounds were extracted using solid phase microextraction (SPME) with 50/30 micrometer divinylbenzene/ carboxen/ polydimethylsiloxane fiber (Supelco Analytical, Bellefonte, PA, USA) to characterize aroma and volatile profiles of lucuma powder samples from various sources. 0.5g of the sample was transferred into 10ml screw-cap vial (Supelco Analytical, Bellefonte, PA, USA) equipped with a polytetrafluoroethylene/silicone septum (Supelco Analytical, Bellefonte, PA, USA). The fiber was cleaned by inserting the fiber in the auxiliary injection port at 150 ^{0}C for 5 minutes before and after each run. Samples were incubated at 40 ^{0}C for 1 minute at 250 rpm using the autosampler. SPME fiber was inserted into the vial and exposed to the headspace at 40 ^{0}C for 1 minute for volatile extraction. The fiber was then removed from the vial. The volatile compounds were desorbed into the gas chromatograph – mass spectrometer (Shimadzu Corporation, Kyoyo, Japan) using a spitless injector for 1 minute at 240 ^{0}C. Helium gas was used as a carrier. The compounds were separated on an SH-Rxi-5Sil

MS column (Shimadzu, Kyoto, Japan; 30m long, 25mm diameter and 0.25 micrometer thickness). The working conditions included ramping the initial temperature of 40 ^{0}C to 130 ^{0}C with the rate of 10 ^{0}C per minute. Then, the temperature was increased to 150 ^{0}C with 5 ^{0}C per minute rate followed up by 14 ^{0}C per minute increase to take it to 200 ^{0}C. Mass spectrometry was performed using electron-impact ionization at 70 eV (200 ^{0}C). The 16.57-minute run time was recorded in full scan mode (35-350 m/z mass range). All samples were analyzed in three replicates by two trained panelists, thereby producing six olfactograms for each lucuma powder sample.

Data Analysis

Analysis of Variance (ANOVA) was performed using sample names (explanatory variable) and attribute intensities from descriptive analysis (dependent variable) to determine significant differences in various attributes across the samples. Fisher's least significant differences (LSD) was used to perform the mean separation. XLStat statistical software (Addinsoft, MS Excel, NY, USA) was used to perform the analysis. Association between sensory aroma attributes (X-matrix) and aroma active volatiles (Y-matrix) was depicted using Partial Least Square – Regression (PLS-R). PLS-R was also performed using XLStat statistical software (Addinsoft, MS Excel, NY, USA).

Results and Discussion

Panelists evaluated ice cream samples for 31 attributes. Final list of attributes included appearance (two attributes), aroma (six attributes), flavor (nine attributes), aftertaste (6 attributes) and texture (eight attributes).

Table 3.1.

Final List of Attributes for Descriptive Sensory Analysis.

Attributes	Definitions	References
Appearance		
Color	Intensity of the color from light to dark.	Porter Paints 6895-1 = 4.0 Porter Paints 6835-1 = 7.0
Flecks	Presence of flecks on the product surface (Y/N).	N/A
Aroma		
Caramelized	A round full bodied medium brown sweet aromatic associated with cooked sugars and other carbohydrates. Does not include burnt or scorched notes.	Werther's original caramel hard candy = 5.0
Fruity, dark	An aromatic impression of dark fruit that is sweet and slightly brown associated with dried plums and raisins.	1/4 cup Sun Maid raisins and 1/4 cup of Sun Maid prunes (chopped), 3/4 cup water = 6.0
Dairy	Aromatics associated with products made from milk such as cream, milk, sour cream or buttermilk	Dillon's 2% Milk = 8.0
Brown sweet	A rich full round sweet aromatic impression characterized by some degree of darkness.	C&H Golden brown sugar = 6.0
Sour aromatics	Aromatics associated with sour substances.	Hiland Sour Cream = 5.0
Vanilla	Aromatic associated with natural or non-natural vanilla, which may include brown.	McCormick Vanilla Extract in Dillon's whole Milk = 3.0
Flavor		
Brown sweet	A rich full round sweet aromatic impression characterized by some degree of darkness.	C&H Golden brown sugar in water = 5.0
Caramelized	A round full bodied medium brown sweet taste associated with cooked sugars and other carbohydrates. Does not include burnt or scorched notes.	Werther's original caramel hard candy = 5.0
Dairy	Flavor associated with products made from milk such as cream, milk, sour cream or buttermilk	Dillon's 2% Milk = 8.0
Fruity, dark	A flavor impression of dark fruit that is sweet and slightly brown associated with dried plums and raisins.	1/4 cup Sun Maid raisins and 1/4 cup of Sun Maid prunes (chopped), 3/4 cup water = 6.0

Vanilla	Flavor associated with natural or non-natural vanilla, which may include brown.	McCormick Vanilla Extract in Dillon’s whole Milk = 3.0
Sweet	A fundamental taste factor of which sucrose in water is typical.	4% Sucrose Solution = 4.0, 6% Sucrose Solution = 6.0
Bitter	A fundamental taste factor of which caffeine in water is typical.	0.01% Caffeine Solution = 2.0, 0.02% Caffeine Solution = 3.5
Salt	A basic taste factor of which the taste of sodium chloride in water is typical.	0.15% Salt solution = 1.5
Sour	The fundamental taste factor of which citric acid in water is typical.	0.015% Citric Acid Solution = 1.5, 0.025% Citric Acid Solution = 2.5
Aftertaste		
Brown sweet	A rich full round sweet aromatic impression characterized by some degree of darkness.	C&H Golden brown sugar in water = 5.0
Caramelized	A round full bodied medium brown sweet aromatic associated with cooked sugars and other carbohydrates. Does not include burnt or scorched notes.	Werther’s original caramel hard candy = 5.0
Dairy	Taste associated with products made from milk such as cream, milk, sour cream, or buttermilk	Dillon's 2% Milk = 8.0
Fruity, dark	An impression of dark fruit that is sweet and slightly brown associated with dried plums and raisins.	1/4 cup Sun Maid raisins and 1/4 cup of Sun Maid prunes (chopped), 3/4 cup water = 6.0
Sour	The fundamental taste factor of which citric acid in water is typical.	0.015% Citric Acid Solution = 1.5, 0.025% Citric Acid Solution = 2.5
Sweet	A fundamental taste factor of which sucrose in water is typical.	4% Sucrose Solution = 4.0, 6% Sucrose Solution = 6.0
Texture		

Firmness	The force to compress the sample between the tongue and palate.	Hiland Sour Cream = 5.5, Kraft Philadelphia Cream Cheese = 9.0
Meltdown	The time required for the product to melt in the mouth when continuously pressed by the tongue against the palate. Sample size is 1/2 tsp. Rinse mouth before testing.	N/A
Fat-feel	Related to the perceived fat content. Refers to the intensity of the "oily" feeling in the mouth when the product is manipulated between the tongue and the palate.	Kroger Half and Half = 5.0, Kroger Whipping Cream = 9.5
Chalkiness	A measure of dry, powdery sensation in the mouth.	Kraft Philadelphia Cream Cheese = 7.5
Grainy	The amount of particles detected in the mouth and on the tongue while the sample dissolves or disintegrates.	Musselman's Apple Butter = 4.0
Oily mouthcoating	A sensation of having a slick/fatty coating on tongue and other mouth surfaces after swallowing.	Kroger Half and Half = 4.5, Kroger Whipping Cream = 8.0
Astringent	The dry, puckering mouth feel associated with an alum solution in the mouth.	0.03% Alum Solution=1.5, 0.05% Alum Solution=2.5
Throat catch	The tendency to want to cough or clear one's throat of substances irritating the throat passage. The panel will mark on the score sheet if this tendency is present (Y/N).	N/A

Appearance and Aroma

Appearance included color intensity and the presence of flecks on the surface of the products. Results showed that color intensity was significantly different across the samples. Superfood by MRM sample had darkest color whereas Herbazest and Caramel samples had lightest color intensities. Terrasoul, Healthworks and Naturevibe were perceived to have intermediate color intensities with statistically significant differences in intensity ratings. Difference in color of the lucuma powder samples could be the reason for the difference in color intensities of ice cream samples. All the samples were perceived to have flecks present on the sample surface. The panelists defined flecks as tiny dots or particles present on the surface of the sample.

