ABSTRACT

CROWN, ERICA ELAINE. Utilizing Survey Methodologies and Consumer Acceptance Testing to Understand Consumer Perception of Sweeteners in Yogurt (Under the direction of Dr. MaryAnne Drake).

Consumers are interested in products with reduced sugar, a trend which has been attributed to consumers associating high-sugar foods with obesity, diabetes, heart disease and high blood pressure. The objective of this study was to evaluate consumer perception of sugar reduction in yogurt – both conceptually and for liking of actual products. An online survey (n=1290) was conducted to evaluate consumer perception of sweeteners available in commercial yogurts. Participants who purchased yogurt at least once in the past 3 months completed a series of exercises that involved demographics, agreement, Kano, and Maximum Difference (MaxDiff) scaling questions. Subsequently, vanilla 1% milkfat yogurts sweetened with sucrose were formulated to iso-sweet taste intensity with either stevia, allulose, a blend of sucrose and honey or a blend of sucrose, stevia and allulose using magnitude estimate scaling followed by paired comparison tests with consumers (n=40). A consumer acceptance test (n=229) was then conducted using the five vanilla yogurts. Half of the consumers (n=115) were primed with the specific yogurt sweetener and the other half were not. Survey and acceptance test data were evaluated by univariate and multivariate analyses. Conceptually, consumers preferred the claim “naturally sweetened” over a reduced sugar claim in yogurt ($p<0.05$). Honey was preferred over other sweeteners, followed by agave nectar and cane sugar ($p<0.05$). Allulose was the least preferred sweetener option conceptually ($p<0.05$). Priming with sweetener type positively impacted consumer acceptance, regardless of sweetener ($p<0.05$). When yogurts were tasted, yogurts sweetened with sucrose were the most preferred regardless of priming ($p<0.05$). Yogurts sweetened with allulose or a blend of allulose, stevia, and sucrose received higher liking scores

than yogurts with stevia ($p<0.05$), suggesting that allulose can assist with sugar reduction in yogurt. Consumers are interested in healthy yogurts that are naturally sweetened, but flavor remains the driving force for liking and purchase. The use of a natural non-nutritive sweetener that delivers the sensory experience of sucrose is ultimately more important than familiarity with the actual sweetener.

Utilizing Survey Methodologies and Consumer Acceptance Testing to Understand Consumer Perception of Sweeteners in Yogurt

by
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BIOGRAPHY

Erica Elaine Crown was born on August 22nd, 1993 to Deirdre (Dee) and Michael (Mike) Crown in Grand Rapids, Michigan and grew up alongside her younger brother Barry. Erica graduated from Forest Hills Central High School in Grand Rapids, Michigan in 2012. From there she obtained a B.S. degree in Food Science and a minor in Nutrition from Michigan State University (MSU) in East Lansing, Michigan. Here she discovered sensory science, which fostered her curiosity for the subject. Erica became part of the product development team at MSU where she and her team competed at IFT. After graduating from MSU in 2017, Erica worked as a Food Safety and Technical Specialist at House of Flavors Inc. in Ludington, Michigan. While this was a great experience for her, Erica wanted to continue fostering her interest in sensory science. Erica left House of Flavors Inc. in 2020 and moved to Raleigh, North Carolina to pursue a Master's degree in Food Science under the direction of Dr. MaryAnne Drake. Erica can be found cooking and baking, where she enjoys making new recipes for others to try. She also enjoys hiking, being by any body of water (the ocean or a lake), thrifting, and traveling.

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Literature Review

Erica Crown

Introduction

Yogurt sales have increased within the United States and are predicted to increase in the foreseeable future (Mintel Group Ltd, 2021). Along with an increase in yogurt sales, there has been an increase in consumer desires for products with reduced sugar. This desire is most likely attributed to how excess sugar intake leads to health complications such as hypertension, type II diabetes, cardiovascular disease, obesity, and dental caries (McCain et al., 2018). However, sugar reduction greater than 30% can affect the liking of dairy products such as flavored yogurt (McCain et al., 2018; Mahato et al., 2021). As a result, sweet taste intensity of products needs to be maintained. Along with a focus on maintaining sweet taste intensity, it is also important to understand consumer trends in relation to reduced sugar. The focus of this literature review will examine previous research on yogurt with an emphasis on vanilla yogurt, sugar reduction studies, and analytical and sensory methodologies that will provide insight on sugar reduction in yogurt and consumer acceptance of sugar reduction in yogurt.

Sweet Taste

Sweet Taste Perception

The primary role of taste is to assist in detecting key nutrients and potentially toxic foods. Taste is composed of 5 basic taste components: sweet, umami, bitter, salty, and sour (Laffitte et al., 2014). Sweet taste strongly influences dietary choice; “a sweet taste of food indicates that the food contains energy-rich carbohydrates, which increases the hedonic tone of food and strongly influences our eating behavior” (Laffitte et al., 2014). Taste is detected through taste receptors, which are located in the taste buds on the dorsal surface of the tongue and soft palate (Fernstrom et al., 2012; Laffitte et al., 2014). The perception of sweet taste is mainly controlled via a single receptor, which is part of the Type 1 taste receptors (T1R) (Laffitte et al., 2014). Type 1 taste receptors belong to a large family of G protein- coupled receptors. These receptors are heterodimers, which means sweet taste is detected by the T1R1 and T1R3 subunits of the Type 1 taste receptors (Fernstrom et al., 2012). The T1R1 and T1R3 subunits contain several binding sites for sweeteners. Every T1R receptor contains an extracellular venus-flytrap (VFT) domain at the N terminus, a seven transmembrane-spanning domain at the C terminus, and a cysteine-rich linker joining them (Fernstrom et al., 2012). Natural and artificial sweeteners such as sucrose, glucose, allulose, stevia and sucralose bind to the VFT of both subunits, dipeptide sweeteners such as aspartame and neotame bind only to the T1R2 VFT, and sweet proteins such as thaumatin and monellin can bind to both subunits and the cysteine-rich linkers (Fernstrom et al., 2012; Turner et al., 2020). The binding process of the T1R1 and T1R3 subunits are illustrated in Figure 1. Once these receptors are activated through the binding process, the subunits release the stimuli onto afferent nerve fibers. This information is relayed to the brain where the taste information and other sensory information is processed and then elicited into the perception of sweet taste (Fernstrom et al., 2012).

With different types of sweeteners on the market, it is important to compare the sweet intensity or relative sweetness of sweeteners to each other to understand how much or how little of a certain type of sweetener should be in a given product. Comparison of sweeteners to each other is mainly done by sensory comparison (Tiefenbacher, 2017). The sweetness of sucrose is the ‘gold standard’ of sweet taste and due to this, the relative sweetness of sucrose is set to 1 or 100% (Peris, 2016; Tiefenbacher, 2017). This means that sweeteners can be divided into high intensity sweeteners (sweeteners that have a relative sweetness above 1) or bulk sweeteners (sweeteners that have a relative sweetness that is lower or just slightly higher than sucrose) (Tiefenbacher, 2017).

It should be noted that conditions also play a significant role in sweetness intensity. Factors such as pH, the presence of other components, and temperature can all effect the perceived sweet taste intensity. Schiffman et al. (2000) examined how temperature, pH, and ions affected sweet taste of various nutritive and non-nutritive sweeteners. Sweeteners used for this study were tested at concentrations equivalent to 2.5%, 7.5%, and 10% sucrose. For the temperature study, samples were served at 50°C and 6°C. Sweet taste ratings for the lowest level (2.5% iso-sweet equivalency of sucrose) of alitame, aspartame, glucose, MAG, mannitol, and rebaudioside-A increased at 50°C. There was an increase in sweet taste intensity for neo-DHC, stevioside, and thaumatin at 6°C (Schiffman et al., 2000). Large molecular weight and high potency sweeteners were more frequently enhanced by hot or cold temperatures. It was also observed that the sweet intensity of sucrose and sorbitol were slightly enhanced at 50°C at the lowest concentration. However, as the concentration of these sweeteners increased the sweet intensity decreased at 50°C (Schiffman et al., 2000). This finding is similar to what Lipscomb et al. (2016) observed. For the pH part of the study, the five pH levels were used: 3.0, 4.0, 5.0, 6.0, and 7.0. No significant difference were found for sweet taste intensity ratings among the sweeteners at the different pH levels (Schiffman et al., 2000). The ions that were used in this study were Na^+, K^+, Ca^2. No significant differences were noted for sweet intensity (Schiffman et al., 2000). As previously stated, not many studies have been performed like this one, but currently it demonstrates that temperature could be the main factor that could influence the sweet intensity of both nutritive and non-nutritive sweeteners.

Food matrices also impact the perception of sweet taste intensity, which can influence the relative sweetness of the sweetener. For instance, solid food matrices such as baked goods are very different than sugar solution in pure water (Tiefenbacher, 2017). Arancibia et al. (2013) explored sweet taste intensity (10% sucrose [w/w]) of different composition of dairy desserts with different milk types (whole or skimmed milk), different types of thickeners (carboxymethyl cellulose [CMC] or starch), and different concentrations of the thickeners. Each thickener and milk type were evaluated at the concentrations of (%w/w) 1.1, 1.3, 3.5, and 4.0. Each matrix sample was evaluated by 28 trained panelists by using a pairwise ranking test which compares all 28 possible pairs of samples and measures the relative intensity of each attribute among the pairs of samples (Arancibia et al., 2013). Different thickeners effected the sweetness intensity. The starch samples had a higher sweet taste intensity than the CMC samples. This result can be attributed on how starch and CMC break down in saliva as the starch may transfer across taste receptors differently than CMC (Arancibia et al., 2013). The milk type also effected the sweet taste intensity of the desserts. Whole milk samples had a higher sweet taste intensity than skimmed milk samples. It was noted that this may be due to the increased fat content of the milk, which may cause a higher concentration of sucrose to disperse within the aqueous phase of the milk (Arancibia et al., 2013). Another study by Bayarri et al. (2007) focused on how sweet taste was impacted by different gelled systems using sucrose and aspartame. The gels that were used were k-carrageenan and gellan gum. Both gel matrices were prepared in two different concentrations of 3 and 9g/L. Two different concentrations of the sweeteners were also used: sucrose was 100 and 150 g/L and aspartame was 0.8 and 1.2 g/L. Eight panelists were chosen and trained on how to perform time intensity. Sucrose and aspartame both had higher I_{max} values in the gellan gel samples. Gellan gel is more brittle than k-carrageenan gels and therefore tends to degrade faster during mastication than k-carrageenan (Bayarri et al., 2007). Quicker degradation upon mastication leads to a larger sweetener release from the gel into the mouth. Sucrose also had a shorter I_{max} than aspartame indicating that sweetener type can also influence sweet taste intensity in various matrices (Bayarri et al., 2007).

Studies also evaluated how protein concentrations and texture effect sweet taste intensity. A study by Parker et al. (2018) focused on how different sweeteners and whey protein concentration impacted sweet taste intensity in ready-to-mix (RTM) vanilla beverages. Whey protein concentration had no significant effect on iso-sweetness (Parker et al., 2018). Wagoner et al. (2018) also used whey protein in their study, but focused on how texture of the protein matrices influenced sweet taste intensity. Texture of the solutions was adjusted by heating the whey protein solutions at different temperatures to produce thin, semi-solid, and thick whey protein solutions. TDS was used to evaluate the sweeteners. Other than sucralose, non-nutritive sweeteners decreased in sweet taste perception with increased viscosity (Wagoner et al., 2018). As discussed previously, mastication may be the plausible reason behind these results. As viscosity increases, the rate of tastant reaching the taste bud receptors declines (Wagoner et al., 2018). Additionally, it was noted that heating whey protein can increase astringency, which could have also played a role in the decrease sweet taste perception with increasing viscosity (Wagoner et al., 2018). Similar to previous studies mentioned, matrices, and in this instance texture, can influence sweet taste perception and intensity.

Nutritive and Non-Nutritive Sweeteners and Metabolism

Sweeteners can be classified into two different categories: nutritive and non-nutritive sweeteners. Nutritive sweeteners are sweeteners that contain carbohydrates and provide energy (calories) (Liauchonak et al., 2019). Non-nutritive sweeteners, on the other hand, are sweeteners that are very low calorie or zero calorie alternatives that provide minimal or no carbohydrates or energy (Liauchonak et al., 2019). These two classifications of sweeteners are each metabolized differently in the human body. For instance, monosaccharides such as glucose and fructose can be directly absorbed into the blood stream upon consumption. Sweeteners like sucrose, lactose, and maltose (disaccharides), are nutritive sweeteners, and need to be broken down into monosaccharides to be metabolized. This is accomplished by enzymes present in the small intestine. The enzyme sucrase breaks down sucrose, the enzyme lactase breaks down lactose, and the enzyme maltase breaks down maltose (Whitney and Sizer, 2018). Once broken down, glucose is directly absorbed in mucosal cells in the small intestine via active transport (Gropper et al., 2005). However, it is not completely understood how fructose is absorbed within the human body. It is believed that one way fructose is absorbed is through active transport similar to glucose since fructose uptake has been shown to occur a concentration gradient. Additionally, in the absence of glucose, it is believed that fructose is absorbed by facilitated transport involving a specific transporter (Gropper et al., 2005). Even though it is very low in calories, allulose, which is a rare monosaccharide, is considered a nutritive sweetener as well. The process of how allulose is metabolized is different than sucrose. A small quantity of allulose is decomposed into short-chain fatty acids by cecal microbes located in the intestines. The remainder is excreted out of the body in the form of urine or feces without being metabolized (Jiang et al., 2020).

A common example of a nonnutritive sweetener is stevia, which is composed of steviol glycosides. The first step of stevia metabolism involves the steviol glycosides passing through the gastrointestinal tract intact. The gut bacteria in the colon then hydrolyze the steviol glycosides by snipping off the glucose units. The steviol is then absorbed by the portal vein. The absorbed steviol is then metabolized in the liver where it becomes steviol glucuronide, which is then excreted in the urine (Ashwell, 2015). Artificial sweeteners, which are synthetic sugar substitutes, fall into both the nutritive and non-nutritive sugar categories (Neacşu and Madar, 2014). As such, artificial sweeteners are all metabolized differently (Pang et al., 2020). For example, sucralose, which is noncaloric, mainly passes through the GI tract and is excreted out of the body in feces (Neacşu and Madar, 2014; Pang et al., 2020). The rest of sucralose is absorbed by the kidneys and then excreted in urine. Aspartame is first broken down in the small intestines into aspartic acid, phenylalanine, and methanol. Aspartic acid and phenylalanine are used for protein synthesis and metabolism and then excreted, while methanol is metabolized by the liver (Pang et al., 2020).

Overview of Sweeteners

Stevia

Originating in the northeast region of Paraguay called Amambay, Stevia, also known as Stevia rebaudiana, is a plant that is part of the Asteraceae family (Gasmalla et al., 2014). Stevia is a perennial woody shrub that can grow up to 80cm upon maturity and in recent years has been wildly cultivated in regions in India. The Stevia genus is made up of at least 110 species, however, there can be as many as 300 species of the Stevia plant. Different species of Stevia each contain different sweetening compounds with *S. rebaudiana* Bertoni being the sweetest (Goyal et al., 2010). Sweetener compounds are found within the leaves of the Stevia plant with the leaves of S. *rebaudiana* Bertoni containing over 30 steviol glycosides. Stevioside and rebaudioside A are the main sweetening components found within the leaves of *S. rebaudiana* Bertoni. As a result, these compounds are extracted from *S. rebaudiana* Bertoni to create a white crystalline powder that is noncaloric and is approximately 300 times sweeter than sucrose (Gasmalla et al., 2014).

The extraction process of stevia normally consists of first steeping the stevia leaves in hot water, similar to preparing loose leaf tea (Barregren, 2020). The next step involves passing the ‘stevia tea’ through an ion exchange chromatograph. With the help of the electrical charge emitting from the chromatograph, the steviol glycosides are captured. The steviol glycosides are then rinsed with alcohol, which aides in releasing the steviol glycosides form the electrical charge. The alcohol is then removed by utilizing membrane filtration and distillation. The product from this is a yellow steviol glycoside syrup. The yellow color of the syrup is removed by passing it through activated carbon. Next, the syrup is pressed to force out a steviol glycoside solution, which is then filtered one last time to remove any small residual particles. Lastly, the steviol glycoside solution is spray dried (Barregren, 2020). The main component that is extracted from stevia leaves (50% to 80%) is stevioside (Barregren, 2020). However, this compound contains unpleasant attributes like bitterness and a metallic aftertaste. To help mitigate these attributes, the primary extract can be refined even further to create rebauduioside (Reb) A and Reb M. Reb A offers better flavor than stevioside and Reb M does not contain any bitter or metallic attributes. Refining is performed by recrystallization of the primary extract with distillation performed multiple times until the end product that is desired is achieved (Barregren, 2020).