The samples were evaluated for six aroma attributes: caramelized, fruity-dark, dairy, brown sweet, sour aromatics, and vanilla. Terrasoul sample was perceived to have the highest intensity for caramelized aroma notes among products, although it still was rated on the lower end of the scale. On the other hand, the caramel product was perceived to have the lowest caramel aroma intensity among all products evaluated. The difference could be attributed to the amount of caramel flavor added while preparing the ice cream. The caramel ice cream was prepared by mixing five percent caramel into standard base recipe at the Dairy plant (Kansas State University, Manhattan, Kansas, USA). Amount of added flavor was kept consistent across all the samples (including lucuma powder), but lucuma powder seemed to have translated more aroma into the final product at the same level of addition than caramel. Fruity-dark aroma was perceived in almost negligible amounts on all products. However, Naturevibe sample was assigned the highest rating of fruity-dark aroma among all the products evaluated. Panelists did not perceive fruity-dark aroma in all the samples. Similarly, brown sweet aroma notes also received low intensity ratings overall, Terrasoul being the highest amongst all samples. Dairy, sour aromatics and vanilla did not show any statistically significant differences between the samples.

Table 3.2.

Analysis of Variance Results for Appearance and Aroma Attributes for Ice Cream Samples.

	Appearance		Aroma				
	Color Intensity	Caramelized	Fruity, Dark	Dairy	Brown Sweet	Sour Aromatics	Vanilla
MRM	7.6 a	2.2b	0.7 abc	4.2 a	2.1 ab	1.9 a	0.7 a
Terrasoul	6.0 c	2.8 a	0.8 ab	4.4 a	2.3 a	1.9 a	0.9 a
Healthworks	6.7 b	2.4 ab	0.9 a	4.1 a	2.0 ab	1.9 a	0.7 a
Naturevibe	5.5 d	2.4 ab	0.9 a	4.2 a	2.1 ab	1.6 a	1.0 a
Herbazest	3.6 e	2.1 bc	0.2 bc	4.0 a	2.1 ab	1.8 a	0.6 a
Caramel	3.5 e	1.7 c	0.1 c	4.1 a	1.8 b	1.9 a	0.5 a
Pr > F(Model)	<0.0001	0.002	0.057	0.922	0.125	0.922	0.560

Note. Values with different letters in a column are significantly different at 5% level (Fisher's LSD).

Flavor

Ice cream samples were evaluated for nine flavor attributes including brown sweet, caramelized, dairy, fruity-dark, vanilla, sweet, bitter, salt, and sour. It was difficult to distinguish between brown sweet and fruity-dark attributes. After an initial assessment during the orientation session, panelists discussed brown sweet and fruity-dark flavor attributes to reach upon a consensus that both the attributes should stay in the lexicon because they both represented different characteristics of the products. Brown sweet was defined as a rich and sweet impression characterized by some darkness whereas fruity-dark was referenced as an impression of dark fruit which is associated with dried plums and raisins (Table 3.1).

Overall, there were no statistically significant flavor differences perceived across the samples except for brown sweet ($p<0.05$). Brown sweet attribute was quantified on the lower end of the scale for all the samples. Superfood by MRM and Terrasoul samples received the highest intensity rating whereas caramel sample received the lowest. Vanilla, dairy, sweet, salt, and sour had similar intensity ratings for all the samples. The similarity could be attributed to the same amounts of ingredients in the base recipe of the ice cream samples. Mean ratings for bitterness of the samples were also quantified. Naturevibe sample was perceived to be slightly bitter than the rest, caramel sample was perceived as the least bitter.

Table 3.3.

Analysis of Variance Results for Flavor Attributes for Ice Cream Samples.

	Flavor								
	Brown Sweet	Caramelized	Dairy	Fruity, Dark	Vanilla	Sweet	Bitter	Salt	Sour
MRM	3.9 a	3.4 ab	5.6 a	1.6 a	0.9 a	3.8 a	1.9 b	1.5 a	1.8 a
Terrasoul	3.9 a	3.4 ab	5.4 a	1.2 ab	0.9 a	3.7 a	2.2 ab	1.4 a	1.7 a
Healthworks	3.3 bc	3.1 ab	5.6 a	1.2 ab	1.1 a	3.8 a	2.0 ab	1.6 a	1.8 a
Naturevibe	3.7 abc	3.2 ab	5.6 a	0.9 ab	1.1 a	3.8 a	2.3 a	1.6 a	1.9 a
Herbazest	3.8 ab	3.5 a	5.6 a	0.8 ab	1.1 a	3.6 a	2.1 ab	1.5 a	1.7 a
Caramel	3.2 c	2.8 b	5.6 a	0.6 b	1.3 a	3.8 a	1.9 b	1.4 a	1.8 a
Pr > F(Model)	0.018	0.322	0.988	0.303	0.969	0.967	0.150	0.945	0.862

Note. Values with different letters in a column are significantly different at 5% level (Fisher's LSD)

Aftertaste

Panel evaluated the ice cream samples for six aftertaste attributes: brown sweet, caramelized, dairy, fruity-dark, sour, and sweet. Descriptive analysis results for aftertaste attributes follow similar trends to flavor attributes. It was difficult to perceive the differences in aftertaste intensities across the samples evaluated. Results show that the panelists perceived that the samples had slight differences on aftertaste attributes but did not find statistically significant differences (p>0.05) between the samples for any aftertaste attribute. Mean intensity ratings show that Superfood by MRM sample was perceived to have highest brown sweet and lowest dairy aftertaste. Healthworks and Terrasoul samples received slightly higher intensity rating for caramelized aftertaste than rest of the samples whereas caramel sample was perceived to be the sweetest. Still, overall differences were small.

Table 3.4.

Analysis of Variance Results for Aftertaste Attributes for Ice Cream Samples.

	Aftertaste					
	Brown Sweet	Caramelized	Dairy	Fruity, Dark	Sour	Sweet
MRM	3.2 a	2.7 a	3.9 a	0.9 a	1.9 a	3.1 a
Terrasoul	3.0 a	2.7 a	4.1 a	0.9 a	1.7 a	2.9 a
Healthworks	2.9 a	2.7 a	4.1 a	0.7 a	1.8 a	2.9 a
Naturevibe	3.1 a	2.5 a	4.0 a	0.8 a	1.9 a	2.9 a
Herbazest	3.0 a	2.3 a	4.2 a	0.5 a	1.7 a	2.8 a
Caramel	2.8 a	2.4 a	4.1 a	0.4 a	1.6 a	3.1 a
Pr > F(Model)	0.505	0.762	0.920	0.455	0.544	0.850

Note. Values with different letters in a column are significantly different at 5% level (Fisher's LSD)

Texture

Followed by extensive discussion on texture attributes, the panel narrowed down the number of texture attributes to eight. These attributes included firmness, meltdown, fat-feel, chalkiness, grainy, oily mouth-coating, astringent, and throat catch. Two texture attributes (i.e., chalkiness and grainy) showed statistically significant differences ($p<0.05$). Results showed that all the lucuma ice cream samples had similar intensity ratings for perceived chalky and grainy attributes whereas caramel ice cream sample was perceived to have lower chalkiness and graininess. It was difficult to perceive differences between the samples for other attributes including firmness, fat-feel oily mouth-coating and astringency. Mean intensity ratings showed that all the samples had intermediate firmness, caramel sample being the least firm. It is important to note that even though the products had a different flavor, they were all prepared using a similar base. Therefore, any texture differences could be created by the flavor ingredient (lucuma powder vs caramel) since lucuma powder was grainy in nature whereas caramel was not. Though the differences were not statistically significant, the astringency also separated the caramel sample from all the lucuma ice cream samples. Caramel sample received lower mean intensity score whereas all the lucuma ice cream samples were rated similarly on the scale.

Fat-feel and oily mouth-coating are commonly associated with dairy products (Ohmes et al., 1998). These attributes were perceived in all the samples, although in lower quantities. Therefore, the panelists used lower section of the scale to quantify these two attributes during evaluation. Samples were also evaluated for meltdown. The amount of air incorporated affects melting properties of the ice cream (Hartel, 1996; Muse and Hartel, 2004). The caramel sample was perceived to have melted quicker than rest of the samples, although the difference was not statistically significant. Evaluators also noticed that some of the ice cream samples were sticking to the back of the throat. They named the attribute “throat catch” and defined it as the tendency to cough or clear one’s throat passage of substances. During individual evaluation, the response of the panelists was divided on throat catch, not all the panelists perceived the throat catch so it was not included in the table below.

Table 3.5.

Analysis of Variance Results for Texture Attributes for Ice Cream Samples.