Stevia offers many applications within the food industry. Stevia is heat stable up to 200 C, does not undergo fermentation, and does not undergo any type of browning reaction (Gasmalla et al., 2014). Due to these characteristics, stevia can be used for baking applications. Stevia is also stable at pH ranges of 2-10, which makes it an ideal sweetener for beverages like hot coffee and tea. Due to its stability stevia is also used for sauces, pickles, yogurt, and candies. Additionally, stevia can prevent tooth decay which makes this sweetener a good choice to utilize in toothpaste, chewing gum, mints, and mouth wash (Gasmalla et al., 2014). Even though stevia can be used for a variety of applications, it has had a rocky past. Stevia was originally banned for cariogenic concerns, but received GRAS status in 2008. Due to its health concerns, stevia had been studied extensively and over 200 peer review papers exist on the safety of consuming stevia (Ashwell, 2015). Based on these studies the Joint FAO/WHO Expert Committee on Food Additives (JECFA) established the acceptable daily intake (ADI) of stevia to be 4 mg/kg of body weight per day (Ashwell, 2015).

Allulose

Allulose, also known as D-allulose, is the C-3 epimer of D-fructose that was first discovered in the leaves of wheat in the 1940's (Zhang et al., 2021). Although allulose is naturally present in nature, it can only be found in a few sources such as beet molasses, processed cane, long-heated fruit juice, steam-treated coffee, raisins, and dried figs (Zhang et al., 2021). Due to its scarcity in nature, allulose is produced synthetically through various avenues that isolates and purify D-allulose. One method that is used is the enzymatic isomerization of fructose using DTEase catalysts, which are enzymes that relate to D-tagatose 3-epismerase (Jiang et al.,2020). Enzymes that are used to purify and isolate D-allulose are D-psicose, 3-epimerases, and ketose 3-epimerase (Jiang et al., 2020). This method can use various steps to achieve D-allulose of different purities. For instance, by using an anion exchange matrix D-allulose can reach a purity of 99.1%. Another method of creating D-Allulose is a biological method that uses yeast. The yeast consumes residual D-fructose to produce ethanol in a mixed system of D-allulose and D-fructose, which produces D-allulose with a purity of 85%. A further purification of D-allulose can be achieved by combining pervaporation technology and cation exchange chromatography to obtain D-allulose that has a purity of 86.2% (Jiang et al., 2020). These methods are applied in countries such as China, Japan, South Korea, and the United States. Despite multiple countries producing D-allulose, the cost of D-allulose is still high due to unsatisfactory activity of the enzymes used in processing and their low reutilization frequencies (Jiang et al., 2020).

With D-allulose only being 0.4kal per gram, 70% as sweet as sucrose, and does not produce any bitter aftertaste, it is an attractive alternate sweetener (Zhang et al., 2021). Other than being used as a natural sweetener replacement, D-allulose also offers other various applications in the food industry. D-allulose can improve the quality of food through Maillard reactions, gelling capabilities, emulsifying stability, and foaming properties (Zhang et al., 2021). Research also has shown that D-allulose has influenced the growth of lactic acid bacteria in milk indicating that D-allulose may be beneficial in regulating acid production in over-fermented milk (Xia et al., 2021). Other than food applications, D-allulose also has potential for other unique non-food applications. Plant-based materials have been derived from D-allulose and have been used to create permanent, water-repellent, eco-friendly light transparent films that can be used for optical devices and crystal displays (Takei and Hanabata, 2015; Zhang et al., 2021). Similar to stevia, allulose also has GRAS status, which was obtained in 2012. The recommended maximum intake of allulose is 30 g per day (Tate & Lyle, personal communication).

Additionally, in the United States, the FDA has several application limits for allulose which are outlined in GRN 400, 498, and 693. These application levels are displayed in Table 1. For dairy and yogurt, the intended usage level of allulose is 5% or 8.5 g per serving. It should be noted, products such as chocolate milk fall into the beverage category for intended usage of allulose. This means that chocolate milk needs to have a usage level no greater than 3.5% or 12.3g of allulose per 8 oz serving (Tate & Lyle, personal communication).

Honey Powder

Since ancient times, honey has been used to sweeten foods due to its naturally sweet taste. The physical and chemical properties of honey are dependent on the types of flowers used by bees and the climate where the bees are located (Donders et al., 2021). Approximately, honey normally consists of 80% sugars, 17% water, and various trace compounds that impact the flavors and the colors of the honey. Fructose and glucose are the most abundant sugars in honey, while other minor sugars consist of maltose and sucrose (which comprises 1% of honey) and other disaccharides such as kojibiose, furanose, isomaltose, and maltulose (which comprise over 7% of honey). Additionally, trisaccharides such as erlose are present along with oligosaccharides. Honey is also composed of trace amounts of acids, proteins, and minerals (Donders et al., 2021).

While honey is popular to use because of its sweet taste, due to its high viscosity and density, honey is difficult to use within the food industry. Furthermore, since honey is a supersaturated glucose solution it can crystallize easily, leading to a shorter shelf life along with decreased consumer acceptance (Samborska, 2019). In order cope with these problems that arise from the properties of honey, manufacturers have come up with a solution; that solution being honey powder. Honey powder offers many advantages compared to liquid honey. Honey powder has a longer shelf life, can be easily blended in with other food ingredients, is easy to weigh and handle due to its free-flowing nature, can easily be stored, and reduces the complexity of cleaning. Honey powder is normally produced via spray drying with the addition of a carrier to enhance the drying process and powder properties of the honey powder (Samborska, 2019). Owing to its high sugar content, spray drying of honey can be challenging. To negate this, drying carriers are needed which aide in reducing the hygroscopicity of the final product (Donders et al., 2021). Various carriers are used in the production of honey powder such as maltodextrin (MD), gum arabic (GA), whey protein, and sodium caseinate. Though these carriers are beneficial for the processing of honey powder, drying carriers cannot be lower than 50% in honey powder. Further research needs to be performed to look into techniques that would make it possible to obtain a honey powder that is more pure as the carriers can take away from the final use and acceptance of the product (Samborska, 2019).

Sucrose

Sucrose is a natural disaccharide (β-d-fructofuranosyl α-d-glucopyranoside) that is produced from sugar beets or sugar cane (Queneau et al., 2007). Since sucrose is cheap, pure, and stable, it is produced and utilized in 123 countries around the world (Queneau et al., 2007; White, 2014). One of the common misconceptions of sucrose is that it is simple to produce. However, food and beverage manufacturers need highly purified sucrose for their final products. Since sucrose is derived from complex botanical sources containing innumerable and potentially overwhelming color, odor, and flavor compounds, the production of sucrose utilizes refining techniques to achieve a highly purified product (White, 2014). The sweetness perception of sucrose is bell shaped in that the sweet taste of sucrose is slow to develop and slow to leave. This attribute assists in leaving a pleasant sweetness in food and beverages and also aides in masking unpleasant flavors (White, 2014). Other than the characteristic sweet taste that sucrose presents in products, it also is used to assist in binding and controlling of water activity in products. For instance, sugar is used to control water activity in bakery icings to prevent stickiness after packaging (Marie et al., 2012). Another important attribute of sucrose is solubility; sucrose is one of the most soluble sugars. Solubility is beneficial as it helps in the preparation of flavored syrups, jams, jellies, and preserves and canned fruit (Tsang and Clake,1988). Lastly, sucrose can be used as a bulking agent, texturizer, used in fermentation, and can assist in the color of products via Maillard reaction (Tsang and Clarke, 1988)

Overview of Yogurt

What is Yogurt?

CFR (Code of Federal Regulations) 131.200 defines yogurt as "…the food produced by culturing one or more optional dairy ingredients with a characterizing bacterial culture that contains the lactic acid-producing bacteria, *Lactobacillus bulgaricus* and *Streptococcus thermophilus*. One or more other optional ingredients may be added, but must be added prior to culturing. Yogurt, before the additional of bulky flavors, contains not less than 3.25 percent milkfat and not less than 8.25% milk solids not fat, and a titratable acidity of no less than 0.9%, expressed as lactic acid. The food (base) may be homogenized and shall be pasteurized or ultra-pasteurized prior to the addition of the bacterial culture. Flavoring ingredients may be added after pasteurization or ultra-pasteurization. To extend shelf life of the food, yogurt may be heat treated after culturing is completed, to destroy viable microorganisms (CFR 131.200 Yogurt, 2023). Other than *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, other strains that are not required by the standard identity can be added to yogurt for health benefits. The extra strains that are selected are based on their rate of acid production, flavor profile, exopolysaccharide production to produce yogurts with specific textural properties, bacteriophage resistance, reduced post-fermentation acidification, and their mild flavor production. Extra strains that can be added to the yogurt are Lactobacillus acidophilus, Bifidobacteria infantis, and Bifidobacteria logum (Clark et al., 2009). Various fat reduced yogurts are also defined by CFR (CFR 131.203). Lowfat yogurt must meet the requirements mentioned previously and must contain no less than 0.5% milkfat and no more than 2% milkfat (CFR 131.200 Yogurt, 2023). Additionally, nonfat yogurt must meet all the requirements from CFR 131.200 and must contain no less than 0.5% milkfat (CFR 131.200 Yogurt, 2023). Styles of yogurt are addressed later in 'Types of Yogurt in the Market'.

Similar to the variety of strains that can be chosen for yogurt, there are a variety of processing steps involved in the manufacture of yogurt. The first step is the initial treatment of milk by alternating its composition by reducing the fat content and increasing the total solids. This process is normally performed by using a standardizing clarifier and/or a centrifuge. The end goal is to get a yogurt with a final fat content between 1% and 10%. The next step of modifying the milk is the standardization of fat and solids-non-fat content (SNF) until it reaches the ranges between 9% to 16% in the final product. This can be accomplished by a variety of ways such as evaporating the water off of the milk or adding concentrated milk, milk powder, whey protein concentrate, or casein powder to the milk (McHugh, 2015). The next step involves pasteurization and homogenization of the milk. Pasteurization of the milk normally entails heating the milk to 85 °C to 90.5 °C for 30-60 minutes (McHugh, 2015). Other than destroying microorganisms that may interfere with the fermentation of the yogurt, higher heat temperature pasteurization can also help in creating a desirable body and texture of the yogurt due to denaturation of whey (also called serum) proteins in the milk. During pasteurization, whey proteins are denatured due to the heat. This in return, increases the water absorption of the protein molecules of the yogurt increasing the firmness and stability of the yogurt (Marie et al., 2012). Additionally, pasteurization facilitates the release of nutrients in the milk and removes dissolved oxygen; both of which help the growth of the starter cultures (McHugh, 2015). Homogenization assists in preventing the separation of milk fat globules (MFG) from milk. This is accomplished by the utilization of pressure, which is normally between 10-20 MPa for dairy products. In terms of yogurt, homogenization also aids in the production of creamy texture. Fermenting the yogurt is the next step, which involves cooling the yogurt to around to 40-44 Cand inoculating it with thermophilic lactic-acid producing culture, also called a starter culture. Once the appropriate pH has been reached (refer to the pH section for more details), the yogurt is cooled and flavoring is added (or the fruit or fruit flavoring is added to the bottom of the package depending on the type of yogurt) (McHugh, 2015). For a flow diagram of the yogurt production process, refer to Figure 2.

Types of Yogurt in the Market

Yogurt was first commercially produced by Danone in 1922 in Madrid, Spain (Chandan et al., 2017). From there, it took off and today the yogurt market is comprised of different types and styles of yogurt. The most popular type of yogurt on the market is stirred yogurt also known as European-style yogurt. This yogurt is made in a large container and then dispensed into serving containers. By doing this, the ‘set’ of the yogurt is broken forming a less firm texture than set yogurt. Set or cup yogurt (also known as Balkan-style yogurt), conforming to its name, is where the yogurt forms in the serving container and is not disturbed. Fruit yogurt is also another popular type of yogurt on the market. Fruit yogurt is where fruit, fruit syrups, or pie filling is added to the yogurt. The fruit additions are added to either the top, bottom, or stirred into the yogurt (Yildiz, 2016). Yogurt beverages also take a share of the yogurt market. This form of yogurt is prepared with reduced milk solids to give the yogurt beverage a low viscosity and normally consists of 1.5%-1.9% milk nonfat solids and up to 8.0% sugar (Shah, 2017). Frozen yogurt is also another type of yogurt found throughout the market. In the United States, frozen yogurt is a blend of 90% ice milk mix and 10% plain yogurt (Yildiz, 2016). In addition to dairy yogurt, the vegan yogurt market share has been steadily growing and is comprised of yogurts that are made from plant sources such as soy, coconut, and oat.

The style of yogurt is also a factor that can divided yogurts within the yogurt market sector. Other than Balkan-style and European-style yogurt mentioned previously, Greek-style yogurt and French-style yogurt are also popular styles within the market. Greek-style yogurt is produced by straining or centrifuging whey from plain yogurt or from partially condensed milk to make this style of yogurt thicker and creamier(due to higher solids) than other yogurts on the market. French-style yogurt, also known as custard-style yogurt, is by direct culturing in a small glass pot and is characterized by a pudding like texture (Weerathilake et al., 2014). Other yogurt products that are notable on the market include whole milk yogurt, international-style yogurts, organic yogurt, and kefir drinks (Chandan et al., 2017).

Yogurt and Consumer Trends

In 2010, Harry Balzer, the Vice President of the market research firm NPD Group, named yogurt the food trend of the decade. “The appearance of significant numbers of advertisements, both print and visual, and an almost four-fold increase in plain and flavored yogurt production from 1989 to 2007 suggest that milk producers, dairy product manufacturers and marketers, and consumers are more aware of yogurt products than they did two decades ago.” (Davis et al., 2010). With this awareness, comes new trends within the yogurt market. Currently, protein and gut health are major drivers of yogurt and drinkable yogurt purchases. Thirty seven percent of consumers look for yogurt options that have 10g of protein or more per serving (Mintel Group Ltd, 2021.). U.S. Consumers are also cognizant of the amount of sugar within the product. Thirty eight percent of yogurt consumers look for options on the market that have 5g of sugar or less (Mintel Group Ltd., 2021). This trend is leading to yogurt brands with reduced/alternative sugar options. Snacking also continues to be the main reason of yogurt consumption among parents and children (Mintel Group Ltd., 2021). The type of yogurt consumption is primarily spoonable yogurt with 63% of consumers stating that they have purchased spoonable yogurt within the past 3 months (refer to Figure 3) (Mintel Group Ltd., 2021). Consumption of drinkable yogurt is also popular with 36% of consumers stating they have purchased yogurt drinks within the last 3 months (refer to Figure 3) (Mintel Group Ltd., 2021). Compared to dairy yogurt, dairy alternative yogurts are struggling against dairy yogurts and against themselves within the market most likely due to flavor issues (Mintel Group Ltd., 2021). However, it should be noted that nearly half of yogurt drink consumption is dairy alternatives, showing that dairy alternative yogurt has a place among the yogurt drink market sector (Mintel Group Ltd., 2021).

Alternative Sweeteners and Reduced Sugar in Yogurt

Multiple studies have evaluated alternative sweeteners and reduced sugar in yogurt. One major impact that alternative sugars have on yogurt are the side taste attributes that they present in the product. One study used alternative sugars to sweeten unflavored yogurt along with other matrices including black tea and chocolate milk. Sweeteners that were used were 10% sucrose (w/v), and the following sweeteners at equi-sweet intensity: acesulfame-k, aspartame, erythritol, *luo han guo* (Monk Fruit), alatinose (Isomaltulose), stevia (Reb A), sucralose, and sucrose-allulose mixture. Trained participants performed Rate-All-That-Apply (RATA) on all of the food matrices. The attributes found by RATA in each sample are shown in Table 2 (Tan et al., 2020). In the food matrices evaluated, aspartame, sucralose, palatinose, and the sucrose-allulose mixture produced similar flavor profiles to the sucrose. Out of all the food matrices that were tested, yogurt had the most differences among the sweeteners. These differences are most likely due to the strong sour taste of yogurt (Tan et al., 2020). Furthermore, alternative sweeteners that elicit bitter taste such as ace-K, stevia, and monk fruit reduced the perception of sweet taste in the yogurt matrix as well (Tan et al., 2020).

Another study investigated natural sweeteners in 2% fat skyr yogurt with mango pulp. Eight sweeteners: sucrose (8.8%), stevia, thaumatin, stevia and thaumatin (2 different blends), sucrose with fructooligosaccharide (FOS), stevia and FOS, thaumatin (Pereira et al., 2021). Magnitude estimation scaling (MES) was then used to find the iso-sweetness of the sweeteners using 8.8% sucrose (Pereira et al., 2021). Descriptive analysis was also performed on the samples: the stevia and thaumatin yogurts (with and without FOS) had the highest sweet taste and sweet aftertaste. The samples with stevia (with were the samples that possessed the highest bitter taste, bitter aftertaste, and metallic flavor (Pereira et al., 2021). A consumer acceptance test was also performed in two separate regions of Brazil with 120 consumers. Stevia (with and without FOS) was the least liked sample and sucrose (with and without FOS) was the most liked yogurt (Pereira et al., 2021).

Using temporal dominance of sensation (TDS), an additional study focused on alternative sweeteners in Greek style yogurt. Four sweeteners were selected for this study: 9g of sucrose 9g per 100g of yogurt, xylitol, stevia, and monk fruit. The sweetener concentrations were selected by finding the iso-sweetness of the sweeteners by using the Difference from Reference method with 9g/100g of sucrose as the reference (Chadha et al., 2022). Trained panelists performed TDS on the samples and additionally each panelist had to give their liking values of the dominant attribute (liking while dominant, LWD). For TDS results, sucrose had a higher dominance duration of sweet taste when compared to stevia and monk fruit, and sucrose had a longer dominance duration for creaminess followed by xylitol, stevia, and monk fruit. All alternative sweeteners, when compared to sucrose, exhibited a higher dominance duration than sucrose for sour. Sour was higher in all alternative sweeteners.

Of note, the yogurt sweetened with stevia was characterized by lingering dominant astringency . and monk fruit had the highest dominance duration in bitter and licorice (Chadha et al., 2022). For LWD, liking was decreased in xylitol for 94% of panelists when sweet was the dominant attribute. For the stevia sample, liking was decreased for 82% of panelists when sour was the dominant attribute. Fifty six percent of consumers also had a decrease of liking for the sucrose sample when mouthcoating was the dominant attribute. Lastly, when sweet was the dominant attribute in the monk fruit sample, there was an increase of liking for 66% of panelists (Chadha et al., 2022). Overall, panelists liked the sucrose sample more followed by the xylitol, stevia, and monk fruit samples. This result along with the previous studies mentioned (Tan et al., 2020; Pereira et al., 2021; Chadha et al., 2022) demonstrates that sucrose is still favorable to use in yogurt.

Other than the flavor of the yogurt that can be impacted by alternative sweeteners, temporality of sweet taste can also be impacted by alternative sweeteners. The study mentioned previously by Tan et al. (2020) also evaluated the effects of alternative sweeteners on the duration of sweet taste in yogurt. The duration of sweet taste was significantly longer in yogurt that was sweetened with sucrose than the yogurts sweetened with stevia and monk fruit (Tan et al., 2020). Tan et al. (2019) also focused on the temporality of sweet taste in multiple sweeteners. This study used Temporal Check All that Apply (TCATA) to compare the temporal profile of 16 alternative sweeteners to each other. Trained panelists performed TCATA on all 16 sweeteners (Tan et al., 2019). Sucrose had the highest onset of sweetness peak citation, while ace-k had the lowest peak sweetness citation. For sweetness decay, erythritol, monk fruit, and sucralose had a longer residual sweetness than sucrose. The sweeteners that had the fastest sweetness decay when compared to sucrose was mannitol, palatinose, sorbitol, and stevia. Overall, dextrose, fructose, maltitol, mannitol, palatinose, and a sucrose allulose mixture had the most similar profiles to sucrose (Tan et al., 2019). These finding are significant as when replacing sucrose with another sweetener in any product, not just the attributes but the temporality of sweet taste must be similar to sucrose to gain consumer acceptance.

Being aware of how alternative sugars effect the sensory properties of the product is important, but it is also important to understand the consumer perception of alternative sugars. Though not many studies have focused on the perceived healthiness of alternative sugars in yogurt, a study mentioned previously in this section by Chadha et al. (2022) examined perceived healthiness and satisfaction in sucrose, xylitol, and stevia sweetened yogurts with trained panelists. The yogurts sweetened with sucrose and xylitol scored the highest in terms of perceived healthiness and satisfaction. If panelists liked a particular yogurt they instinctively rated it higher for perceived healthiness (Chadha et al., 2022). These findings correlate to a similar study by Luckow and Delahunty (2004) on consumer acceptance of a regular and probiotic blackcurrant juice. Most consumers rated the juice that they preferred as healthier than the sample they least preferred (Luckow and Delahunty, 2004).

Alternative sweeteners can provide sweetness to products without the same caloric content as sucrose. Still, it is fundamental to address consumer acceptance of sucrose reduction as it can be an asset to lower sugar in a product, while maintaining the product's appealing characteristics (Chollet et al., 2013). Chollet et al. (2013) looked at sugar reduction in flavored 2% yogurt. This study consisted of two consumer acceptance tests. The first test consisted of flavored yogurt with different concentrations of added sucrose. The flavoring in the yogurt was strawberry at a concentration of 9% and coffee at a concentration of 0.52%. The concentrations of sucrose that was used was 5%, 7%, and 10% (Chollet et al., 2013). Consumers (n=192 and 197) evaluated the strawberry and coffee flavored yogurts. The results for both flavorings were similar with the highest concentration of sucrose being the most liked. For the second part of the test, the sucrose concentration remained the same at 7% but the concentration of flavorings changed. Consumers then indicated they liked the samples that contained the lowest flavoring concentrations (Chollet et al., 2013). Even though consumers suggest that they want reduced sugar products, the results indicate that consumers still prefer a higher intensity of sucrose in products. Furthermore, from this study, consumers preferred yogurt samples that had less flavoring which demonstrates that a high concentration of flavoring may not increase the overall sweet taste perception of the product (Chollet et al., 2013).

Another study also focused on consumer acceptance of strawberry flavored full fat yogurt with different sucrose concentrations. The sucrose concentrations of the yogurt samples (g of sucrose per g of yogurt) were 12/100 (the control), 10.25/100, 8.50/100, 6.75/100, and 5.00/100. The first test was a consumer rejection threshold (CRT) test, and the second test was an acceptance test. CRT is used to assess preference by using a series of concentration steps of stimulus which are added to the product. Consumers are then asked to indicate which of the two samples they prefer-the sample with stimulus or the sample without stimulus. The CRT results were fitted using a regression model and the data was then extrapolated. Based on the extrapolated data, strawberry-flavored yogurts could have a sugar reduction up to 56.3% (5.25/100g) (Torrico et al., 2020). The consumer acceptance test identified the 8.50/100 g of yogurt sample the most liked. The 12.00/100 g of yogurt sample, 10.25/100 g of yogurt sample, and the 6.75/100 g of yogurt sample were at parity with each other, and were the second most liked samples. The sample that was the least liked was the 5.00/100g of yogurt sample which is equivalent to a sucrose reduction of 58.33%. This confirms that any sucrose reduction below 56.3% will not meet consumer acceptance. (Torrico et al., 2020).

Vanilla

Vanilla Flavoring

Natural vanilla flavor can be obtained from 110 species of the plant from the genus *Vanilla*. *Vanilla*, belongs to the family of Orchidaceous, which are tropical orchids. Although there are 110 species of *Vanilla*, only two species, *Vanilla planifolia* and *Vanilla tahitensus*, are used in the production of vanilla extract. However, *Vanilla planifolia* is mainly preferred to use than *Vanilla tahitensus* due to its pod quality and yield. *Vanilla planifolia* is primarily grown in Indonesia and Madagascar with the United States, Germany, France, and the Netherlands being the main consumers of vanilla (Vijayalakshmi et al., 2019). Natural vanilla flavoring is derived from the cured pods of the *Vanilla* plant and the presence of the flavor and aroma of vanilla comes from vanillin (4-hydroxy-3-methoxybenzaldehyde). The sensory attributes of vanilla extract are dependent on the type of vanilla beans used. The most common vanilla beans used for vanilla extract are Bourbon-Madagascar, Mexican, and Tahitian. These three vanilla beans each have their own distinct sensory profiles (Vijayalakshmi et al., 2019). Natural vanilla extract is produced commercially primarily by percolation and oleoresin methods. The percolation method involves circulating a mixture of ethanol and water containing 35%-50% alcohol with whole vanilla bean pods for 48-72 hours. The end result from this method is four-fold strength vanilla. It should be noted that a single 'fold' of vanilla extract is defined by 13.35 oz of vanilla pods per gallon of solvent or 100 g of extractable material per liter. The other method, the oleoresin process, is performed by crushing whole vanilla pods and then circulating ethanol over the crushed pods under vacuum conditions at 45°C. The excess is then removed via evaporation. The process in its entirety takes about 8-9 days and results in 10-fold strength vanilla (Sinha et al., 2008).

Natural vanilla extract is costly due to *Vanilla* being difficult to cultivate. *Vanilla* must be pollinated by hand, which for example, to obtain one kg of cured beans about 600 hands are needed to pollinate the plants. Consequently, to meet the growing demand for vanilla extract, synthetic vanilla extract was created. Synthetic vanillin is made from petrochemical by-products from the paper industry. There are two types of synthetic vanillin that are used in industry- lignin based and guaiacol based. Guaiacol based vanillin is more cost effective than lignin based vanillin; however, lignin based vanillin has a richer flavor (Vijayalakshmi et al., 2019). The uses of both synthetic and natural vanilla are numerous in food industry flavor applications. Vanillin has also been reported to have antioxidant properties in complex foods containing polyunsaturated components and it has also been observed that vanilla has antimicrobial properties (Ramachandra Rao and Ravishankar, 2000).

The Role of Vanilla on Sweet Taste

The sensory profile of vanilla is known to influence sweet taste perception in foods. The influence of sweet taste by the usage of vanilla is achieved mainly by cross-modal aroma-taste interactions. That is perceived intensity of sweet taste can be influenced by aroma. In terms of sweetness perception, the addition of aromas related to sweet products such as vanilla, caramel, or fruity notes increase the perception of sweet taste intensity through previous associations with the complex stimuli (Alcaire et al., 2017). This idea of previous associations influencing taste is called "learned synaesthesia." Learned synaesthesia is when qualities in one sensory system (in this case olfaction) are able to evoke qualities in another sensory system (in this case taste) due to a result of their prior co-occurrence (Prescott, 2012).

Multiple studies have demonstrated that vanilla can increase the sweetness of foods. One such study focused on sugar reduction in yogurt and investigated how natural flavors like vanilla influenced the sweetness perception of the product (Oliveira et al., 2021). This study consisted of Time Intensity (TI) for sweetness with a trained panel and Temporal Dominance of Sensation (TDS) with a trained panel, and a consumer acceptance test to determine the effects of sugar reduction and flavoring in yogurt. Yogurts with 25% sucrose reduction and 0.1% vanilla flavoring were statistically equal for sweet taste intensity to the control with no flavoring. Additionally, the yogurt with 25% sucrose reduction and 0.2% vanilla flavoring was also statistically equivalent to the control for sweet taste (Oliveira et al., 2021). Consumers evaluated the control and the 25% sucrose reduced samples with the respective flavoring concentrations of 0%, 0.1%, and 0.2%. There were no differences in acceptance among the samples, which also demonstrated how vanilla can help with sugar reduction in products (Oliveira et al., 2021).

A similar study that addressed the use of vanilla aroma on sweet intensity perception was performed by Bertelsen et al. (2021). This study was conducted with consumers and alternative sweetener/sucrose blends: sucrose, sucrose + tagatose, and tagatose + rebaudioside A that were blended into water. The iso-sweet levels were found for each sweetener to 2.5% w/w sucrose were used. This study was conducted in two different countries: Denmark and China. Danish consumers ranked both sweet aroma and sweet taste intensity higher than Chinese consumers in samples with added vanilla showing that eating habits between cultures along with different associative learnings have an influence on how the cross-modal effects of vanilla impact products (Bertelsen et al., 2021).

Other studies also demonstrated that vanilla flavoring can increase the perception of sweet intensity in products (Hoppert et al., 2013; Oliveira et al., 2015; and Wang et al., 2018). Hoppert et al. 2013 used vanilla flavoring in 30% sucrose reduced sucrose dietary fiber enriched plain yogurts and compared the results to non-reduced sucrose vanilla flavored dietary fiber enriched yogurts via a consumer acceptance test (Hoppert et al., 2013). JAR scores indicated that elevating flavor (such as vanilla) of reduced sugar products may increase acceptance. Consumers indicated the non-reduced sucrose yogurt samples to be too sweet, while the yogurt samples with the lower sucrose concentration to be just about right (Hoppert et al., 2021). Oliveira et al. (2015) examined if added artificial vanilla increased sweetness perception in probiotic whole chocolate milk with various sugar reductions of 0%, 20%, 40%, and 60%. Each chocolate milk was formulated either with or without vanilla extract at concentrations of 0.050% and 0.025%. A trained panel performed TCATA on each sample and found that artificial vanilla at 0.050% increased the perception of the attribute sweet for chocolate milk with 40% reduced sugar, and artificial vanilla at either 0.025% or 0.050% increased sweet taste perception for the 60%

reduced sugar chocolate milk sample (Oliveira et al., 2015). Interestingly, this study also had consumers (n=100) perform TCATA on the chocolate milk samples and observed that artificial vanilla flavor did not lead to significant differences of sweetness (Oliveira et al., 2015). Lastly, Wang et al. 2018 studied 2-fold (2x) vanilla flavoring at concentrations between 0.0% to 0.75% (w/w) in skim milk with multiple sucrose reductions between 0% (control, plain skim milk) to 5% (w/w). Consumers (n=108) then did an acceptance test on the samples along with rating perceived intensities of the samples for sweetness, vanilla flavor, milk flavor and thickness on an unstructured line scale (0 to 100) with the anchors of 'very weak to 'very strong.' Vanilla aroma enhanced perceived sweetness of the samples (Wang et al., 2018).

Vanilla in Yogurt

Spoonable vanilla yogurt is the second leading flavor, with strawberry being the first, in global new product launches (Glanbia, 2021). The point in the process where vanilla extract is added to the yogurt is dependent on what type of yogurt it is. For blended yogurt, typically vanilla extract is added to the yogurt after fermentation, while for cup set yogurt, vanilla extract is added prior to fermentation. Some manufacturers will choose to use powdered vanilla in their yogurt to prevent dilution caused by the alcohol in the vanilla extract (Chandan et al., 2008). Vanilla in processed syrup (vanilla extract in liquid sugar syrup) is also another way that manufacturers flavor their yogurts. Other than using just artificial vanilla to flavor yogurt to save money, manufacturers will also prefer to use a mix of synthetic vanillin and pure vanilla extract. Generally, vanilla extracts that are from 1-fold (1x) to 3-fold (3x) are used to flavor yogurts. The end result that is targeted in vanilla flavored yogurt is a yogurt that has a sugar content of 8%-9%. The target of this sugar level assists in balancing the sweetness and acidity in yogurt, while also delivering a well-rounded vanilla flavor to the consumer (Chandan, 2017)

The Consumer

Factors That Affect Consumer Behavior Highlighting Dairy Products

The consumer is complex and can be influenced by a variety of factors. Due to this issue, it is important to understand what those factors are and how they shape the consumer to effectively get an accurate picture of the market. These factors can be broken down into the following four components: cultural, social, personal, and psychological factors (Jisana, 2014). From there, these factors can then be broken down into multiple sub-factors which are presented in Figure 4. The factors can then be equated into the conceptual model for consumer purchase and decision processing and consumer behavior (Figure 5). Focusing on social factors as an example, a recent study by Ortez et al. (2021) determined that households that have children have different purchase behaviors for dairy products than households without children. Households with children purchased larger quantities of fluid milk and yogurt along with fluid milk that had a higher fat content. Consumer behavior models can also assist in providing insight to how to effectively attract, engage, and retain consumers. These models are either defined as traditional or contemporary consumer behavior models. Traditional models were created to help economists understand what consumers purchase based on their wants and needs. In comparison, contemporary models focus on the rational and deliberate decision-making processes than focusing on consumer emotions or unconscious desires (Needle, 2021).