	Texture					
	Firmness	Fat-feel	Chalkiness	Grainy	Oily mouth-coating	Astringent
MRM	7.7 a	4.2 a	3.6 a	1.0 a	3.5 ab	2.0 a
Terrasoul	7.5 a	4.1 a	3.1 a	0.9 a	3.5 ab	2.0 a

Healthworks	7.4 a	4.2 a	3.4 a	1.0 a	3.5 ab	2.0 a
Naturevibe	7.5 a	4.1 a	3.2 a	0.9 a	3.5 ab	2.0 a
Herbazest	7.5 a	4.2 a	3.5 a	1.0 a	3.3 b	2.1 a
Caramel	7.3 a	4.6 a	2.2 b	0.0 b	4.0 a	1.9 a
Pr > F(Model)	0.953	0.785	0.001	0.020	0.360	0.604

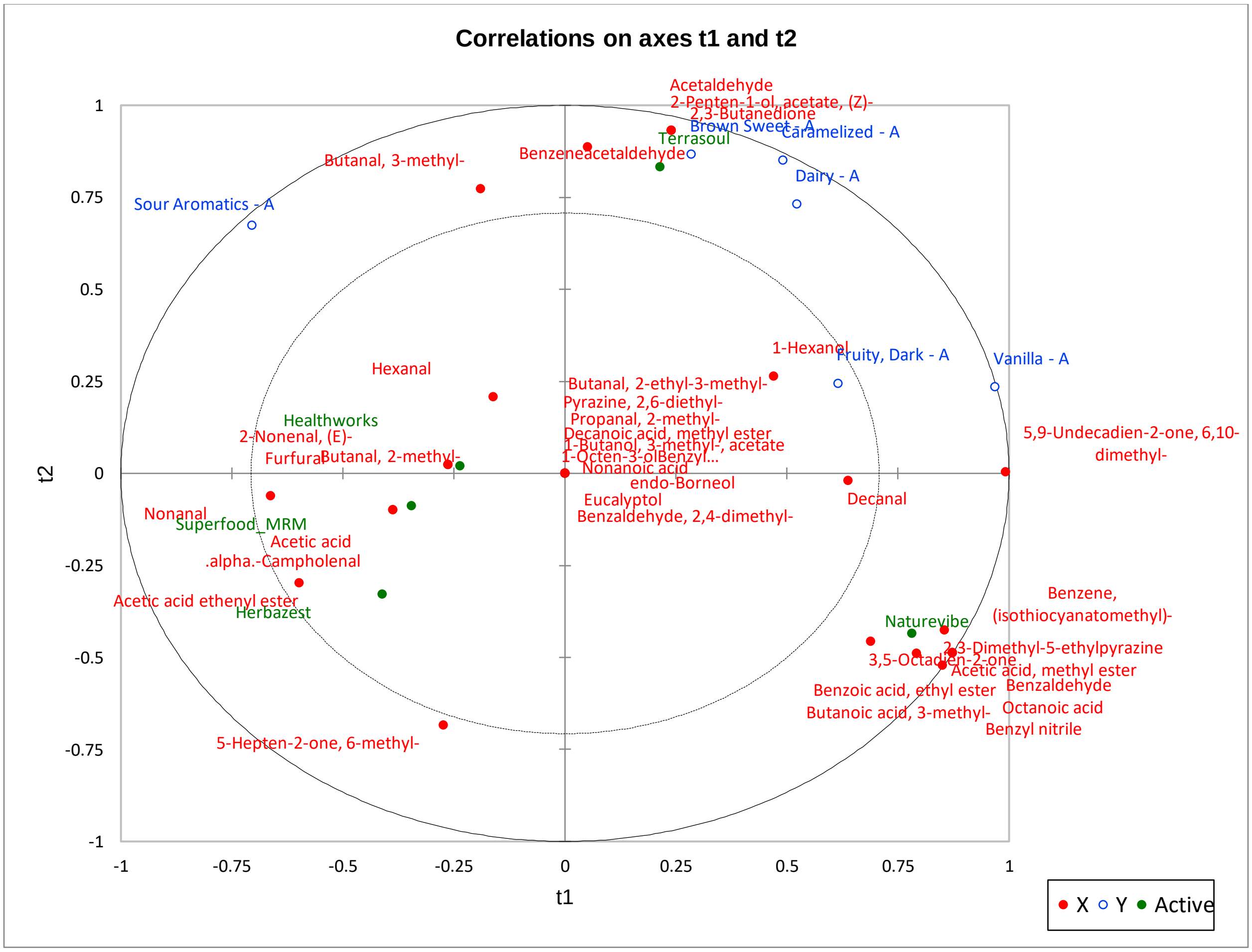
Note. Values with different letters in a column are significantly different at 5% level (Fisher's LSD)

Association of Sensory and Instrumental Data

The relationship between descriptive sensory aroma attributes and volatile aroma profile generated by gas chromatography – olfactometry has been depicted using partial least square – regression (PLS-R) technique (Figure 3.1). The graphical representation showed the correlations between sensory and instrumental data.

Figure 3.1.

Partial Least Square - Regression Using Descriptive Sensory Aroma Attributes and Instrumental Analysis Data.



Note. X-matrix: GC-O Volatile Compounds; Y-matrix: Descriptive Aroma Attributes; Green dots (Active variable): Samples

Compounds such as benzeneacetaldehyde, 2,3-butanedione, acetaldehyde and 2-penten-1-ol, acetate (Z)- were found to correlated with descriptive aroma attributes such as brown sweet, caramelized and dairy (Figure 3.1). Chen et al (2019) reported that benzeneacetaldehyde has sweet and fruity odor. Furthermore, caramel aroma notes were positively correlated with benzeneacetaldehyde, 2,3-butanedione, acetaldehyde and 2-penten-1-ol, acetate (Z)- ($r > 0.85$). Brown sweet and dairy odors were shown to be highly correlated ($r = 0.96$ and 0.80 respectively) with 2,3-butanedione, acetaldehyde and 2-penten-1-ol, acetate (Z)-. However, previous research described 2,3-butanedione to possess buttery, sweet, and lucuma-like odor notes (Toledo et al., 2016; Inga et al., 2019). Figure 3.1 also depicted that Terrasoul sample was associated with the above-mentioned compounds (upper right corner of the graph).

Vanilla odor was positively correlated with benzene compounds such as ethyl benzoate (r = 0.73), benzyl nitrile (r = 0.70) and benzyl isothiocyanate (r = 0.73), although these compounds were shown to be responsible for nutty, cucumber and chemical aroma notes respectively (Chapter 2). Vanilla attribute was also found to be highly correlated with 6,10-dimethyl-5,9-undecadien-2-one (r = 0.97). In this study, panelists detected this compound during GC-O analysis and assigned brown sweet, sweet and grain aroma notes to it. Furthermore, other compounds such as octanoic acid, 3-methyl-butanoic acid and 2,3-dimethyl-5-ethylpyrazine were also shown to have high correlation with vanilla aroma (r>0.7). Pyrazines are usually associated with nutty and roasted aroma (Qian and Reineccius, 2002). Also, fruity-dark aroma attribute was positively correlated with benzaldehyde (r = 0.6).

Figure 3.1 shows that Naturevibe sample was positively correlated with compounds such as 2,3-dimethyl-5-ethylpyrazine, 3,5-octadien-2-one, 3-methyl butanoic acid, benzaldehyde, acetic acid (methyl ester), benzyl isothiocyanate, benzyl nitrile, octanoic acid and ethyl benzoate present on the lower right corner of the figure. These compounds are negatively correlated with sour aromatics whereas it was positively correlated with 3-methyl butanal (r = 0.79) and benzeneacetaldehyde (r = 0.64).

Herbazest sample was shown to be positively associated with acetic acid (ethenyl ester). In this study, acetic acid (ethenyl ester) was found to be responsible for buttery and brown sweet aroma notes during the GC-O analysis. Additionally, Superfood by MRM sample has been positively correlated with nonanal, acetic acid and alpha-campholenal. Acetic acid was responsible for sweet and sour aroma whereas the aldehydes (nonanal and alpha-campholenal) were assigned sweet, burnt, and waxy odors. Previous research associated nonanal with peanut and almond aroma (Xia et al., 2015). Healthworks was another sample to be studied. Figure 3.1 shows the sample to be associated with compounds such as 2-nonenal, (E)- (leather), 2-methylbutanal (burnt and musty/dusty), furfural (musty/dusty) and hexanal (green).

Study Limitations

Due to the ongoing pandemic, descriptive analysis could not be conducted in a designated panel room where the conditions (temperature, pressure, and lighting) were controlled. Instead, the panel was set-up in another room which may or may not have the same conditions. It could affect the perception or the ability to perceive various attributes, although it was a group of highly trained panelists. The descriptive analysis panel consisted of six evaluators, but it would have been better to have a greater number of panelists available to conduct the study. Higher number of panelists could have accounted for more variability between the samples. Lastly, the lucuma products selected for evaluation were selected to include some variability due to processing conditions. Other commercial lucuma ice cream products were not included because of availability issues in the US market. Lucuma powder from different sources was the most available option in the US. Even though some differences were noted among lucuma powder sources, products were not very different. Future research should consider including other commercial sources of lucuma flavor (as a final product or as an ingredient).

Conclusion

Six ice cream samples were evaluated using a newly developed lexicon with 31 attributes including appearance, aroma, flavor, aftertaste, and texture. The samples included five lucuma ice cream products made from lucuma powder from different commercial sources and another caramel flavored ice cream. Lucuma ice cream samples were compared against each other and a more mainstream ice cream product for the United States market (caramel ice cream). Descriptive analysis results show that the lucuma ice cream samples were perceived to be mostly similar to each other and slightly different from the caramel ice cream. Samples were found to be not statistically significantly different ($p>0.05$) for most of the attributes. Only five attributes: color intensity (appearance), caramelized (aroma), brown sweet (flavor), chalkiness (texture) and grainy (texture) were found to be statistically significant ($p<0.05$). The associations of descriptive results with instrumental data showed that different lucuma samples were associated with different volatiles. Benzeneacetaldehyde, hexanal, furfural, 2,3-dimethyl-5-ethylpyrazine and benzyl nitrile were the key compounds separating the lucuma samples along with descriptive aroma attributes such as brown sweet, caramelized (Terrasoul), sour aromatics (Healthworks) and vanilla (Naturevibe). This information helps better understand the sensory properties of lucuma powder and its variability across different sources and provide a starting point for further exploration of the usage of lucuma powder into other finished products such as smoothies and baked goods.

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Chapter 4 - Consumer Perception of a Novel Ice Cream Flavor

Abstract

Six ice cream samples were prepared including five samples with lucuma powder (from five different sources) as a flavoring agent and a caramel flavor ice cream. The objectives of this study were 1) to investigate consumer liking of ice creams made with lucuma powder with different sensory profiles (purchased from different sources), 2) understand how Lucuma ice cream compares to a more mainstream ice cream flavor that is more familiar to US consumers, and 3) assess food neophobia to segment US consumers and understand how they differ on their perception of Lucuma ice cream. A central location consumer test was performed using untrained panelists who were frequent ice cream users. Results showed that lucuma and caramel ice creams were perceived to be different by consumers, but the differences were small. Overall liking, overall aroma liking, and flavor liking were significantly higher ($p<0.05$) for the lucuma ice cream samples whereas texture liking was significantly higher ($p<0.05$) for caramel sample. Terrasoul sample was the most liked among products evaluated. Food neophobia results suggested that consumers with lower food neophobia are willing to try new or unfamiliar foods. A total of 42% of consumers responded that they would probably buy lucuma ice cream, if available on the shelves. This study helps understand the consumer perception towards lucuma ice cream and shows a potential market space for it in the US, especially if positioned as a healthier alternative. Further research can explore other formulations of lucuma ice cream, including commercial products and also the study of consumer perception of lucuma powder applied into other finished products such as yogurts, smoothies, and baked goods.

Introduction

Ice cream is a complex system consisting of air bubbles, fat and ice crystals dispersed in a solution of sugars, proteins, stabilizers, and emulsifiers (Clarke, 2004). It is extremely popular in the United States holding a significant market share. The sensory quality of ice cream plays an important role in determining consumer acceptance (Hettiarachchi and Illeperuma, 2015). With the growing health concerns among consumers, the demand for healthy alternatives in such products has been increasing. It is important to recognize the determining factors for healthier eating habits and to identify the market segments that are more interested in health benefit claims of the products (Chrysochou et al., 2010; Conner et al., 2002, Povey et al., 2000). Some studies have suggested that consumers may perceive enrichment of healthy foods less satisfying than that of non-healthy foods (Bech-Larsen and Grunert, 2003; Krutulyte et al., 2011, Lahteenmaki, 2013).

New varieties of ice cream catering to the functional and dietary requirements of the consumers are becoming popular, although a proper understanding of how consumers perceive food products is necessary for different aspects of new product development (Ares, 2015; Fonseca et al., 2016; Meilgaard et al., 1999). The manufacturers have made various attempts to provide healthier products using alternative ingredients such as probiotics, prebiotics, dietary fibers (Soukoulis and Tzia, 2010), and amaranth (Yakovleva, 2012) in ice cream formulations to respond to consumer health concerns. Moreover, there is an expectation from the consumer perspective that conventional foods should only be replaced by foods or ingredients perceived as healthy, which is paramount in determining consumer acceptance of such products (Bech-Larsen et al., 2001).

Lucuma fruit is a good source of dietary fiber. (Glorio et al., 2008). It tastes sweet but has low glycemic index, which can provide for an excellent functional ingredient for various food products such as ice cream, smoothies, yogurt, cakes, cookies etc. Typically, lucuma powder or frozen pulp are used as an ingredient in the food products. Since lucuma is native to Peru, lucuma ice cream is extremely popular in the country. It regularly outsells strawberry as well as chocolate ice creams and can be found throughout Peru including some fast-food chains, and the flavor can be described as sweet, pleasant, caramel-like and maple-like (Gill, 2012). Unfortunately, lucuma ice cream is not well-known outside of South America. Lucuma powder can be considered as a healthy addition to ice creams that can provide excellent taste and numerous health benefits.

Central location test (CLT) is a common type of quantitative consumer test and is performed at a location organized by the sensory professionals with a controlled environment. Several research studies have used this approach to determine consumer liking or acceptance of ice creams with functional ingredients. Fernandes et al. (2017) studied how the addition of cassava derivatives in ice cream impacted its sensory properties as well as consumer acceptance. Another study utilized this methodology when studying soy protein fortification of an ice cream (Friedeck et al., 2003).

Furthermore, attitudinal consumer research is another way to assess market segmentation and generate deeper consumer understanding. Food Neophobia Scale (FNS) is a psychometric tool developed by Pliner and Hobden (1992) to measure food neophobia where respondents indicate their agreement or disagreement with 10 statements about foods or eating situations (Ritchey et al., 2003). Food neophobia can be defined as reluctance to eat unfamiliar foods or food products (Loewen and Pliner, 2000). Cultural factors can play a major role in food selection. Beliefs, meal preparation, meal preferences and conditions of consumption vary from one culture to another (Rozin, 1990; Rubio et al., 2008).

Since lucuma ice cream is not popular in the United States, information on consumer acceptance testing for this product is lacking. Therefore, the objectives of this study were 1) to investigate consumer liking of ice creams made with lucuma powder with different sensory profiles (purchased from different sources), 2) understand how lucuma ice cream compares to a more mainstream ice cream flavor that is more familiar to US consumers, and 3) assess food neophobia to segment US consumers and understand how they differ on their perception of Lucuma ice cream. A central location test was performed using untrained panelists who were frequent ice cream users.