With any new dairy products or products in general, consumer acceptance is the final criterion. High failure rates for new products on the market demonstrate that consumers consider a variety of factors when accepting or rejecting new products (Grunert et al., 2000) – it is far more than overall liking of the product. In relation to dairy products, from a consumer perspective, quality of dairy products involves much more than the sensory properties of the product. Quality can be classified into dimensions for dairy products (and food in general) as hedonic, health-related, convenience-related, and process-related dimensions (Grunert et al., 2000; A. Kumar, 2014). These four dimensions are defined as the following:

- Hedonic Quality: relates to the sensory pleasure and is therefore mainly linked to flavor, smell, and appearance (Grunert et al., 2000)
- Health-Related Quality: relates to how consumption of the product will affect consumer physical health (Grunert et al., 2000)
- Convenience-Related Quality: relates to time and effort which has to be expended while buying, storing, preparing, and consuming the product (Grunert et al., 2000)
- Process-Related Quality: relates to the characteristics of the production process which consumers have taken an interest in such as organic production, production involving genetic modification, and animal welfare (Grunert et al., 2000)

Out of these four dimensions, the hedonic and health-related dimensions of quality are relatively stable within the market. However, the importance of convenience-related quality and process-related quality has been rising among consumers. The dairy industry has met these rises in quality dimensions by launching functional foods which combine both health and convenience. Organic dairy products can also position in the market by highlighting production processes. Another observation that should be taken into account is that the composition of these four dimensions cannot be determined by consumers until after purchasing the product (Grunert et al., 2000). Therefore, meeting or exceeding consumer expectations is crucial along with communicating the foundation of the product. For instance, since consumers do not have the opportunity to *experience* the degree of healthiness before tasting or the production of the dairy product, marketing dairy products requires quality dimensions such as health and processing to be communicated in a way in which consumers will find credible (Grunert et al., 2000).

Bytyqi et al. (2020) investigated factors that influence consumer behavior for milk and dairy products. This study took place in Kosovo, so this should be considered when interpreting the results. 669 milk and dairy consumers were interviewed. The results indicated that 60.7% of consumers find product quality important and 47.2% of consumers find product safety and price important for milk and dairy products (Bytyqi et al., 2020). Consumers also indicated that factors such as brand, packaging, origin, and product content were not important factors when purchasing and consuming milk and dairy products (Bytyqi et al., 2020). Another study by Pinto et al. (2016) took place in Brazil. Again, the location of this study needs to be accounted for when interpreting the results. This study also conducted interviews on dairy consumers (n=300) to determine consumer behavior in relation to dairy products. Important factors were added together and then the average was taken to find the sum of orders (M) (Pinto et al., 2016). The structure of this scale was based on 1 to 7 where 1 was most important and 7 was least important. Consumers indicated that quality was the most important factor when purchasing dairy products (M=2.2), followed by shelf life (M=3.0), price (M=3.5), brand (M=4.1), and origin (M=5.4). Packaging (M=5.4) and serving size (M=5.3) were the least important factors to consumers when purchasing dairy products (Pinto et al., 2016). Both Bytyqi et al. (2020) and Pinto et al. (2016) demonstrated that quality is very significant to consumers when purchasing dairy products.

Consumer Perception of Sucrose, Honey, Stevia, and Allulose

The perception of sucrose and alternative sugars have been drastically changing throughout the last two decades. The usage rate of low-calorie sweeteners has increased within the last decade (Sylvetsky and Rother, 2016). However, even with a shift of utilizing alternative sweeteners, consumers still desire ‘their ideal sweetener’ to be as sweet as sucrose, colorless, odorless, and noncariogenic. The more a sweetener tastes and functions like sucrose, the greater the consumer acceptability of the product will be (O’Brien-Nabors, 2001). With this in mind, the focus of understanding consumer perception (conceptual and actual) and acceptability of sweeteners in this review will emphasize sucrose, honey, allulose, and stevia.

The attitudes of sucrose have shifted in response to consumer health and wellness goals. Fifty three percent of consumers indicated that they are eating less sugar as a preferred method of weight loss demonstrating that "…consumers are choosing to avoid sugar with the desire to increase general wellness and for a feeling of healthiness" (Shoup, 2021). A survey from Mintel also had similar results (Figure 6) (Mintel, 2020). Though there has been a shift of consumer perception of sucrose, studies have shown that consumers still have higher or parity acceptance rates for sucrose when compared to other alternative sweeteners (Li et al., 2015a; Medeiros et al., 2022; Sipple et al., 2022). Li et al. (2015a) conducted a consumer acceptance test with children and their parents with skim chocolate milk sweetened with sucrose, stevia, monk fruit. Parents were primed or unprimed of the type of sweetener in the sample. From priming, two clusters of parents were identified. When primed, cluster 1 parents favored samples sweetened with stevia over sucrose, while cluster 2 primed parents favored samples sweetened with sucrose (Li et al., 2015a). Medeiros et al. (2022) performed a consumer acceptance test with peach juice sweetened with sucrose, sucralose, neotame, stevia, and a blend of acesulfame, sucralose, and neotame. Consumers had a higher overall liking score for peach juice sweetened with sucrose and the sucrose blend followed by sucralose (which was in parity with sucrose and neotame) and neotame. Sipple et al. (2022) also observed consumer acceptance of sucrose in ice cream for primed and unprimed consumers. Primed and unprimed consumers (n=186) tasted commercial vanilla ice creams sweetened with sucrose, acesulfame K and sucralose (NSA), stevia and erythritol (STE), and monk fruit and allulose (MFR). Sucrose and NSA were at parity for overall liking for both primed and unprimed consumers (Sipple et al., 2022).

Sucrose has been at the forefront over honey in terms of consumer usage rates, however; with the growing usage rate of honey as a sweetener, the gap between the usage rate of sucrose and honey is starting to close (Figure 7). As a sweetener, honey is leveraged as a natural sweetener with ‘better for you’ (BFY) attributes (Mintel, 2020). Sweeteners such as honey, are in a unique position as they have the opportunity to drive consumers into purchasing it by marketing honey as both nutritionally healthy and an indulgent sweetener (Mintel, 2020). Although the consumer perception of honey is favorable, studies suggest that consumers still favor sucrose over honey as a sweetener. For instance, Popa and Ustunol (2011) sweetened strawberry yogurt with sucrose, high fructose corn syrup (HFCS), sage honey, alfalfa honey, and sourwood honey. This study did not go into detail on how sweetener concentrations were chosen, and as a result this could be a drawback of this study. The main part of this study involved a consumer acceptance test with 99 participants. Consumers had a greater overall acceptance for strawberry yogurt samples sweetened with sucrose followed by HFCS (sweetener were at parity) (Popa and Ustunol, 2011). The honey that was the most preferred was the sage honey. Mohan et al. (2020) also focused on consumer acceptance of yogurt sweetened with Manuka honey (5% w/v), invert sugar (5% w/v), or unsweetened. Consumers preferred the yogurt sample sweetened with invert sugar over any of the honey samples (Mohan et al., 2020). Another study focused on jelly candies made from pomegranate juice and sweetened with either 25% (w/w) sucrose or 25% honey (w/w) (Cano-Lamadrid et al., 2020). A consumer test (n=100) consisted of blind (n=50) and unblind participants (n=50). Unblind participants were told what the formulation components of the samples were such as the sweetener used, flavoring used, etc. Both blind and unblind consumers scored the sucrose sweetened samples higher than the honey samples (Cano-Lamadrid et al., 2020).

Allulose is a relatively new alternative sweetener within the market, therefore; understanding consumer perception of allulose is important. A survey conducted in April 2021, surveyed participants to gauge their familiarity of sweeteners. Of the 992 participants, only 15% said that they were familiar with allulose (Food Insight, 2021). Another survey that was performed in 2021, measured the acceptability and openness of consumers trying allulose before and after given the definition of the sweetener. The definition that consumers were given for the survey described allulose as a rare sugar that tastes and functions like sugar and contains nearly no calories or grams of sugar and it is a FDA-approved ingredient (Danley, 2021). Of the 1,400 participants, pre-definition, only 7% of consumers said allulose was an acceptable ingredient. However, after given the definition 95% of consumers said it was an acceptable ingredient. The key takeaway from this survey was that consumers were interested in that allulose ‘contains low/no sugar’ and is a ‘good alternative to sugar’ (Danley, 2021). However, these findings are only based on conceptual conclusions. Other studies performed consumer acceptance tests to assess consumer acceptance of allulose. Mora et al. (2022) conducted a consumer acceptance test on vanilla flavored yogurt sweetened with sucrose, allulose, stevia, or sucralose. Yogurt was unsweetened non-fat Greek yogurt from Wegmans Food Market and was flavored with 1.3% vanilla extract (wt/wt) and sweetened with 6% sucrose (wt/wt), 11% allulose (wt/wt), 0.01% stevia (wt/wt), and 0.02% sucralose (wt/wt). Sweetness equivalency was obtained for vanilla flavored yogurt for allulose, stevia, and sucralose by benchtop testing based on literature values and using 6% sucrose as the reference value. (Mora et al, 2022). However, it should be noted that sweet taste equivalency was never confirmed, which is a significant shortcoming of this study. One hundred consumers completed the study, there was no significant difference between sucrose, allulose, and sucralose for overall liking. Stevia was the least accepted sample (Mora et al., 2022). Consumers were also asked a purchase intent question for each of the samples. Additionally, at the end of the study, participants were unblinded to the type of sweeteners used in the yogurt samples. Once unblinded, consumers were asked a follow up purchase intent question for each of the samples. The purchase intent scores for allulose and stevia samples increased, while the purchase intent for the sucrose and sucralose samples decreased (Mora et al., 2022). Another study examined consumer acceptance of different allulose blends in pound cake (Lee et al., 2020). The control pound cake samples were sweetened with 150g of sucrose and the blend samples were 75%:25% sucrose: allulose, 50%:50% sucrose: allulose, 25%:75% sucrose: allulose, and 100% allulose. Fifty-six consumers went through the consumer acceptance test, which is a limitation of this study. The control pound cake had the highest acceptability among consumers. The sample that contained 100% allulose was the least accepted among the samples. For any baked product, texture is an important attribute; there was not significant difference of texture liking among the samples (Lee et al.,2020). These results imply that allulose can be used as a blend to assist in sugar reduction in baked products. Due to how relatively new this sweetener is, not many studies have been performed on the consumer acceptance of allulose in different matrices. However, these results highlight that allulose can be an acceptable alternative sweetener to utilize in products.

As mentioned previously, stevia was originally banned in in 1991 in the United States due to carcinogenic concerns, however; these concerns were refuted and in 2008, the FDA implemented stevia with GRAS status (Muth, 2001). Despite its ambiguous start within the United States, stevia has taken off globally. Just in 2017, there have been 4,300 new product launches globally that contain stevia. Consumers perceive stevia to be healthful and it has a positive perception when put on a product label (Cargill, 2018). However, even though consumers perceive stevia has healthy, sensory palatability and acceptance of products with stevia remain a challenge. A study evaluated sucrose, xylitol, erythritol, stevia A (90%

rebaudioside), stevia B (20% rebaudioside), and sucralose in yogurt (Costa et al., 2019). Participants evaluated yogurt samples on the 1st day of storage and on the 28th day of storage. In terms of favorable sweeteners, sucralose and xylitol had similar overall impression scores to sucrose for both days. Yogurts with stevia had a lower acceptance score when compared to the sucrose sample for day 1 (Costa et al., 2019). This study attributed these results due to the bitter taste of stevia. Rocha and Bolini (2015) also examined stevia and other sweeteners in passion fruit juice. Sweeteners that were evaluated in passion fruit juice were sucrose, aspartame, sucralose, stevia, saccharin, and neotame. Consumers (n=124) assessed all six passion fruit samples. The sucrose, aspartame, and sucralose scored the highest and were all at parity for overall impression and flavor. The stevia samples had the lowest acceptance for aroma, flavor, texture, and overall impression (Rocha and Bolini, 2015).

Sensory Methods

Overview of Sensory Science

Sensory science has been defined as a scientific method used to evoke, measure, analyze, and interpret responses to products as perceived through the sense of light, smell, touch, taste, and hearing (Lawless and Heymann, 2010). By interpreting these responses, product developers, food scientists, and management can become knowledgeable of their products in relation to consumers (Lawless and Heymann, 2010). Depending on the objective of the study, there are multiple sensory methods that can be performed to obtain specific results from consumers. One sensory method that is used is a survey/ online survey. Survey research tools allow companies to quantitatively assess what consumers will buy without tasting products (Orme, 2014). Though survey results lead to beneficial conceptual data, it is also significant to understand how consumers *actually* perceive the product. This can be accomplished by the use of acceptance tests (consumer testing). Acceptance tests are used to gauge consumer appeal of products with actual tasting of products followed by the use of scaling methods (Lawless and Heymann, 2010). Additionally, descriptive analysis is an important analytical sensory tool that uses a small panel of trained individuals to explain which attributes comprise a product along with the intensity of those attributes.

Likert Scales and Maximum Difference Scaling

Online surveys allow researchers to obtain both quantitative and qualitative data from a large number of consumers across many geographic areas (Speight et al., 2019; Schiano et al., 2020). Likert scales are used in a variety of different attitude measurements and can encompass psychology, sociology, health care, marketing, and quality control (Göb et al., 2007; Lawless and Heymann, 2010). When given a questionnaire with a likert scale, respondents are given value judgements/ statements. An example of a value statement could be "I buy food products that are healthy for me." These value judgements help define respondent attitudes towards feelings, wants, desires, and cognitive dispositions, etc. (Göb et al., 2007). The value judgements are then defined using either five-grade or seven-grade likert scales that are tied into value statements (Göb et al., 2007). Most commonly these values statements are:

1. Strongly disagree
2. Disagree
3. Neutral (undecided)
4. Agree
5. Strongly Disagree

In terms of consumer perception of products, these scales can be used even further to grasp broader issues such as product usage and perception of product label information (Lawless and Heymann, 2010).

Another form of scaling is best-worst scaling also know as maximum difference scaling (MaxDiff). This scaling method was developed by Louviere and Woodworth in 1990 based on Thurstone's method of paired comparisons that was developed in 1927. (Finn and Louviere, 1992). This scaling method allows respondents to choose two objects in sets that consists of three or more objects. Respondents choose these two objects based on how they feel what the largest perceptual difference (Finn and Louviere, 1992). Finn and Louviere (1992) used best-worst scaling to conduct a survey to determine consumer concerns about food safety. Participants completed two different sets of best-worst scaling. The first MaxDiff exercise involved participants concern about food safety and public issues and the second MaxDiff exercise involved participants concern about food safety issues that were based on a review about food safety literature and interest in the government department. (Finn and Louviere, 1992).

Other studies have used MaxDiff scaling for a variety of products including foods. Schiano et al. (2020) used MaxDiff scaling to have consumers measure which dairy product attributes affect perception of sustainability. Another study used two separate MaxDiffs in a survey about pork bacon (McLean et al., 2017). Respondents looked at photos of bacon in their packages to determine what visual attributes matter to consumers (McLean et al., 2017).   To negate scale use bias, MaxDiff does not use a scale. Instead MaxDiff begins with a list of 8 or more attributes. From the list of attributes, respondents are shown a few at a time and are asked which attribute is most important to them and which attribute is least important to them. MaxDiff is carefully designed to show each item an approximately equal number of times and that each item appears approximately an equal number of times with every other item. The results obtained from MaxDiff can then be analyzed to identify most and least appealing attributes or statements (Orme, 2014).

Consumer Acceptance Testing

In consumer acceptance testing or generally in any sensory testing, the main concern is to acquire quality data as economically as possible. The data gathered is dependent on the purpose of the measurement, the type and number of samples, and practical constraints such as time available for designing, executing, and reporting the study (Piggott, 1995). The data gathered from a consumer acceptance test is gathered by having untrained panelists try products and fill out a questionnaire about the products. Essentially the questionnaire measures the subjective responses of consumer preference, acceptance, liking, or perception of a product’s benefits (Marques et al., 2022). In order to capture consumer responses, the questionnaire utilizes multiple scaling techniques. One such scaling technique is hedonic scaling, which has been the most commonly used scale for testing consumer preference and acceptability of foods (Lim, 2011). This 9-point scale, also known as the degree of liking (DOL) scale, uses the following descriptors:

1. Dislike Extremely
2. Dislike Very Much
3. Dislike Moderately
4. Dislike Slightly
5. Neither Like nor Dislike
6. Like Slightly
7. Like Moderately
8. Like Very Much

9. Like Extremely

With the use of these descriptors the scale is a balanced bipolar scale around a neutral center and four negative categories and four positive categories on each side (Lim, 2011). A mean score of 7 or higher usually is indicative of a highly acceptable product and can be used to set a good illustration of ‘target quality.’ This provides physical references to be based off of in terms of understanding what products realistically represents consumer acceptance limits (Lim, 2011). Once data is collected, the data is evaluated by analysis of variance (ANOVA) with means separation (Wichchukit and O’Mahony, 2015).

Bimodal JAR (Just About Right) scales are also used commonly within acceptance testing. The purpose of these scales is to highlight what sensory attributes interfere with product acceptance (Marques et al., 2022). The “JAR” point of the scale falls in the midpoint of the scale. The ends of each endpoint of the scale are represented by “extremes” of the attribute in question such as “not nearly salty enough on the far left to “much too salty” on the right as shown below (Marques et al., 2022).

1. Not Nearly Salty Enough
2. No Salty Enough
3. Just About Right
4. Too Salty
5. Much Too Salty

The information obtained from this scale helps optimize product key features. The JAR scale coupled with the hedonic scaling can provide directional information for product re-formulation. Additionally, by using the overall acceptance ratings from the hedonic scaling, the JAR scale can pinpoint if anything is lacking in the product and if there is something lacking is it affecting the overall acceptance of the product (Lawless and Heymann, 2010). This concept is called penalty analysis or “mean drop.” A larger mean drop is suggestive that the product needs to be modified. Though hedonic scaling and JAR scales are most commonly used in acceptance tests, other methods can be used such as paired preference testing of samples or ranking samples in order of liking (Lawless and Heymann, 2010). When performing a consumer acceptance test, it is also important to consider the number of consumers needed. Typically, 75-100 panelists is often considered a sound number of panelists for sensory testing (Drake, 2007).

Descriptive Analysis

The purpose of descriptive analysis (DA) is to determine what attributes are present and the intensity of those attributes. DA is performed by a trained panel that is normally comprised of 8-12 panelists. There are two fundamental approaches to DA panel training: quantitative descriptive analysis (QDA) or Spectrum descriptive analysis. QDA is product specific descriptive analysis that uses an unstructured line scale. This type of descriptive analysis does not heavily rely on the panel lead, which can be beneficial if the panel lead is not adequately trained. However, since QDA only uses a product specific scale, products cannot be compared to each other; the sweetness of a candy bar is different than the sweetness of cheese when using this scale. Though this is a limiting factor of QDA, it can also be advantageous. Every time the panel needs to evaluate a new product, they must take the time to be trained to that specific product. Contrastingly, the Spectrum method is not product specific and uses both universal and product specific scales that rely heavily on the panel lead for direction (Lawless and Heymann, 2010). For example, a salty 5 is the same for cheese, chips, or a protein drink. The advantage of this approach is that it allows multiple different products to be compared against each other. Unlike QDA, the Spectrum method requires a lot more training so the panel can function as a single unit so the results can be consistent throughout the panel (Lawless and Heymann, 2010).

Analytical Methods

Magnitude Estimation Scaling

Magnitude Estimation Scaling (MES) was developed by S. S Stevens at Harvard University in the 1950's. The premise of using MES is to assess the psychological sensation of a physical stimulus (McGee, 2003). This means that participants can assign numerical values to sensory stimuli so that ratios of the numerical assignments reflect the ratios of the sensory perceptions (Moskowitz, 1977). MES is a highly documented method that is extremely efficient and has had success in many different environments such as trial evidence (physical stimulus) with guilt (per perception), life events with emotional stress, and psychotic symptoms with severity of mental disorder (McGee, 2003). In terms of analytical sensory science, the food industry is interested in techniques for quantitative sensory analysis that relate sensory properties of a food product and consumer preference by using a precise objective measurement (Chen et al., 2021). MES is most often used to establish the iso-sweet points (sweetness equivalency) of sweeteners within the realm of food science research.

Obtaining sweetness equivalency is significant when comparing multiple sweeteners to each other. Sweetness equivalency is the same amount of sweetener substitute (either nutritive or non-nutritive) that produces the same sweetness intensity as the sucrose target amount (Parker et al., 2018; Keefer et al., 2020). Sweetness equivalency can be used to compare different sweeteners at the same sweetness intensity so that other attributes (besides sweet taste) can be assessed. Multiple studies have performed MES to investigate attribute changes and consumer liking in different products sweetened with various sweeteners. Keefer et al. (2020) used MES to compare different sweeteners protein bars. The sweeteners used in this study were sucrose, sucralose, monk fruit, stevia, and fructose. Significantly, protein type influenced the amount of sweetener needed to reach iso-sweet concentration. Pea protein and whey protein isolate needed more sweetener to reach sweetness equivalency than milk protein (Keefer et al., 2020). Another study performed MES on sucrose in water, sucrose in skim milk, and sucrose in skim chocolate milk (Li et al., 2015). The power function (which is the log of the concentration as a function of the log of the geometric mean in regard to MES) of sucrose was lower in milk than in water. This was attributed to milk being a more complex matrix than water (Li et al., 2015). Using 100m*M* of sucrose in water as a reference along with using a well- accepted commercial fat-free chocolate milk, 205 m*M* sweetness level (17 g of added sucrose per 240 mL) skim chocolate milk was determined as the benchmark/ iso-sweetness (Li et al., 2015). An acceptance test with the benchmark chocolate milk and sucrose reductions in chocolate milk was then conducted. Young adult consumers rated the benchmark and a 30.6% sucrose reduction in chocolate skim milk as just about right (JAR) (Li et al., 2015). MES was also used to find the iso-sweetness of sucrose MNEI (a variant of the sweet protein monellin), xylitol, and sorbitol in set and stirred whole yogurts by using (Miele et al., 2019). Iso-sweetness of both sorbitol and xylitol were the same for both set and stirred yogurt. This study was unable to find the iso-sweetness of MNEI in set yogurt, so the iso-sweetness of MNEI in set and stirred yogurts cannot be compared (Miele et al., 2019).

With the value that MES can bring to sensory science it is important to understand the foundation of MES. The foundation of MES is built upon Steven's Power Law. This law applies the following the equation: $S = kI^a$ (refer to Figure 8). The Steven's Power Law equation relates the sensation magnitude to stimulus intensity so when plotted on log-log axes the power law plots a straight line with a slope of the exponent (Stevens' Power Law). In order to plot a straight line, geometric averaging is used since participants can construct scales of vastly different magnitudes. Therefore, the MES data needs to undergo normalization prior to parametric analysis. The pertinent property of using log scores is that ratio information is preserved despite any addition or subtraction of a constant (e.g., the offset). The averaging procedure utilizes this property to construct a common scale conserving all participant ratio information. The antilog step then reinstates the 'average' units of the original raw estimates, while preserving all original ratio information" (McGee, 2003).

Though Steven's Power Law has been seen as landmark of achievement within the history of sensory science, it still has its limitations. Sensory perception is composed of complicated internal psychophysical mechanisms and due to this, cautions must be made. The natural link between a sensory attribute and its corresponding physical stimulus are still different in nature and therefore, are complicated to duplicate. Additionally, the equation itself of Steven's Power Law has two major drawbacks. First the validity of Steven's Power Law comes into question due to the outcome that different results could be obtained if the physical stimulus is expressed as a different unit. Secondly, the law can only be applied to a single physical stimulus and is obsolete if multiple stimuli are present (Chen et al., 2021). However, as long as researchers are aware of these shortcomings, Steven's Power Law still offers valuable insight on how to quantify physical stimuluses.

pH Measurement with a pH Meter

pH is a very important aspect in food manufacturing as it affects the preservation of foods, assists in processing roles such as fermentation, denaturizing, gelification, enzymatic activities, and also plays a part in the sensory aspects of the overall product (Andrés-Bello et al., 2013; Food-Tech®, 2021). pH is the defined as the measure of free acidity or the negative log of hydrogen ion concentration. The pH scale ranges from 0 to 14 with the pH of 7 being neutral, values lower than 7 acidic, and values greater than 7 basic (alkaline). The pH value corresponds to the amount of free hydrogen ions present; the more free hydrogen ions that are present, the lower the pH will be. For food products, this influences how sour the food product will taste. Acids in foods release free hydrogen ions, which contributes to the overall sourness of the product (Clemson University Cooperative Extension, 2021). In addition to influencing sour taste, pH can affect multiple sensory attributes such as color and texture. Lower pH also influences the texture of food products by causing variations within the proteins, which ultimately changes the texture of foods such as meat, fish, and dairy (Food-Tech®, 2021).

Since pH can impact many factors in terms of food processes and sensory characteristics, pH is very important to control. As a result, accurately measuring the pH is essential during the stages of food processing. However, though it is important to obtain an accurate pH measurement, reporting accurate pH data has been a long-standing issue due to the effects of temperature and pressure (Andrés-Bello et al., 2013). An increase in temperature of any solution can cause multiple outcomes in relation to the pH of the solution. Increasing temperature can cause a decrease in viscosity which can lead to an increase in the mobility of hydrogen ion concentrations. Hydrogen ions can also become increased in number in correlation with increased temperature due to the dissociation of molecules, which especially is significant in weak acids and bases (Andrés-Bello et al., 2013). These occurrences can all lead to inaccurate pH readings.

The most common method to measure pH is a pH-sensitive glass electrode and a reference electrode (Andrés-Bello et al., 2013). Glass pH probes are known as ion selective electrodes (ISE), which means the ISE is used to react with hydrogen ions in the solution

(Cushman, 2019). The pH- sensitive glass electrode and the reference electrode are usually combined into the sensing half-cell and the reference half-cell. The sensing half-cell takes the measurement of the system, which typically contains a membrane that is sensitive to changes in pH. The reference half-cell then provides a stable reference potential that is needed in order to obtain a pH measurement (Cole-Parmer Antylia Scientific Instrument Company, 2023) . This is important because pH measurement (with a glass electrode) relies on the measurement of voltage (Cushman, 2019). The reference electrode maintains a constant electrical potential, while the ISE attains an electrical potential that is dependent on the hydrogen ions. The difference in voltage is measured (mv) on the pH meter between the two electrodes, and through the use of the Nernst equation the pH meter can calculate the pH value. Other factors that contribute to attaining the pH is the electrolyte and the junction. The electrolyte provides a connection to the sample via the junction and closes the electrical circuit in the electrode. The junction assists in creating electrical contact between the reference half-cell and the sample. It also helps in maintaining the outflow of the electrolyte (Cushman, 2019).

Objectives

Consumers are actively looking to reduce their sugar intake to meet their health and wellness goals. One such product that consumers are looking at for reduced sugar options is yogurt. As a result, it is important to understand how utilizing alternative sweeteners in yogurt for sugar reduction, can impact consumer acceptance. The objective of this study was to determine consumer perception of sweeteners in yogurt by using both quantitative and qualitative sensory methods on vanilla yogurt sweetened with sucrose, honey, stevia, and allulose.

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Table and Figures

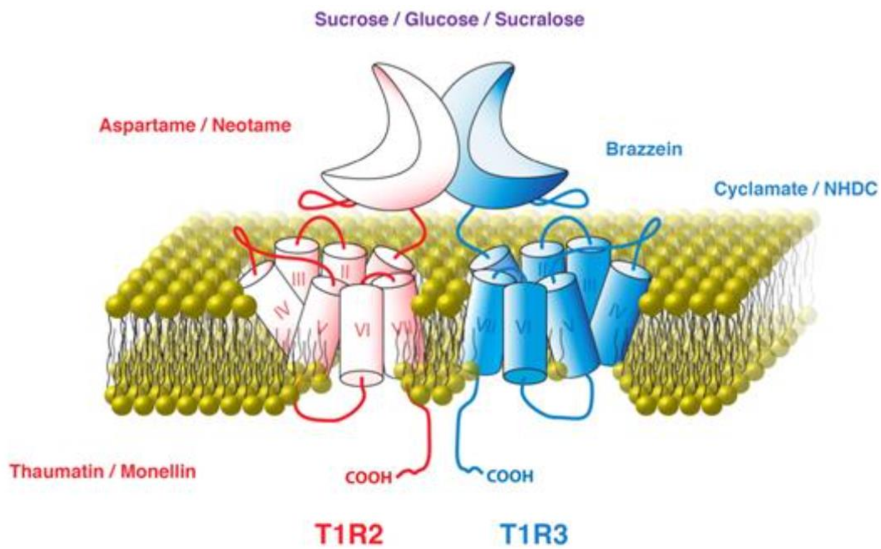

Figure 1.1: T1R2 and T1R3 taste receptors and the compounds that can activate them taken from Fernstrom et al., 2012.

Table 1.1: Allulose usage levels set for food and beverages in the United States taken from Tate & Lyle, 2018.

Food Category	GRN 400	GRN 498	GRN 693
Bakery products (rolls, cakes, pies, pastries, and cookies	10%	-	10-100%
Beverages (non-alcoholic)	-	3.5%	3.5%
Cereals	10%	5%	5%
Chewing gum	50%	50%	50%
Confections and frostings	-	5%	5%
Frozen dairy desserts (ice cream, soft serve, sorbet	5%	5%	5%
Yogurt (regular and frozen)	5%	5%	5%
Dressings for salad	-	5%	5%
Gelatins, pudding and fillings	-	10%	10%
Hard candies (including pressed candy, mints)	70%	50%	50%
Soft candies (non-chocolate, plain chocolate, chocolate coated)	25%	25%	25%
Jams and jellies	-	10%	10%
Sugar	-	10%	10%
Sugar substitutes	100%	100%	100%
Sweet sauces and syrups	-	10%	10%
Fat based creams	10%	-	5%
Medical foods	15%	-	10%
Coffee mix	30%	-	10%

Approvals:

GRN 400, CJ Cheiljedang Inc., 2011
Calculated EDI based on conditions of use (Cheiljedang data)
Mean = 12.6 g/p/d
90th percentile = 28.5 g/p/d

GRN 498, Matsutani Chemical Industry Ltd., 2013
Calculated EDI based on conditions of use
Mean = 9.0 g/p/d
90th percentile = 24.8 g/p/d

GRN 693, Sam Yang Corp., 2017
Calculated EDI based on conditions of use
Mean = 11 g/p/d
90th percentile = 30 g/p/d

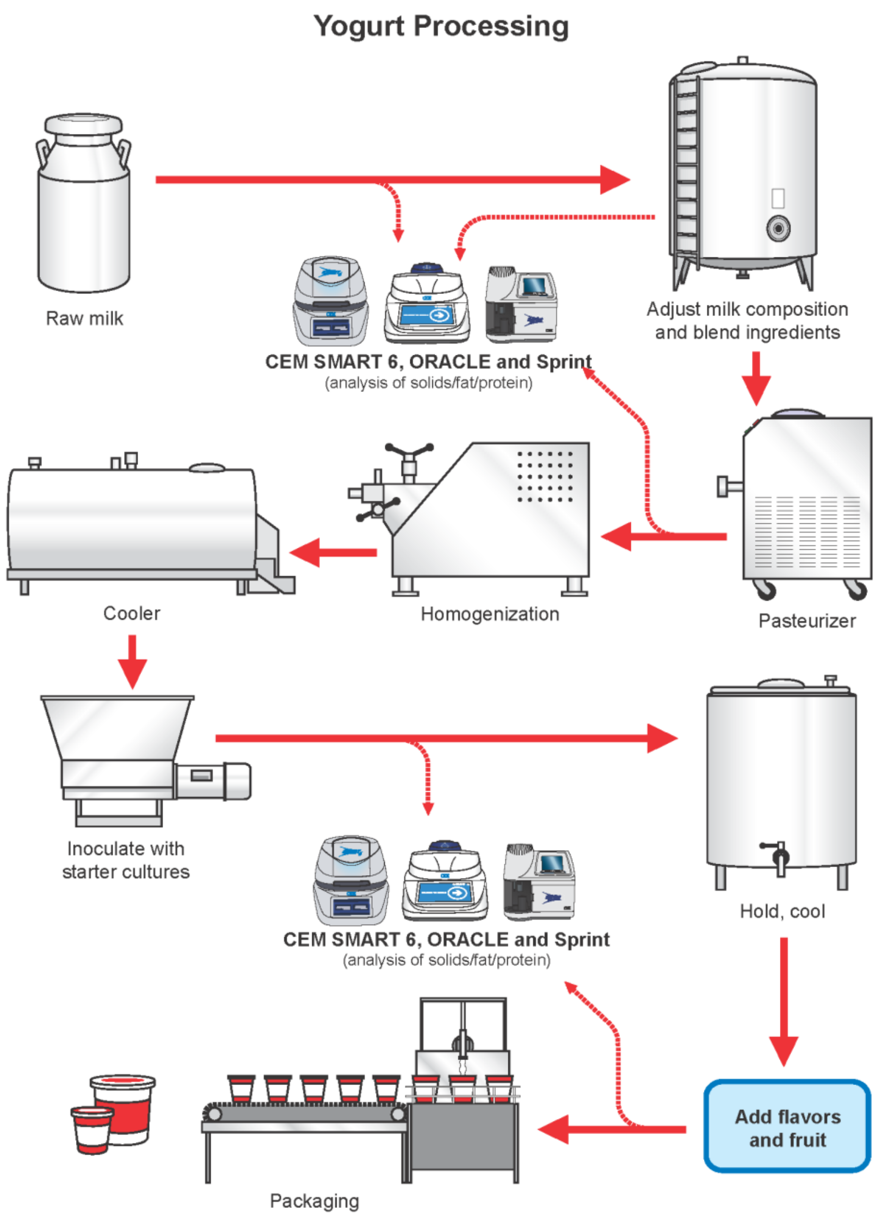

Figure 1.2: Yogurt Production Process taken from CEM, 2020.