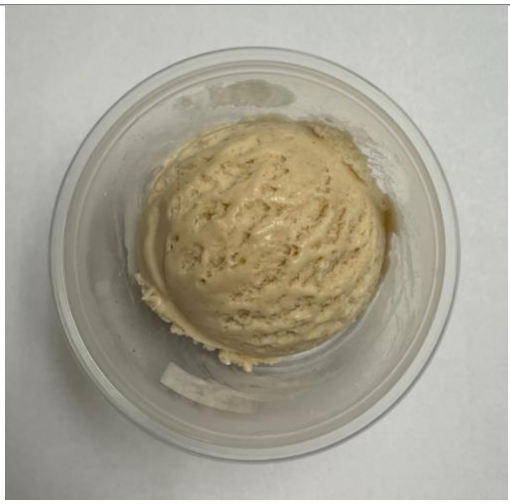
Materials and Methods

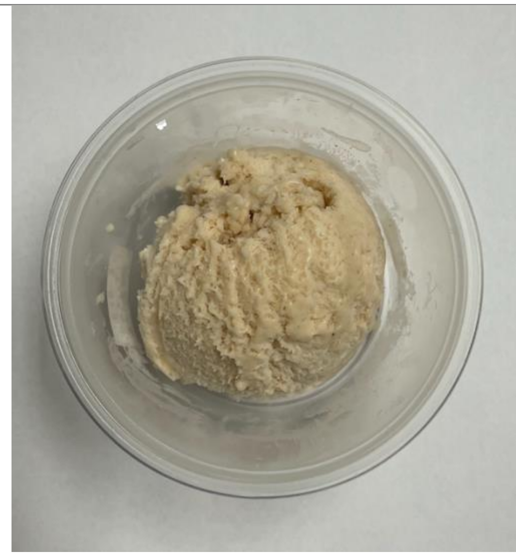
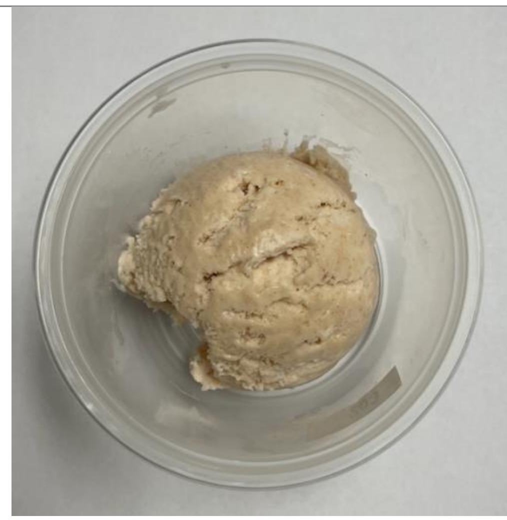
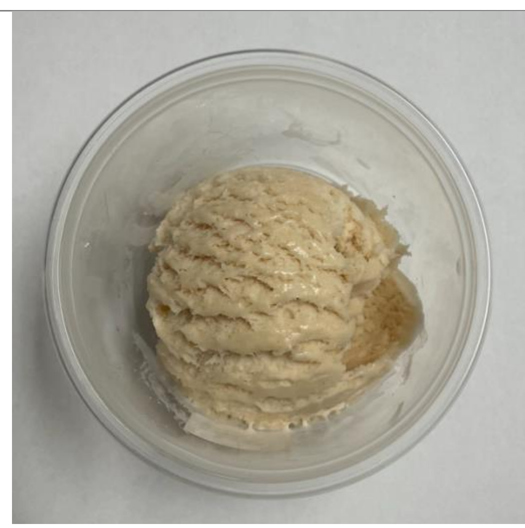
Samples

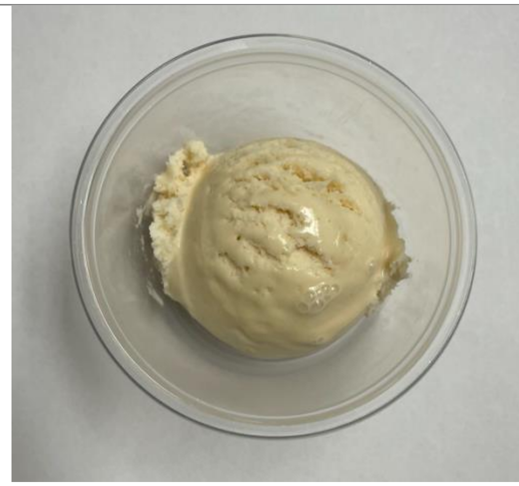
Five lucuma powder samples were selected using volatile analysis to conduct descriptive sensory analysis of the finished product (ice cream) alongside a mainstream and more familiar ice cream product (i.e., caramel ice cream). The five selected lucuma powder products selected for this study had different aroma volatile compositions. These were Naturevibe, Terrasoul, Healthworks, Herbazest and Superfood by MRM. Ice cream products were prepared using a standard base recipe at Dairy Plant, Kansas State University (Manhattan, Kansas, USA). The recipe consisted of cream, milk, non-fat dry milk (NFDM), sugar, corn sugar, and stabilizer icepro2004)**.** All the ingredients except cream were mixed and heated to 38 ^{0}C. Then, cream was added to the mixture and was pasteurized at 74 ^{0}C. Mixture was held at 74^{0}C for 30 minutes followed by cooling it down to 60 ^{0}C. Then, the mixture was homogenized at 8274 kPa (1200 psi) pressure. After the homogenization, the mixture was cooled down to 10 ^{0}C. It was then placed into a holding tank (Creamery Package Manufacturing Company, Lake Mills, WI) for 24 hours. Five percent each of lucuma powders and caramel were added to the base mix as flavoring agents. Samples were prepared using batch freezer (Emery Thompson Machine and Supply Co., Bronx, NY). Batch freezer is an equipment used for commercial production of frozen desserts such as ice cream and gelato. Final ice cream product consisted of approximately 12-13% of fat (by weight) with approximately 11% total solids. Ice cream was transferred into half gallon plastic containers and stored in blast freezer overnight. Then, all the samples were transferred to walk-in freezer at -18 ^{0}C. For central location test (CLT), one scoop (approximately 2oz) of the sample was served in 4oz disposable polystyrene translucent plastic souffle cups (Dart, Mason, Michigan, USA) covered with clear lids. Sample cups were labeled with random three-digit codes. The consumers were presented with the samples and were referred to as “ice cream” samples. No flavor reference was provided at the time of serving. Water was used as a palate cleanser. Table 4.1 shows the pictures of the samples used in the study.

Table 4.1.

Ice Cream Sample Used in the Central Location Test.

Sample	Picture
Naturevibe	
Terrasoul	

Healthworks	
Superfood by MRM	
Herbazest	

Caramel	

Participant Recruitment

A total of 106 participants (26 males and 80 females) were recruited from the Kansas City area from the consumer database of Sensory and Consumer Research Center at Kansas State University (Olathe, Kansas, USA). A wide age distribution of participants ranging from 18 years to 65 years was allowed. Consumer demographics are shown in table 4.2. Consumers were required to be frequent caramel ice cream users. Caramel ice cream was selected to be a part of this study as a comparative flavor because lucuma ice cream has been described to taste caramel-like. Therefore, it would provide better comparison than any other ice cream flavors present in the US market. Participants were also required to be employed and should have no food allergies. Additionally, they should not have participated in consumer research in past three months. The study was conducted at the Sensory and Consumer Research Center at Kansas State University, Olathe, Kansas, USA. Participants were compensated for their time.

Table 4.2.

Consumer Demographics from Central Location Test (N = 106).

Characteristics	Categories	Percentage (%)
Gender	Male	25
	Female	75
Age	Under 18 years	0
	18 – 24 years	2
	25 – 34 years	10
	35 – 44 years	26
	45 – 54 years	22
	55 – 65 years	40
Ice cream consumption	Daily	4
	Once a week	26
	Several times a week	52
	2-3 times a month	12
	Once a month or less	6

Questionnaire

Informed consent was obtained from the participants prior to product evaluation. Compusense software (Compusense Inc., Guelph, Ontario, Canada) was used for recruitment, screening of participants, questionnaire preparation as well as data collection.

Questionnaire consisted of questions such as overall liking, color liking, aroma liking, flavor liking, texture liking and aftertaste liking. Participants were instructed to answer these questions on a 9-point hedonic scale (1 = dislike extremely and 9 = like extremely). Several questions evaluating the intensities of specific attributes on a 7-point scale were also present in the questionnaire (1 = none and 7 = extreme). It included caramel flavor intensity, sweetness intensity, and aftertaste intensity. Additionally, 5-point Just-About-Right (JAR) scale was used to determine product penalties by the consumers. On 5-point JAR scale, 1 indicated “much too weak”, 3 was “just about right” and 5 represented “much too strong”. JAR questions included fruit flavor, caramel flavor, sweetness, and powdery mouthfeel.

Furthermore, participants were asked to agree or disagree to the 10 statements regarding food neophobia on a 7-point scale (1 = strongly disagree and 7 = strongly agree). Food neophobia scale (Pliner and Hobden, 1992) statements (Table 4.3) were used to examine consumer attitude and to determine food neophobia among consumers when it comes to trying unfamiliar or novel foods or food products.

Table 4.3

Food Neophobia Scale Statements.

Number	Statements
1*	I am constantly sampling new and different food.
2	I don’t trust new food.
3	If I don’t know what it is in a food, I won’t try it.
4*	I like foods from different countries.
5	Ethnic foods look too weird to eat
6*	At dinner parties, I will try a new food.
7	I am afraid to eat things I have never had before.
8	I am very particular about the food I will eat
9*	I will eat almost any food.
10*	I like to try new ethnic restaurants.

Note. Statements 1, 4, 6, 9 and 10 were reversed (*).

The questionnaire also included a concept consisting of a picture of lucuma fruit and a brief explanation regarding lucuma, its uses and health benefits (Figure 4.1). After consumers read through the lucuma concept, they were asked “how interested would you be in buying lucuma ice cream” on 5-point scale (1 = definitely will not buy and 5 = definitely will buy).