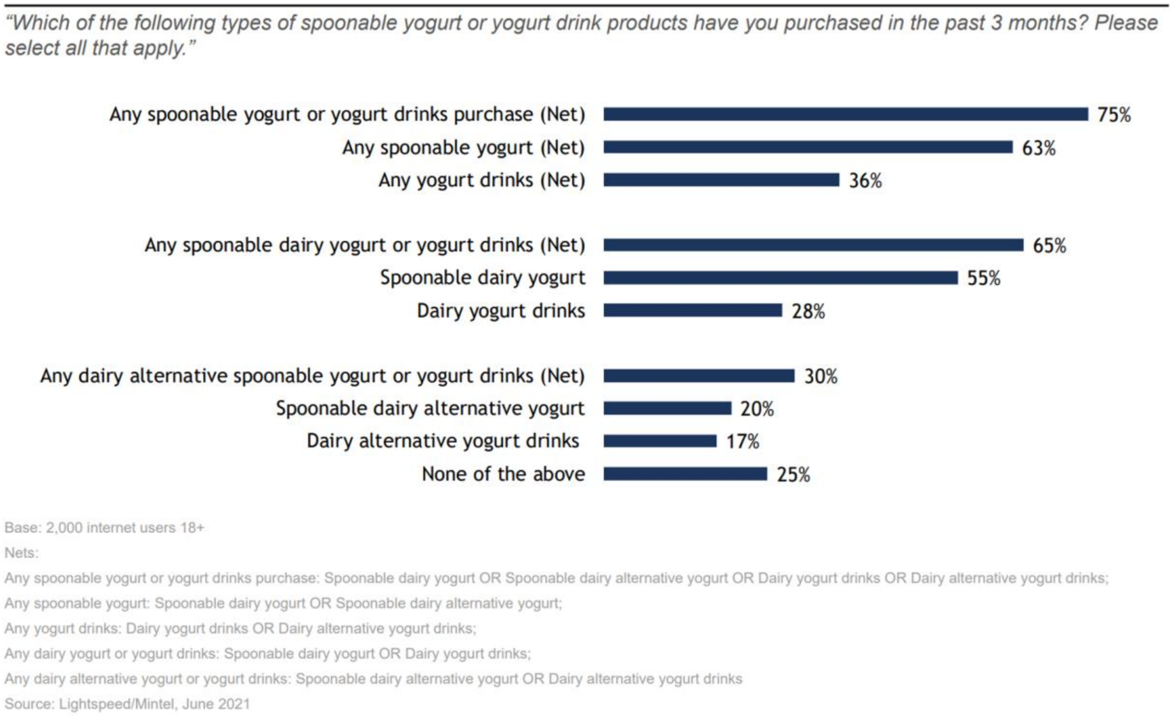

Figure 1.3: Yogurt product purchased in the past 3 months (n=2,000) taken from Mintel Group Ltd., 2021.

Table 1.2: Summary of attributes in sweeteners based on findings from Tan et al., 2020.

Black Tea	Chocolate Milk	Yogurt
Sucrose: Strong tea flavor with sweet taste, and floral taste. All other samples did not significantly differ (p>0.05) in terms of tea flavor, sweetness, astringency, floral taste, and residual sweetness	**Sucrose**: Strong chocolate flavor, moderate sweet taste, dairy flavor, malty taste, low bitterness, low chemical taste, and low residual sweetness. All other samples did not significantly differ (p>0.05) in terms of chocolate flavor, dairy flavor, malty taste, honey taste, and sweetness (except stevia)	**Sucrose**: Strong dairy flavor, high sweet taste, creaminess, sour taste and was low in bitterness, chemical taste, and astringency. All other samples did not significantly differ (p>0.05) in terms of dairy flavor, creaminess, and sourness
Ace-K: higher bitterness and chemical taste than sucrose	**Ace-K**: higher bitterness (nonsignificant)	**Ace-K**: lower sweet taste intensity, lower dairy flavor, and higher chemical taste than sucrose
Stevia: higher bitterness and chemical taste than sucrose. Lower honey taste in tea	**Stevia**: higher in bitterness, higher chemical taste, and less sweeter than sucrose	**Stevia**: lower sweet taste intensity and higher chemical taste than sucrose
Luo Han Guo: higher bitterness and chemical taste than sucrose	**Luo Han Guo**: higher bitterness and chemical taste than sucrose	**Luo Han Guo**: lower sweet taste intensity and higher chemical taste than sucrose
Aspartame: Taste profiles not significantly different than sucrose	**Aspartame**: Taste profiles not significantly different than sucrose	**Aspartame**: Taste profiles not significantly different than sucrose
Sucralose: Taste profiles not significantly different than sucrose	**Sucralose**: Taste profiles not significantly different than sucrose	**Sucralose**: Taste profiles not significantly different than sucrose
Erythritol: Taste profiles not significantly different than sucrose	**Erythritol**: Taste profiles not significantly different than sucrose	**Erythritol**: Taste profiles not significantly different than sucrose
Palatinose: Taste profiles not significantly different than sucrose	**Palatinose**: Taste profiles not significantly different than sucrose	**Palatinose**: Taste profiles not significantly different than sucrose
Sucrose-Allulose: Taste profiles not significantly different than sucrose	**Sucrose-Allulose**: Taste profiles not significantly different than sucrose	**Sucrose-Allulose**: Taste profiles not significantly different than sucrose
Sucrose-Allulose: Taste profiles not significantly different than sucrose	**Sucrose-Allulose**: Taste profiles not significantly different than sucrose	**Sucrose-Allulose**: Taste profiles not significantly different than sucrose

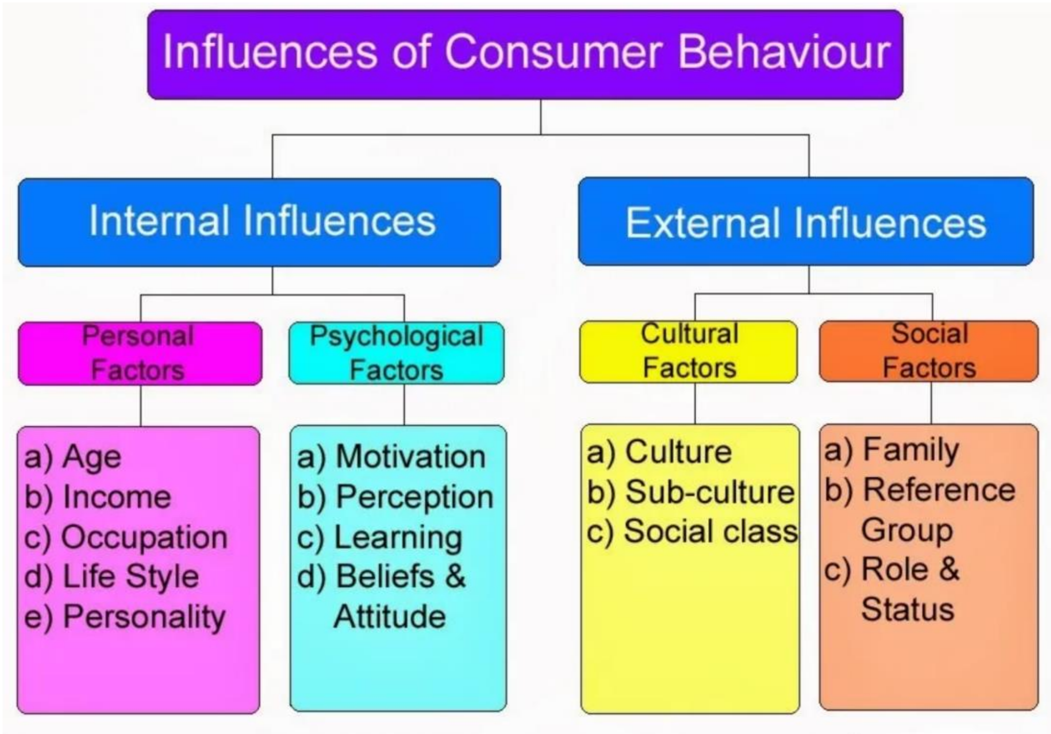

Figure 1.4: Influences of consumer behavior broken into internal and external influences taken from Factors Influencing Consumer Behavior, 2019.

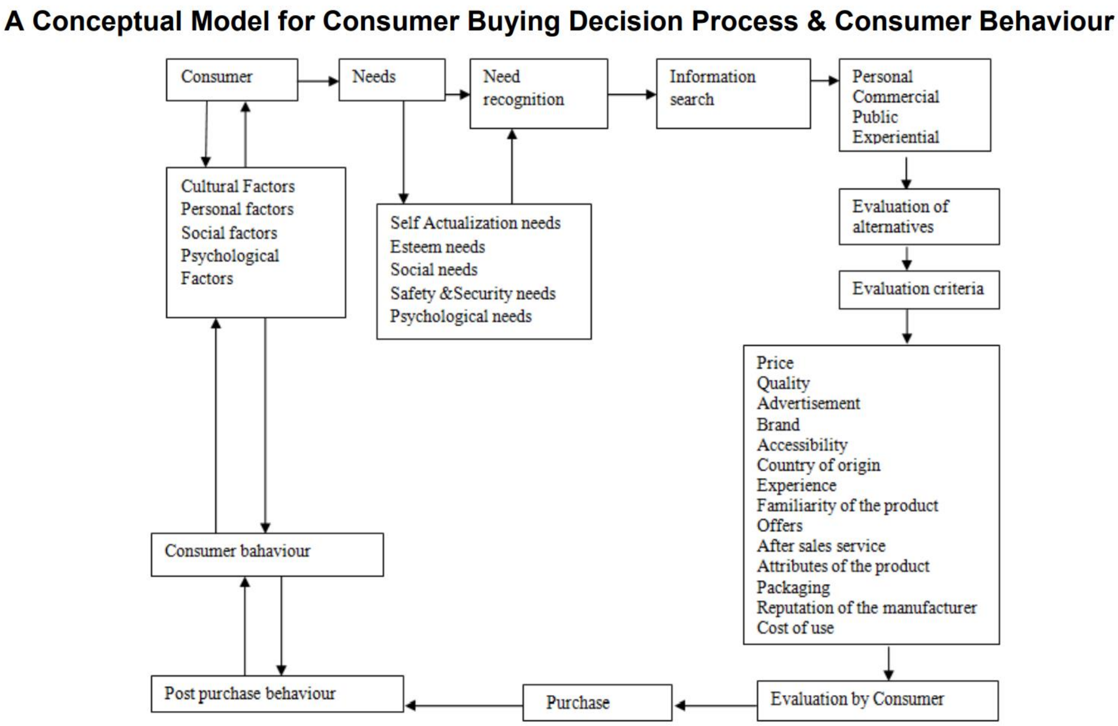

Figure 1.5: Consumer buying process and behavior taken from Jisana, 2014.

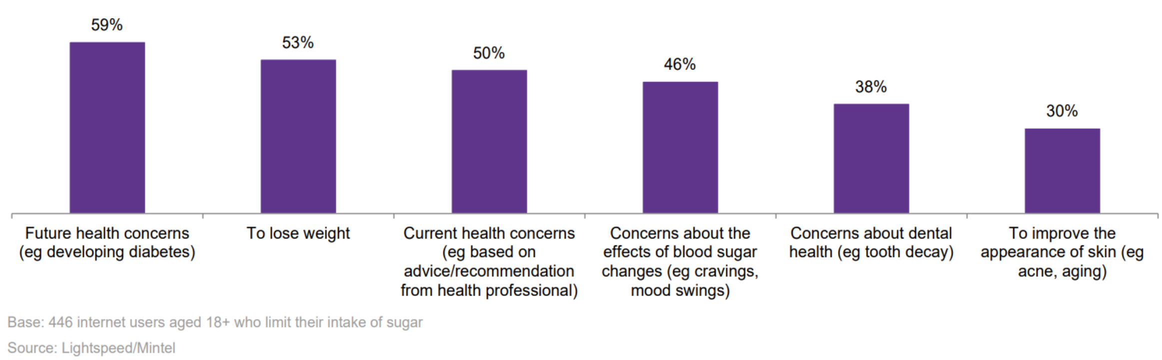

Figure 1.6: Factors on why consumers are limiting their sugar intake (n=446) taken from Mintel, 2020.

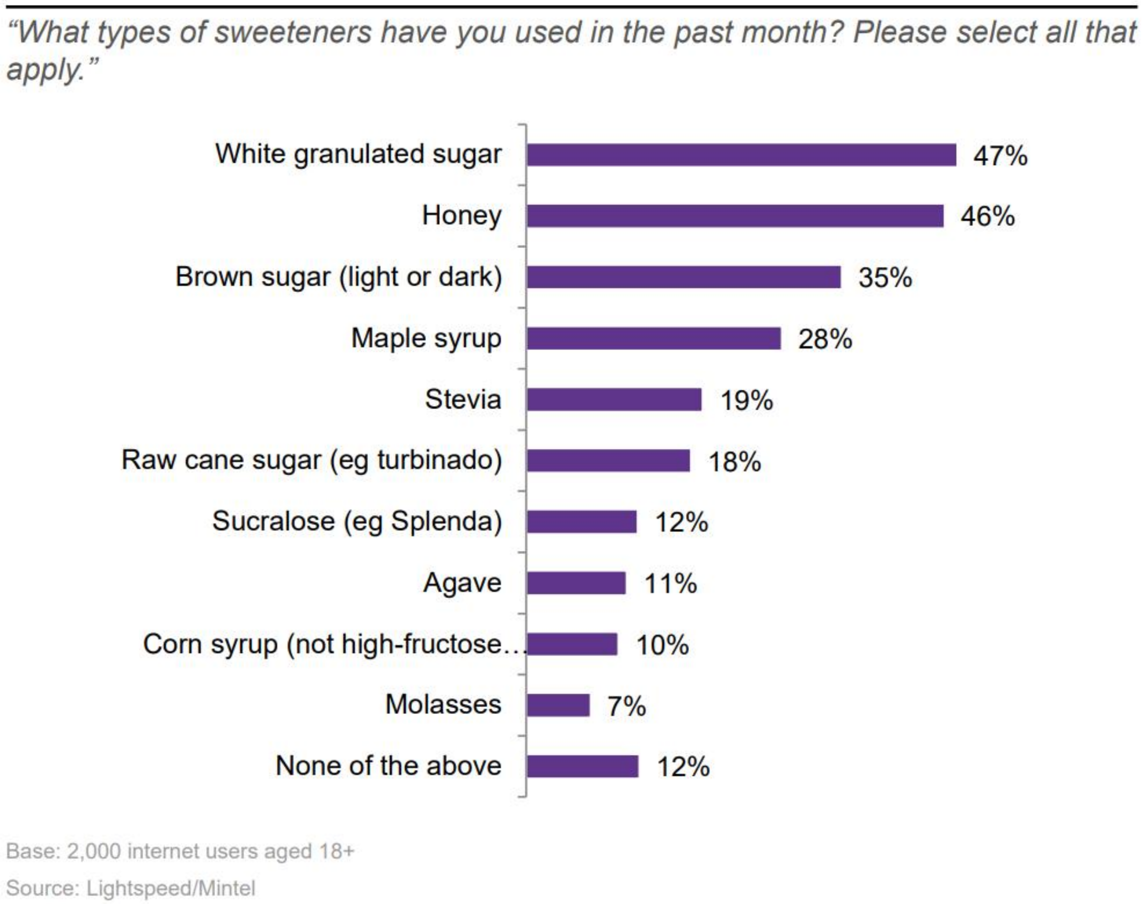

Figure 1.7: Sweeteners consumers have used in the past month (n=2,000) taken from Mintel, 2020.

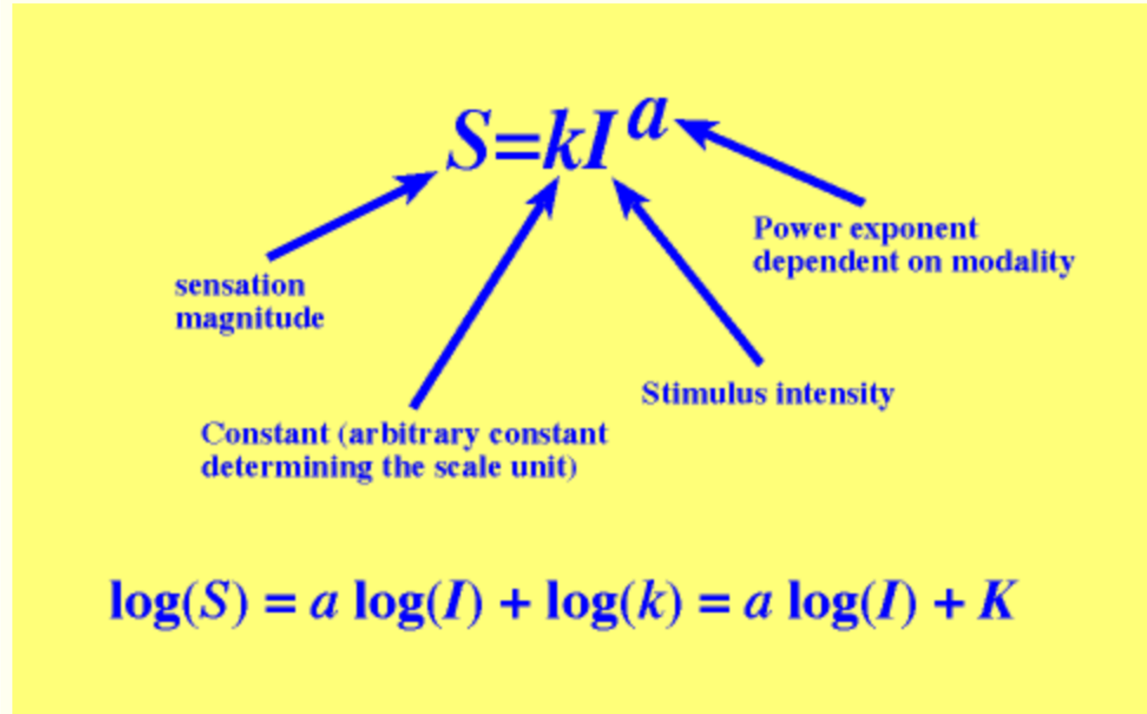

Figure 1.8: Steven's Power Law equation taken from Stevens' Power Law, n.d.

CHAPTER 2:
CONSUMER PERCEPTION OF SWEETENERS IN YOGURT

Consumer Perception of Sweeteners in Yogurt

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INTERPRETIVE SUMMARY

Consumer perception of sweeteners and sugar reduction in yogurt were evaluated. Conceptually, consumers preferred naturally sweetened yogurts with honey, cane sugar or agave. With or without priming, consumers preferred yogurts sweetened with sucrose.

ABSTRACT

Consumers are interested in products with reduced sugar, a trend which has been attributed to consumers associating high-sugar foods with obesity, diabetes, heart disease and high blood pressure. The objective of this study was to evaluate consumer perception of sugar reduction in yogurt – both conceptually and for liking of actual products. An online survey (n=1290) was conducted to evaluate consumer perception of sweeteners available in commercial yogurts. Participants who purchased yogurt at least once in the past 3 months completed a series of exercises that involved demographics, agreement, Kano, and Maximum Difference (MaxDiff) scaling questions. Subsequently, vanilla 1% milkfat yogurts sweetened with sucrose were formulated to iso-sweet taste intensity with either stevia, allulose, a blend of sucrose and honey or a blend of sucrose, stevia and allulose using magnitude estimate scaling followed by paired comparison tests with consumers (n=40). A consumer acceptance test (n=229) was then conducted using the five vanilla yogurts. Half of the consumers (n=115) were primed with the specific yogurt sweetener and the other half were not. Survey and acceptance test data were evaluated by univariate and multivariate analyses. Conceptually, consumers preferred the claim "naturally sweetened" over a reduced sugar claim in yogurt ($p<0.05$). Honey was preferred over other sweeteners, followed by agave nectar and cane sugar ($p<0.05$). Allulose was the least preferred sweetener option conceptually ($p<0.05$). Priming with sweetener type positively impacted consumer acceptance, regardless of sweetener ($p<0.05$). When yogurts were tasted, yogurts sweetened with sucrose were the most preferred regardless of priming ($p<0.05$). Yogurts sweetened with allulose or a blend of allulose, stevia, and sucrose received higher liking scores than yogurts with stevia ($p<0.05$), suggesting that allulose can assist with sugar reduction in yogurt. Consumers are interested in healthy yogurts that are naturally sweetened, but flavor remains the driving force for liking and purchase. The use of a natural non-nutritive sweetener that delivers the sensory experience of sucrose is ultimately more important than familiarity with the actual sweetener.

Key Words: yogurt, sugar reduction, consumer acceptance

INTRODUCTION

At the conclusion of 2022, the yogurt sector was expected to reach $9.7B which marked a 6% growth rate within this sector (Mintel Group Ltd., 2022). In 2023, the yogurt market is projected to grow to more than 9 million dollars in the United States alone (Mintel Group Ltd., 2022). One continued trend for yogurts, and dairy foods in general, is sugar reduction (McCain et al., 2018; Mahato et al., 2020). A local assessment of 21 commercial yogurts (14 different brands) in April 2023 documented that yogurts can contain up to 17g of added sugar per 5.5 oz (a serving). High sugar intake can increase the risk of developing obesity, cardiovascular disease, obesity-related cancers, and dental caries (Vos et al., 2017). With increasing public awareness of these adverse effects from excessive sugar consumption, consumers have had an increased interest for natural low-calorie or zero-calorie sweeteners in products (Philippe et al., 2014; Gandhi et al., 2018; Castro-Muñoz et al., 2022).

Sugar reduction in yogurt is a challenge. The use of sugar not only masks the sour taste of yogurt, but also contributes to the total solids of the final product and aids in texture, viscosity, and moisture retention (Harper et al., 1991; Popa and Ustunol, 2011). Moreover, consumers expect the sensory quality of reduced sugar yogurt to be similar to that of full-sugar versions (Johansen et al., 2010; Torrico et al., 2020). To address these obstacles, various flavors such as strawberry or vanilla can be added to yogurt to increase consumer perception of sweet taste (Chollet et al., 2013; Oliveira et al., 2021). Several studies have examined consumer acceptance of flavored yogurt sweetened with various alternative sweeteners (Narayanan et al., 2014; Pereira et al., 2021b; Mora et al., 2022). Narayanan et al. (2014) performed a consumer acceptance test on vanilla flavored plain low-fat yogurt sweetened with different concentrations of sucrose, aspartame, a blend of erythritol, 95% rebaudiana A (Reb A) stevia, 95% blend of maltodextrin and steviol glycosides, and a stevia extract. The authors observed that overall consumers accepted the yogurt sample sweetened with 14% sucrose (Narayanan et al., 2014). Pereira et al. (2021b) also observed similar results on mango skyr yogurt sweetened with either sucrose, stevia, thaumatin, and a stevia/thaumatin blend and four other formulations with the same sweeteners with fructooligosaccharide (FOS). Pereira et al. (2021b) completed two consumer acceptance tests in different cities in Brazil. It was noted that the Southeast city favored the yogurt samples sweetened with sucrose, sucrose and FOS, and thaumatin and FOS, while there were no significant differences among sample sweetened with sucrose, sucrose and FOS, thaumatin, thaumatin and FOS, stevia/thaumatin blend, and stevia/thaumatin blend and FOS for consumers in the Northeast city (Pereira et al., 2021b). Lastly, Mora et al., 2022 noticed there were no significant differences in overall liking and flavor liking for Greek vanilla flavored yogurt sweetened with sucrose, sucralose, and allulose, while there was a significant difference for overall liking and flavor liking with the yogurt sample sweetened with stevia (Mora et al., 2022).

Additional studies have also investigated alternative sweeteners in yogurt using various methods other than consumer acceptance. Studies such as these can assist in identifying how different sweeteners behave in yogurt prior to performing consumer acceptance testing or can clarify consumer acceptance results. Tan et al. (2020a) evaluated eleven sweeteners in yogurt and other foods using training panelists and a Rate-All-That-Apply (RATA) procedure. The RATA procedure entailed panelists selecting and rating attributes from a list. Attributes that the panelists could select were creaminess, sweetness, sourness, dairy flavor, chemical taste, bitterness, astringency, and residual sweetness of the yogurt samples (Tan et al., 2020a). Results from the RATA procedure showed that acesulfame-K, stevia, and monk fruit all how lower rated sweetness intensity than the other sweeteners most likely due to the sides tastes that these sweeteners exhibit (Tan et al., 2020a). Another study utilized temporal dominance of sensations (TDS) in combination with consumer acceptance of Greek style yogurt sweetened with sucrose, xylitol, stevia, or monk fruit (Chadha et al., 2022). The yogurt sweetened with sucrose had a longer dominance duration of sweet than the yogurts sweetened with stevia and monk fruit, which was noted that it is possibly attributed side tastes that were observed such as bitter, licorice, and astringent. Results also indicated that the sucrose sample was more liked than the other four sweeteners used in this study (Chadha et al., 2022). Additionally, Reis et al. (2011) conducted an assessment of sweet taste equivalency of sweeteners in strawberry flavored full fat yogurt. Sweeteners/ blends evaluated included aspartame, aspartame and acesulfame-K, sucralose, cyclamate and saccharin, and a blend of cyclamate, saccharin, and stevia. Authors noted that the lowest amount of sweetener needed to achieve the same sweet taste intensity of 11.5% sucrose in strawberry flavored yogurt was sucralose.

Other investigations have concentrated on direct reduction of sugar yogurt. Oliveira et al. (2021) focused on sugar reduction in yogurt flavored with different concentrations of vanilla or strawberry flavoring. A sucrose reduction of 25% without a decrease in consumer acceptance was possible with the addition of flavoring to yogurt (Oliveira et al., 2021). A similar study completed by Chollet et al. (2013) examined sugar reduction in full fat plain yogurt flavored with either strawberry or coffee flavoring. Both the strawberry and coffee flavored yogurt samples that had 10% sucrose, were more liked than the 7% and 5% sucrose concentrations.

Acceptance or liking tests are applied to evaluate consumer liking of a product. Other techniques can be applied to evaluate consumer knowledge and beliefs. One way to gauge consumer beliefs is through maximum difference (MaxDiff) scaling. Also known as best-worst scaling, MaxDiff scaling is a survey method utilized to determine consumer importance or preference within a list of items (Orme, 2014). Multiple studies have been conducted that have used MaxDiff scaling to examine consumer preferences/importance of attributes in dairy products (Harwood and Drake, 2018; Speight et al., 2019; Sipple et al., 2022). Another survey method that is frequently used is Kano analysis. Fundamentally, Kano analysis shows how participants react when certain attributes are present or missing (Oltman et al., 2015; Harwood and Drake, 2018). Multiple studies have also used Kano analysis for dairy products (Li et al., 2014; Oltman et al., 2015; Harwood and Drake, 2018). In order to compare actual consumer responses of alternative sweeteners, the iso-sweet concentration or sweetness equivalency must be obtained. The iso-sweet concentration is the amount of alternative sweetener that is needed to reach the same sweet taste intensity as the sucrose target (Keefer et al., 2020). This process can be accomplished through a combination of methods which involves the application of magnitude estimation scaling (MES), descriptive analysis, and 2-alternative forced choice testing (2-AFC) (Cardello et al., 1999; Lawless and Heymann, 2010; Keefer et al., 2020). Priming consumers can also be an effective technique to use during consumer acceptance testing to gauge the role of labels and information on consumer liking (Veldhuizen et al., 2010; Oltman et al., 2015). No current studies have explored consumer perceptions of alternative sweeteners in yogurt *conceptually* with the use of survey techniques followed by *actual* consumer acceptance of yogurt with alternative sweeteners. The objective of this study was to determine consumer perception and knowledge of sweeteners in yogurt followed by consumer acceptance testing with yogurts.

MATERIALS AND METHODS

Experimental Overview

All survey and sensory testing were reviewed and approved as exempt by the North Carolina State University Institutional Review Board (IRB). An online survey was initially conducted with yogurt consumers (n=1,290). The online survey utilized Kano, likert scales, a product build exercise, and Maximum Difference (MaxDiff) scaling (Figure 1). From survey results, four sweeteners were selected (sucrose, honey, allulose, and stevia) to be used in the formulation of vanilla 1% milkfat yogurts. Magnitude Estimation Scaling (MES) with 2-Alternative Forced Choice (2-AFC) and descriptive analysis was used to confirm iso-sweetness of sweetened 1% yogurt with and without vanilla flavor. Three sweeteners and two sweetener blends were then incorporated into vanilla 1% milkfat yogurts for consumer acceptance testing. Consumers evaluated yogurts under primed (n=115) or unprimed (n=114) conditions.

Online Survey

The objective of the online survey was to assess consumer perception of sweeteners and yogurt. The online survey was developed using Lighthouse Studio (Sawtooth Software, Version 9.8.0, Orem, UT). Participants were recruited from a database of >10,000 respondents maintained by the Sensory Service Center in Raleigh, NC. Participants (n=1,290) who were at least 18 y and self-reported yogurt consumers completed the survey. The first part of the survey was comprised of demographic questions. Participants were asked to indicate their gender, age, frequency of yogurt consumption, involvement in household grocery shopping, and household yogurt consumption patterns. After demographic questions, participants completed a Kano exercise related to yogurt attributes. Kano is a technique where product attributes are classified based on how consumers assess them when certain elements are present or are missing (Kano, 1984; Erto et al., 2011; Oltman et al., 2015). Participants were shown both functional and dysfunctional attribute statements (e.g. yogurt that has reduced sugar and yogurt that does NOT have reduced sugar) and rated the relative importance of attributes on a 5-point scale where 1 = this would be appealing to me, 2 = this is a basic requirement for me, 3 = this would not affect me, 4 = this would be a minor inconvenience for me, 5 = this would be major problem for me.

Next, participants went through a series of 5-point Likert-scaled agreement questions, which asked participants how much they agree or disagree with the statements involving yogurt. Statements included 'organic yogurt contains less sugar than conventional yogurt,' 'I enjoy trying new flavors and varieties of yogurts,' 'I consume yogurt because I enjoy the flavor or texture,' 'I typically read the ingredient list when purchasing yogurt,' 'reducing the sugar content of yogurt makes it a healthier product,' 'I always buy the same brand of yogurt,' 'when purchasing yogurt I am willing to sacrifice flavor and texture for health benefits,' 'healthier yogurts have worse flavor and texture than indulgent yogurts,' 'plant-based yogurts are healthier than those made with dairy milk,' 'I am familiar with different ingredients that are used to sweeten yogurt,' 'I am interested in trying novel or unusual yogurt products,' 'I consume yogurt because it supports my digestive or gut health,' 'most yogurts today have similar nutritional value,' 'most yogurts available today contain too much sugar,' 'I consume yogurt because it supports my bone health,' 'I would prefer to buy an all-natural yogurt product that has a higher total sugar content,' 'I would prefer to buy a yogurt product that a lower total sugar content and contains artificial non-nutritive sweeteners,' and 'I would prefer to buy a yogurt product that has a low total sugar content and contains natural non-nutritive sweeteners.' Respondents were shown a series of statements about yogurt shopping/consumption habits, as well as perception of yogurt taste and nutritional profiles and asked to rate their level of agreement on a 5-point scale where 1 = completely disagree, 2 = somewhat disagree, 3 = neither agree or disagree, 4 = somewhat agree, and 5= completely agree. Next, participants were asked to indicate which types of yogurts they typically purchased. Survey respondents were then asked to imagine they were designing a yogurt in their favorite flavor and to choose which options from a provided list would be most appealing to them (Build Your Own (BYO) exercise). Options included added sugar, sweetener type, protein content, total fat, saturated fat, and label claims. Participants were then asked which attribute they would be most likely to compromise on if their ideal yogurt was not available.

Respondents were then asked which characteristics they would find helpful when selecting a new yogurt. Provided answer choices included nutrition facts, ingredient list, label claims, package size, flavor of yogurt, type of yogurt, other, and none of the above. Next, survey respondents were shown a conceptual nutritional label (Figure 2) and asked questions about the information on the label to evaluate understanding of ingredient labels. After completing the nutritional label exercise, respondents were asked to rate their familiarity with common sweetening ingredients used in yogurt. Familiarity was rated using a 5-point scale in which 1 = not at all familiar, 2 = slightly familiar, 3 = somewhat familiar, 4 = moderately familiar, and 5 = extremely familiar. Sweeteners that were used in this exercise were sucralose, Acesulfame K, cane sugar, erythritol, stevia leaf extract, agave nectar, allulose, fructose, sucrose (table sugar), honey, monk fruit, and corn syrup.

Next, participants completed the first of two MaxDiff exercises. In the first exercise (sugar claims MaxDiff), seven different label claims related to sugar content in yogurt were presented. Consumers were asked to consider which of the sweetener labels was the most and least appealing when selecting a yogurt. Following this exercise, respondents completed a series of agreement questions related to yogurt attributes and ingredients using the agreement scale described earlier. Participants then completed a second MaxDiff exercise in which they had to select which of eleven sweeteners they found most and least appealing in yogurt. For the sugar claims MaxDiff exercise, each consumer completed nine sets of best-worst questions with three items per set, and for the sweetener MaxDiff exercise each consumer completed nine sets with five items per set. Attention check questions were asked throughout the survey to ensure that participants were actively engaged. The survey took respondents approximately 30 minutes to complete and respondents who fully completed the survey were entered into a raffle where they could win one \$100 target gift card, one of four \$50 Target gift cards, or one of ten \$20 Target gift cards.