Figure 4.1.

Lucuma Concept Presented to Consumers Before Purchase Intent Question.

Lucuma, also known as the “Gold of the Incas”, is a fruit native to Peru high in beta carotene, iron, zinc, calcium, protein, and fiber. It also contains antioxidants and potassium, which are said to be good for your heart, immune system, and skin. This fruit is used as a sweetener and as flavoring for beverages and desserts such as ice creams, custards, marmalades, yogurt, among others.

Data Analysis

Analysis of Variance (ANOVA) was performed using Tukey’s Honest Significant Difference (Tukey’s HSD) for consumer liking data. Penalty analysis was performed on JAR data to determine the penalties accrued by the participants. It also showed the percent mean drop on liking score when the participants did not rate a particular sample characteristic as just-about-right. The data analysis was performed using XLStat software (Addinsoft, New York, USA). Food neophobia scores were calculated based on the sum of each response for a participant from the 10-item food neophobia scale. Then, food neophobia scores were divided into tertile cut-offs to classify the levels of food neophobia as low, medium, and high (Flight et al., 2003; Stratton et al., 2015). Five statements (1, 4, 6, 9 and 10) were reversed and considered while analyzing the results. Analysis of Variance was performed for overall liking attribute to determine the differences between food neophobia classifications.

Results and Discussion

Consumer liking

Table 4.4.

Consumer Liking Results from Consumer Evaluation of Ice Cream Samples on 9-Point Hedonic Scale (N = 106).

	Color Liking	Overall Aroma Liking	Overall Liking	Flavor Liking	Texture Liking	Aftertaste Liking
Terrasoul	6.2 ab	5.9 a	6.2 a	6.1 a	5.8 ab	5.2 a
Nature Vibe	6.2 ab	5.5 b	5.8 ab	5.6 ab	5.8 ab	5.0 ab
Caramel	6.5 a	5.3 b	4.7 c	4.4 c	6.2 a	4.7 ab
Herbazest	6.2 ab	5.2 b	5.4 b	5.3 b	5.5 bc	5.0 ab
Superfood by MRM	6.0 b	5.3 b	5.5 b	5.3 b	5.5 bc	4.9 ab
Healthworks	6.2 ab	5.3 b	5.4 b	5.5 ab	5.1 c	4.6 b
Pr > F(Model)	0.268	0.000	<0.0001	<0.0001	0.006	0.273

Note. Means with same letter are not significantly different (p>0.05)

Overall liking, overall aroma liking, flavor liking, and texture liking were significantly different ($p<0.05$) for the ice cream samples whereas color and aftertaste liking were not ($p>0.05$).

Average overall liking score was highest for Terrasoul sample followed by other lucuma samples including Herbazest, Superfood by MRM and Healthworks. Caramel ice cream sample received the lowest mean rating for overall liking. Naturevibe sample did not significantly differ from rest of the samples. As far as overall aroma and flavor are concerned, Terrasoul sample was perceived to be more liked ($p<0.05$). Once more, Caramel sample was perceived to be lower in overall flavor liking. However, Caramel sample was perceived to have significantly higher texture liking as compared to all lucuma ice creams ($p<0.05$), although mean liking score was 6 (i.e., liked slightly).

Color liking results showed that Superfood by MRM had the lowest mean ratings (below 6) while all the other samples were rated greater than 6. Therefore, the results suggested that color of the samples was “liked slightly” by the consumers. Similarly, average liking score for aftertaste also revolved around 5 for all the samples, thereby suggesting that the participants “neither liked not disliked” the aftertaste of the samples. However, no significant differences were perceived between lucuma ice cream samples and caramel flavor ice cream.

Intensity Ratings

Ice cream samples were evaluated for caramel flavor, sweetness flavor and aftertaste intensities on a 7-point scale (1 = none and 7 = extreme). Analysis of variance results for average liking scores are shown in Table 4.5.

Table 4.5.

Intensity Liking Scores from Consumer Evaluation of Ice Cream Samples on 7-Point Scale (N = 106).

	Caramel Flavor Intensity	Sweetness Intensity	Aftertaste Intensity
Terrasoul	4.5 a	4.2 a	4.3 a
Caramel	3.6 b	4.0 ab	4.4 a
Nature Vibe	3.8 b	3.8 bc	4.0 ab
Healthworks	3.7 b	3.9 abc	4.0 ab
Superfood by MRM	3.6 b	3.8 bc	4.0 ab
Herbazest	3.6 b	3.6 c	3.7 b
Pr > F(Model)	<0.0001	0.016	0.023

Note. Means with same letter are not significantly different (p>0.05)

Average liking score for various intensities were shown to be significantly different for the ice cream samples (p<0.05). Terrasoul was perceived to have significantly higher mean score for caramel flavor intensity (Table 4.5). Caramel ice cream was one of the lowest rated samples on caramel flavor intensity. This could be attributed the percentage of caramel flavor used while preparing the ice cream. Perhaps there was space for adding a higher percentage of caramel flavor to the base recipe, but it was kept at the same level as lucuma powder percentages to maintain the consistency across the samples. Terrasoul and Caramel samples were perceived to have significantly higher sweetness and aftertaste intensities respectively ($p<0.05$) than the rest of the samples (Table 4.5). Regarding texture, previous research showed that lucuma products have a grainy texture feel, which is not present in the caramel product (Chapter 3). This could be the reason why the texture of the caramel product was liked more.

Penalty Analysis

Penalty analysis explains the drop in liking due to less-than-optimal perception of various attributes such as fruit flavor, caramel flavor, sweetness, and powdery mouthfeel (Table 4.6). All products evaluated skewed towards a weak flavor perception. Terrasoul sample receive the highest JAR % among products for fruit flavor (35% consumers), caramel flavor (54% consumers) and sweetness (67% consumers) whereas Caramel flavored ice cream sample received the highest JAR % for its powdery mouthfeel (67% consumers). Still, all products could be considered below optimal.

Table 4.6.

Percentage of Consumer Responses and Mean Drop for Color, Fruit Flavor, Caramel Flavor, Sweetness and Powdery Mouthfeel on Just-About-Right (JAR) Scale (N = 106).

	Level	**Color**	**Mean drop %**	**Fruit flavor**	**Mean drop %**	**Caramel flavor**	**Mean drop %**	**Sweetness**	**Mean drop %**	**Powdery mouthfeel**	**Mean drop %**
Naturevibe	Too little	25%	0.5	71%	1.3	54%	**1.7**	31%	**1.7**	8%	0.4
	JAR	63%		27%		36%		59%		47%	
	Too much	11%	0.7	2%	2.7	10%	2.0	9%	-0.1	45%	1.0
Terrasoul	Too little	12%	0.6	58%	1.3	33%	**2.1**	22%	**2.1**	3%	0.3
	JAR	73%		35%		54%		67%		47%	
	Too much	15%	0.9	7%	2.9	13%	2.7	11%	2.7	50%	**1.6**
Healthworks	Too little	23%	1.2	68%	**2.0**	49%	**2.4**	25%	**2.0**	6%	0.7
	JAR	69%		28%		42%		60%		37%	
	Too much	8%	1.5	4%	3.9	9%	2.2	14%	0.9	58%	1.0
Superfood by MRM	Too little	25%	0.5	71%	1.0	55%	**2.0**	33%	**1.7**	4%	0.6
	JAR	53%		25%		37%		58%		47%	
	Too much	22%	0.7	5%	1.7	8%	1.7	9%	0.8	49%	1.2

	Too much										
Herbazest	Too little	21%	0.2	64%	**1.9**	55%	**2.2**	35%	**1.9**	8%	0.9
	JAR	64%		26%		36%		59%		43%	
	Too much	15%	1.8	9%	2.1	9%	2.5	6%	1.6	49%	1.4
Caramel	Too little	33%	0.1	-	-	60%	**2.5**	34%	**1.8**	14%	1.3
	JAR	59%		-		22%		47%		67%	
	Too much	8%	-0.1	-	-	18%	3.0	19%	1.8	19%	1.8

Note. Mean drop percentage in bold are strong penalties.

All lucuma powder ice cream samples: Naturevibe, Terrasoul, Healthworks, Superfood by MRM and Herbazest were strongly penalized for having too little fruit flavor, caramel flavor, and sweetness. Also, all these samples were strongly penalized for having too much powdery mouthfeel (Table 4.6). Strong penalties across the samples suggest that all the attributes studied on just-about-right scale matter to the consumers as the consumers rated the products lower when the attributes were perceived to be not JAR. They described the lucuma ice cream samples as “weak or no flavor”, “not enough caramel”, “too powdery”, “unflavored” etc. when asked to describe in one word why they liked or disliked a particular sample using open-ended questions providing a wide range of descriptors. No samples were penalized for their color.

Although some of the samples had lower mean drops, they managed to receive significant overall penalties because of high percentage of consumers that rated the products away from JAR. Naturevibe sample is an example of such penalty. Terrasoul, though it was the most liked sample overall, also received mean drops of greater than two points for having too little caramel flavor and sweetness. Healthworks sample also received such decline in liking scores for fruit and caramel flavor. Superfood by MRM and Herbazest samples also receive higher mean drop for caramel flavor.

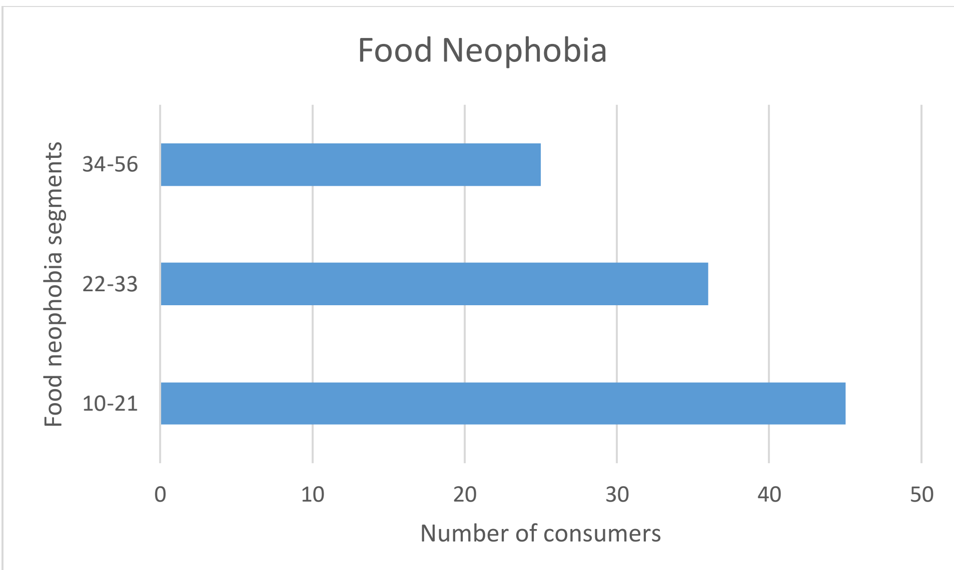
Consumers also strongly penalized caramel ice cream sample for too little caramel flavor and sweetness. Participants used the descriptors such as “plain”, “nothing”, “not much flavor” and “bland” etc. on the open-ended questions. This explains a higher decline in the mean liking scores for caramel flavor in the caramel sample. However, 67% of the consumers rated the caramel sample as Just-about-right for powdery mouthfeel (Table 4.6). Caramel ice cream sample was not evaluated for fruit flavor on the JAR scale.

Food Neophobia

Food neophobia scores were calculated using participant responses to each of the statements on food neophobia scales. Food neophobia scores ranged from 10 to 56 (possible range of 10 to 70) with a mean score of 27.97 (standard deviation = 11.63). The higher the food neophobia score, the greater the degree of food neophobia. Participants were classified by their degree of food neophobia based on percentile cut off including low range with scores from 10 to 21, medium range with scores of 22 to 33 and high range with scores of 34 to 56.

Figure 4.2.

Food Neophobia Segments Based on Percentile Cut-Off (N = 106).



As shown in Figure 4.2, approximately 42% participants received lower range of food neophobia scores suggesting they would have lesser resistance when trying new foods whereas 24% of the evaluators would show reluctance towards new foods or food products. Also, 34% participants were moderately food neophobic.

Furthermore, analysis of variance results (Table 4.7) showed that Low (FN score = 10-21) and high (FN score = 34-56) food neophobia groups liked lucuma samples more than caramel samples (p<0.05). This could be attributed to the fact that the consumers did not consider lucuma ice cream samples to be unfamiliar. Since, it relates to caramel ice cream because of its caramel-like flavor, they were willing to try lucuma flavored ice cream despite having higher food neophobia according to their responses on food neophobia scale.

Table 4.7. .

Overall Liking Scores for Low, Medium and High Food Neophobia (FN) Segments.

	Low FN	Medium FN	High FN
	Overall liking	Overall liking	Overall liking
Terrasoul	6.5 a	5.8 a	6.2 a
Nature Vibe	5.8 ab	5.5 a	6.1 a
Healthworks	5.7 ab	5.4 a	5.7 a
Superfood by MRM	5.6 ab	5.3 a	5.5 a
Herbazest	5.5 ab	4.9 a	5.2 a
Caramel	4.7 b	4.9 a	4.6 a
Pr > F(Model)	0.006	0.385	0.049

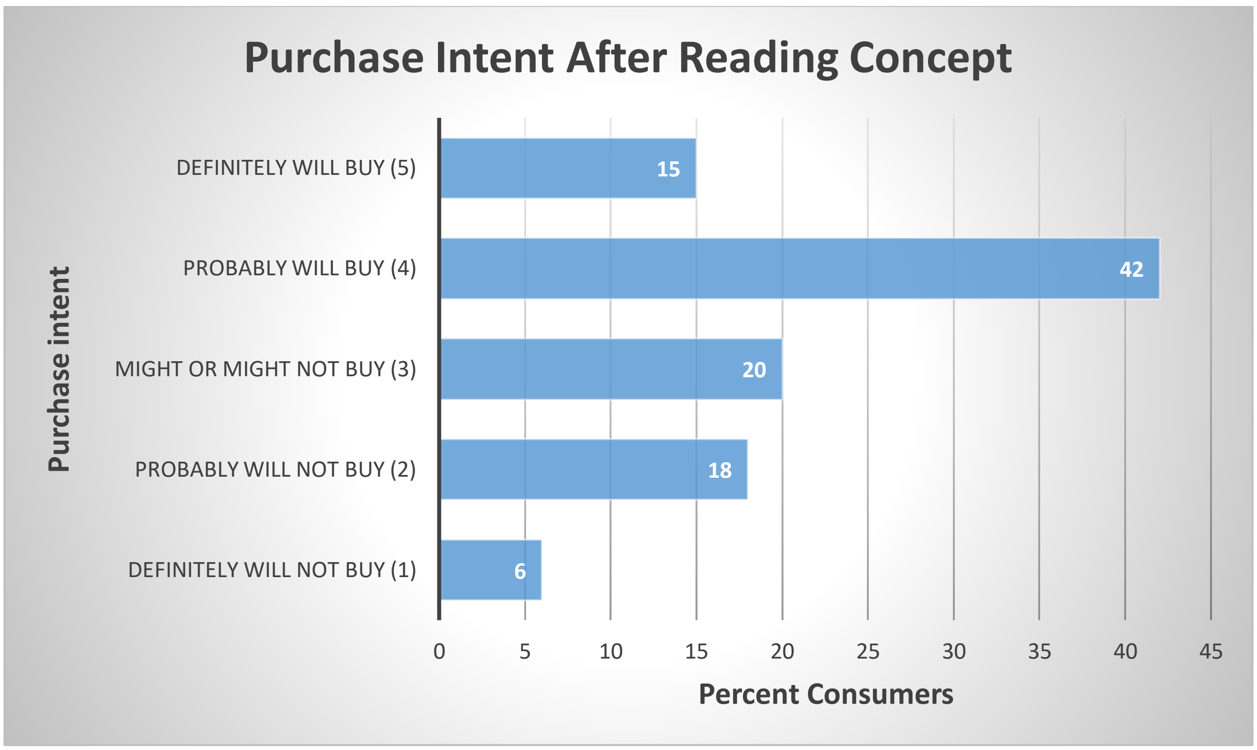
*Means with same letter are not significantly different (p>0.05)

Purchase Intent

A total of 15% of consumers answered that they “definitely will buy” lucuma ice cream. Large share of participants i.e., 42% responded that they “probably will buy” the product where only 6% answered that they “definitely will not buy” the ice cream samples (Figure 4.3). Furthermore, after linking the purchase intent data with food neophobia segments, it was found that 64% of the high food neophobic consumers (high FN group) indicated that they would “probably or definitely” buy lucuma ice cream whereas only 20% participants responded saying that they would “probably or definitely not” buy lucuma ice cream. These results are contrary to the idea that higher food neophobic consumers would be less willing to try new or unfamiliar products. Consumer perception might have changed based on the number of health benefits mentioned in the concept. The hypothesis is that this information could affect consumer liking score if they were presented with the concept at an earlier stage on the questionnaire. A consumer was quoted that they would have rated the ice cream samples higher, had they known about the health benefits of lucuma. Further research will be needed to confirm this hypothesis.

Figure 4.3.

Purchase Intent of Consumers After Reading Lucuma Concept.



Study Limitations

There were some limitations in the study. During sample preparation, same amount of caramel and lucuma powder were used as flavorings to keep the formulation consistent. In the hindsight, perhaps the percentage of caramel in caramel ice cream sample could have been higher as it was not as intense as lucuma powder, which eventually returned consumers labeling it as bland. Participants were recruited based on how willing they were to try new flavors. Consumers who indicated “strongly agree” or “agree” to the statement, qualified for the study. This could have influenced how they evaluated the product as well as their purchase intent. Consumer evaluation of commercial lucuma ice cream samples would have been ideal, but it was not feasible because of availability issues. Another limitation of the study was that no data was collected pertaining to the type of ice cream (premium/high fat, reduced fat/calorie, or no sugar) the consumers would typically consume. Therefore, author was unaware of the type of ice cream or type of dairy in the ice cream they would consume. Consumer familiarity with such products could have affected overall liking scores as well as liking for other key attributes. This study provides perception of consumers from Kansas City area. It would be interesting to examine how lucuma ice cream would perform if tested at various locations throughout the US to gather more insights from a larger population base.

Conclusion

Six ice cream samples were evaluated using a central location consumer study. Results showed that lucuma and caramel ice creams were rated different by consumers, but the margin was small. This shows that even though the formulation is not ideal, lucuma ice cream may have a competitive opportunity in the US market. Overall liking, overall aroma liking, and flavor liking were significantly higher ($p<0.05$) for the lucuma ice cream samples whereas texture liking was significantly higher ($p<0.05$) for caramel sample. Terrasoul was the most liked product among products evaluated. This could be related to relative higher intensities of caramel and sweetness intensities even though this product was still penalized for weak flavor. Previous chapter also showed that the Terrasoul product had a slightly higher caramelized aroma and brown sweet flavor compared to most of the other samples evaluated. These attributes have been associated with benzeneacetaldehyde, acetaldehyde and 2,3-butanedione volatile compounds (Chapter 3). Food neophobia results suggested that consumers with lower food neophobia are willing to try new or unfamiliar foods. A 42% of consumers responded that they would probably buy lucuma ice cream, if available on the shelves. This study helps understand the consumer perception towards lucuma ice cream and shows a potential market space for it in the US, especially if positioned as a healthier alternative. Further research can explore other formulations of lucuma ice cream, including commercial products and the study of consumer perception of lucuma powder applied into other finished products such as yogurts, smoothies, and baked goods.

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Appendix A - Screener and Questionnaire Used in Consumer Study (Chapter 4)

Screener

SQ 1. What is your gender?

Male

Female

CONTINUE, If 1 or 2

SQ 2. What is your age?

Under 18

18-29

30-49

50 or older

DQ, If 1

CONTINUE, If 2-4

SQ 3. Do you, or does anyone in your household, work for any of the following types of companies?

A marketing, promotions, or market research company

An advertising agency

A manufacturer or distributor of food or non-food products

None of the above

DQ, If 1-3

CONTINUE, If 4

SQ 4. Do you have any food or non-food allergies?

Yes

No

DQ, If 1 selected

CONTINUE, if 2 selected

SQ 5. Are you currently experiencing any cold or COVID-19, or flu-like symptoms?

Yes

DQ, If 1 selected

CONTINUE, if 2 selected

No

SQ 6. When was the last time you participated in any type of consumer taste test or marketing research study about a food or non-food product?

Within the past month

Within the past 2-3 months

Within the past 4-6 months

More than 6 months ago

Never

DQ, If 1 or 2
CONTINUE, If 3-5

SQ 7. What of the following desserts do you like to consume? (Check all that apply)

Puddings

Ice cream

Brownie

Cake

None of above

Must select 2

SQ 8. You said you like to consume Ice cream. What kind of Ice creams do you like to consume? (Check all that apply)

Caramel

Butterscotch

Vanilla

Chocolate

None of the above

Must select 1

SQ 9. You said you consume Caramel flavored ice creams. How often do you consume the caramel ice creams?

Once a week

Once a month

Once in two months

Once in six months

Once a year

CONTINUE, If 1 or 2

SQ 10. Please answer if you agree or disagree with following statement.

I am willing to try new flavors of ice creams.

Strongly Agree

Agree

Neither Agree nor Disagree

Disagree

Strongly Disagree

CONTINUE, If 1 or 2

Congratulations! You have qualified for Ice cream study test on *4/13/2021* (Tuesday). The study will take approximately 45 minutes, and you will be compensated *_$AMOUNT_* for your time.

Are you interested in participating for this study?

Yes

No

Must select 1

Questionnaire

Q1: How much do you like or dislike the overall color of this ice cream sample?

Dislike extremely – Like Extremely (9-point)

Q2: The color of this ice cream is:

Much too light

Somewhat too light

Just about right

Somewhat too dark

Much too dark

Q3: How much do you like or dislike the overall aroma of this ice cream?

Dislike extremely – Like Extremely (9-point)

Q4: Considering the appearance, taste, and texture of this ice cream, how much do you like or dislike the sample overall?

Dislike extremely – Like Extremely (9-point)

Q5: Using single words or descriptors, what characteristics did you like about this ice cream?

Open-ended________

Q6: Using single words or descriptors, what characteristics did you dislike about this ice cream?

Open-ended_______

Q7: How much do you like the overall flavor of this ice cream?

Dislike extremely – Like Extremely (9-point)

Q8: How would you describe the intensity of the fruit flavor in this ice cream?

None – Extreme (7-point)

Q9: How would you describe the fruit flavor of this ice cream?

Much too weak

Somewhat too weak

Just about right

Somewhat too strong

Much too strong

Q10: How would you describe the intensity of caramel flavor in this ice cream?

None – Extreme (7-point)

Q11: How would you describe the caramel flavor of this ice cream?

Much too weak

Somewhat too weak

Just about right

Somewhat too strong

Much too strong

Q12: How would you describe the intensity of the sweetness of this ice cream?

None – Extreme (7-point)

Q13: How would you describe the sweetness of this ice cream?

Not at all sweet enough

Not quite sweet enough

Just about right

Somewhat too sweet

Much too sweet

Q14: How much do you like or dislike the overall texture of this ice cream?

Dislike extremely – Like Extremely (9-point)

Q15: How much do you like or dislike the aftertaste of this ice cream?

Dislike extremely – Like Extremely (9-point)

Q16: How would you describe the intensity of the aftertaste of this ice cream?

None – Extreme (7-point)

Q17: How would you describe the powdery mouthfeel of this ice cream?

Not at all powdery enough

Not quite powdery enough

Just about right

Somewhat too powdery

Much too powdery

Q18: Please rate if you agree or disagree with the following statements:

Q18.1: I am constantly sampling new and different food.

Strongly disagree – Agree (7-Point)

Q18.2: I don’t trust new food.

Strongly disagree – Agree (7-Point)

Q18.3: If I don’t know what is in a food, I won’t try it.

Strongly disagree – Agree (7-Point)

Q18.4: I like foods from different countries.

Strongly disagree – Agree (7-Point)

Q18.5: Ethnic foods look too weird to eat.

Strongly disagree – Agree (7-Point)

Q18.6: At dinner parties, I will try a new food.

Strongly disagree – Agree (7-Point)

Q18.7: I am afraid to eat things I have never had before.

Strongly disagree – Agree (7-Point)

Q18.8: I am very particular about the food I will eat.

Strongly disagree – Agree (7-Point)

Q18.9: I will eat almost any food.

Strongly disagree – Agree (7-Point)

Q18.10: I like to try new ethnic restaurants.

Strongly disagree – Agree (7-Point)

Q19: Please rate the following questions about yourself.

Q19.1: What is your gender?

Male

Female

Q19.2: Which one of the following includes your current age?

18-24 years

25-34 years

35-44 years

45-54 years

55-65 years

Q19.3: How often do you eat consumer ice cream?

Daily

Several times per week

Once per week

2-3 times per month

Once per month or less

Includes a picture of the lucuma concept (Figure 4.2)

Q19.4: After tasting these ice cream samples, how interested would you be in buying Lucuma Ice Cream?

Definitely will not buy

Probably will not buy

Might or might not buy

Probably will buy

Definitely will buy