Yogurt Preparation

Plain unsweetened, unflavored yogurt (1.7 ± 0.05 % milkfat, 3.7 ± 0.08 % protein, pH 4.4 ± 0.06 at 4°C) was provided by overnight service from an industry partner in the Midwest. Pure 2-fold vanilla extract was provided by Synergy (Wauconda, IL) and incorporated at 0.75% w/v (per supplier recommendations). Sweeteners used were sucrose (purchased locally), honey in the form of honey powder (ProDry Honey Powder HSD NGMOP, Ohly Americas, Boyceville, WI), allulose powder (Dolcia Prima DS crystalline allulose, Tate and Lyle, Decatur, IL), and stevia (Intesse steviol glycosides, Tate and Lyle). For mixing with sweeteners, ingredients and white mass were placed in a stainless steel container and gently hand mixed with a spatula for approximately one minute.

Magnitude Estimation Scaling (MES) for Iso-Sweet Concentrations of Sweeteners in Yogurt with and without Vanilla

A preliminary sensory assessment was conducted on 14 commercial vanilla yogurts to identify a target sweet taste intensity. A target sweet taste intensity of 6% (w/v) sucrose solution was selected which represented the average sweet taste intensity encountered in the commercial vanilla yogurts. Power functions for sucrose, honey powder, allulose, and stevia were generated using MES in both unflavored and vanilla flavored yogurt. Panelists (n=10; 5 women, 5 men ages 23 to 28 y), each with a minimum of 10 h of training on MES, generated power function curves for each of the sweeteners (Parker et al., 2018; Keefer et al., 2020). The MES scaling method was used to create power function curves by utilizing a 6 % (w/v) sucrose solution as the reference for both sweetened unflavored and vanilla-flavored yogurt. The 6% (w/v) sucrose solution was used as a reference intensity of 100 and additional scale anchors of 3% w/v sucrose (reference intensity 50, half as sweet as the reference 100) and 12% sucrose (reference intensity of 200, twice as sweet as the reference) were also provided (Keefer et al., 2020). Panelists were instructed to refer to these references when tasting yogurts. Each of the MES series contained 7 yogurts with yogurts being just noticeably sweet to just as sweet or sweeter than the reference. For each MES series presented to panelists, a step factor of 1.4 was used for sweetener concentration (Keefer et al., 2020). Yogurts were given to panelists at 4°C in 64 mL lidded soufflé cups that each had a random 3-digit blinding code. Samples were randomized and data was collected using an electronic ballot and test design through Compusense Cloud Software (Compusense Cloud, Guelph, Canada). A 3 min rest was enforced between samples and unsalted crackers and bottled spring water were provided for palate cleansing. All MES series were evaluated in duplicate by each panelist in separate sessions.

Confirmation of Iso-Sweetness of Sweeteners in Yogurts

Descriptive analysis was used to confirm and adjust the iso-sweetness values generated by MES scaling (Li et al., 2015; Parker et al., 2018). Subsequently, sweet taste equivalency of each sweetener in yogurt with and without vanilla flavor was confirmed by 2-AFC testing with consumers (ASTM, 2016; Parker et al., 2018; Keefer et al., 2020). Consumers (n=40) were recruited from the university community. Consumers were given 40 g of sweetened unflavored or vanilla yogurt in 64 mL lidded soufflé cups that each had a random 3-digit blinding code. Each yogurt was compared to a reference sample of yogurt sweetened with sucrose that had a sweet taste intensity of a 6**.** Samples were served at 4°C. Consumers were instructed to taste the samples from left to right, and then choose the sample that they believed to be the sweetest. Unflavored yogurt and vanilla yogurt were tested with each sweetener relative to the unflavored or vanilla yogurt sucrose reference sample. No more than two pairs of samples were presented to consumers in a session. Panelists were instructed to take a sip of bottled spring water during the mandatory three-minute rest between samples and sample sets. Data was collected using an electronic ballot and test design through Compusense Cloud. Two sweetener blends (50:50 honey powder: sucrose, HP blend, and 50:10:40 allulose, sucrose, and stevia, ALL blend) were formulated from the single sweetener iso-sweet results. Iso-sweetness of each vanilla yogurt blend was confirmed by descriptive analysis and 2-AFC as described.

Descriptive Analysis and Consumer Testing of Vanilla Yogurts with Different Sweeteners

Five sweetener or sweetener blends were selected for consumer acceptance testing in vanilla 1% milkfat yogurts: sucrose (SUC), allulose (ALL), stevia (STE), HP blend, and ALL blend. Yogurts were formulated as previously described. Descriptive analysis was performed on the 5 vanilla yogurts to document objective sensory properties. Eight trained panelists (5 women, 3 men ages 23 to 50 y) documented the flavor and texture properties of the yogurts. Each of the panelists had more than 80 h of experience with descriptive sensory analysis of milk and cultured dairy products, including yogurt. An established lexicon was used in conjunction with a 0 to 15 point universal intensity scale consistent with the Spectrum descriptive analysis method (Desai et al., 2013; Keefer et al., 2020). Yogurts were served at 4°C in 120 mL lidded soufflé cups that each had a random 3-digit blinding code. Each yogurt was evaluated by each panelist in duplicate in separate sessions. A 3 min rest was enforced between samples. Compusense Cloud was used for data collection.

Consumer Testing

Consumer testing was performed in February 2022 and was modified for COVID-19 safety per university IRB restrictions at that time (Racette and Drake, 2021). Consumers were recruited from a database of >10,000 respondents maintained by the Sensory Service Center at Raleigh, NC. Recruitment and consumer testing was conducted with Compusense Cloud Software. Self-reported yogurt consumers that did not have any food allergies, food sensitivities, or dietary restrictions and were > 18 y were recruited. To fully participate in the study, participants must have consumed yogurt at least once every two weeks. Additionally, participants had to indicate that they liked vanilla yogurt. Qualified participants filled out additional check all that apply (CATA) questions. The CATA questions asked respondents to specify which flavor(s) of yogurt, fat content, and brands of yogurt that they purchased and consumed most often.

On the day of the consumer test, 229 recruited consumers were provided with 35 g of each of the 5 vanilla yogurts with the different sweeteners. Yogurts were served at 4°C in 64 mL lidded soufflé cups with a randomly generated 3-digit blinding code. Qualified consumers picked up yogurts in a thermal bag (ULINE, Please Prairie, WI) along with a commercial package of unsalted saltine crackers, a commercial bottle of spring water, and commercially wrapped spoons. Participants were instructed to take the samples home/to work and then click on the provided hyperlink and complete the test within 3 h of pickup (Racette and Drake, 2021). Participants who fully completed the test received a $30 Amazon gift card. Samples were presented using a Williams design (Compusense Cloud).

Once logged into the electronic ballot, consumers were randomly assigned to either a primed ballot (n=115) or an unprimed ballot (n=114). Primed consumers were shown priming statements that included the types of sweetener(s) in the yogurt, the number of calories contributed by the sweetener and if it was a low or non-caloric sweetener (Table 1). After each priming statement, (primed) consumers were asked a purchase intent question prior to sample evaluation. The purchase intent question was presented on a 5-point scale where 1 and 2 = would not purchase, 3 = maybe/ maybe not purchase, and 4 and 5 = would purchase. For each yogurt, consumers were asked to evaluate the overall appearance, color, and aroma prior to tasting. The overall appearance color, and aroma were scored on a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely. A Just-about-right (JAR) scale was presented after the color hedonic scale where 1 and 2 = too light, 3 = just about right, and 4 and 5 = too dark. A JAR scale was also presented after the aroma hedonic scale where 1 and 2 = too weak, 3 = just about right, and 4 and 5 = too strong.

After these initial questions, consumers were then instructed to taste the yogurt. Overall liking was scored on a 9-point hedonic scale followed by flavor liking, vanilla flavor liking, sweet taste liking, sour taste/tartness liking and texture liking (scored on a 9-point hedonic scale).

JAR questions were asked after each liking question where 1 and 2 = too weak/little, 3 = just about right, 4 and 5 = too intense/strong. Additionally, perceived artificial sweetness was evaluated after sweet taste liking on a 5-point scale where 1 and 2 = tastes artificial, 3 = unsure, 4 and 5 = tastes natural. Subsequently, consumers were asked if they detected an aftertaste. If they answered ‘yes’ panelists were asked to evaluate the strength of the aftertaste on a 9-point scale where the only anchors were 1 = extremely weak and 9 = extremely strong, and they were also asked to evaluate aftertaste liking on a 9-point hedonic scale. If panelists answered ‘no’ for aftertaste detection, skip logic was used to skip the aftertaste strength and liking question. Next, consumers were asked to evaluate if the sample met their expectations for a vanilla yogurt on a 5-point scale where 1 and 2 = does not meet expectations, 3 = maybe/maybe not meets expectations, 4 and 5 = meets expectations. Additionally, participants were asked purchase intent on a 5-point scale where 1 and 2 = probably would not purchase, 3 = might or might not purchase, 4 and 5 would purchase. A CATA question was asked following purchase intent, and consumers were asked to describe the yogurt they just tasted by checking the attributes that applied to the sample: creamy, milk, sour, fermented, bitter, astringent, healthy, indulgent, natural, good-for-me, metallic, other (please specify). The last question asked consumers to evaluate how healthy they thought the yogurt was on a 5-point scale where 1 and 2 = not healthy, 3 = somewhat healthy, 4 and 5 = healthy. After the evaluation of each sample, a 5 min rest was enforced. Participants were asked to cleanse their palates by using the provided unsalted saltine crackers and bottled water. After all yogurts were evaluated, consumers were asked to rank the samples in order of perceived naturalness with 1 = being the most natural and 5 = being the least natural vanilla yogurt sample.

Statistical Analyses

Statistical analyses were performed at a 95% confidence level ($p < 0.05$). For survey analysis Kano results were evaluated by the model proposed by Kano (1984). This model uses the following labels for classification of results: *Attractive*- unexpected by the consumer; consumers are satisfied if this attribute is present. *Indifferent*- attributes that the consumer does not care about. *Must have*- expected by the consumer; if unavailable, consumers are dissatisfied. *Performance (one-dimensional)*- as the attribute increases, so does consumer liking. *Reverse*- leads to dissatisfaction (Kano, 1984; Erto et al., 2011; Oltman et al., 2015). Hierarchical Bayes estimation was performed in Sawtooth Software (Version 9.8.0, Orem, UT) to calculate most and least appealing (importance scores) MaxDiff attributes. All other analyses for survey results were performed in XLSTAT (version 2022.1.2 Boston, USA). Means separation of importance scores for MaxDiff results were performed by one-way analysis of variance (ANOVA) with Fisher's least significant difference. Clustering of consumers from MaxDiff results was determined by agglomerative hierarchical clustering with Euclidean distances and Ward's linkage to place participants in similar clusters based on similar responses of importance scores (Sipple et al., 2022). All analyses for 5-point agreement questions were evaluated by Kruskal-Wallis with Dunn's post-hoc test. Frequency data was analyzed by taking the average of each option that was selected by respondents and then using the average to find the percentage of the responses selected.

Power curves for MES sweetener data were constructed by plotting the logarithm of the geometric mean of the average sweet taste intensity response of each sweetness concentration level against the logarithm of the sample sweetener concentration (ASTM, 2016; Parker et al., 2018; Keefer et al., 2020). Iso-sweetness concentrations from power curves were confirmed by

2-AFC using the minimum number of correct judgements for 2-AFC tests at 95% confidence (p<0.05) (ASTM, 2008; Meilgaard et al., 2016). Two-way ANOVA (vanilla x sweetener) was used to determine the effect of vanilla on sweetener type by comparing slopes found through MES. Data from descriptive analysis was analyzed by one-way ANOVA with Fisher's LSD. For consumer acceptance data, a 2-way ANOVA (priming x liking) with Fisher's LSD was utilized to determine the effects of primed and unprimed conditions. Just about right (JAR) scale data was analyzed using chi-squared with Marasciulo procedure. Other 5-point non-JAR scale data and ranking data were analyzed using Kruskal-Wallis with Dunn's post-hoc test. CATA responses from consumers were evaluated by frequencies and by visualization of responses by generation of symmetric row plots.

RESULTS

Online Survey Demographics and Shopper Behavior

Survey participants were comprised of 76.0% females and 24.0% males. Respondents represented a wide range of age groups, with 29.9% 18 to 24 y, 23.4% 25 to 34 y, 15.6% aged 35 to 44 y, 12.4% aged 45 to 54 y, 12.6% aged 55 to 64 y, and 6.9% aged 65 to 74 y. Most respondents were frequent yogurt consumers, with 27% of respondents indicating that they consumed yogurt at least once per day, 37.9% 2-3 times per week, 21.1% once per week, and 14% occasionally. Greek yogurt (flavored) and fruit-flavored spoonable yogurt were the most commonly purchased types of yogurt. Respondents agreed the most with the statement that 'they consumed yogurt because they enjoyed the flavor or texture' followed by the statements that 'they enjoyed trying new flavors and varieties of yogurt', and 'they consumed yogurt for digestive health.' Respondents disagreed the most with the statement that they would 'prefer to have yogurt that is lower in sugar content and contains artificial/ non-nutritive sweeteners' (Table 2).

In the BYO exercise, a yogurt with 2 g of added sugar, sweetened with honey or cane sugar, containing 10 g of protein, 2 g of fat, and an 'all natural' label claim was conceptually the most appealing yogurt to consumers. Respondents were divided on which compromises they would make when deviating from their ideal product, 26.8% indicated they would compromise on label claim, 15.4% added sugar, 19.3% sweetener, 18.1% stated protein, 12.9% stated total fat, and 7.4% saturated fat. Flavor and type of yogurt were major purchase decision factors for yogurt, with 81.9% and 76.3% of survey respondents indicating they considered these characteristics when selecting a new yogurt to purchase. Nearly two-thirds of participants also reported making a selection based on package size (64.6%) and referring to nutritional information (63.9%). Label claims were the least commonly cited purchase decision factor, with only 31.2% indicating that they look at label claims. Participants indicated a high level of proficiency when interpreting information from a conceptual nutritional label with the exception of added sugar. Ninety six percent of participants selected the correct amount of saturated fat, 97.9% selected the correct amount of protein, while 83.8% of participants selected the correct amount of added sugar. Consumers were most familiar with honey as a sweetener followed by sucrose (table sugar), and corn syrup (Table 3). The sweetener that participants were least familiar with was allulose.

Maximum Difference Scaling (MXD) Exercise

The first MaxDiff exercise evaluated label claims related to sugar content in yogurt. Participants were primed with the following statement: *"Please consider how important the* *ingredient list is to you when selecting a yogurt to purchase. Considering only these sweetener labels, which is the most appealing and which is the least appealing."* Overall, naturally sweetened was the most appealing label claim, followed by no artificial sweeteners, no high fructose corn syrup, and no added sugar (Figure 3). Four distinct clusters of consumers were identified for label claims related to sugar content (Figure 3). Cluster 1 (n= 247) were consumers who generally found low sugar and reduced sugar to be the most important label claims. They were the only cluster to not place importance on no artificial sweeteners or naturally sweetened label claims. These consumers were categorized as the *reduced sugar/artificial sweetener cluster*. The defining attribute of cluster 2 (n=551) was that they found the sugar claim 'no high fructose corn syrup' to be the most important. Cluster 2 consumers did not place importance on reduced sugar or low sugar claims and were deemed the *traditional sweetener cluster*. Cluster 3 (n=279) placed extreme importance for the 'naturally sweetened' label claim, and were categorized as the *naturally sweetened cluster*. The last cluster, cluster 4 (n=213), indicated that unsweetened was the most important sugar claim. Cluster 4 consumers also indicated that no added sugar was also important compared to the other three consumer clusters. Cluster 4 consumers were identified as the *unsweetened/ no sweeteners cluster*.

The second MaxDiff exercise addressed which sweeteners consumers found most and least appealing in yogurt. Respondents were primed with the following statement: *Please consider how important different sweeteners are when selecting a yogurt product to purchase. Considering only these sweeteners, which is the most appealing and which is the least appealing."* Across all consumers, honey was the most appealing sweetener to have in yogurt followed by agave nectar and cane sugar (Figure 4). For this MaxDiff exercise, three consumer clusters were identified. Cluster 1 (n=384) consumers found monk fruit and stevia leaf extract and stevia leaf extract the most appealing sweeteners. These consumers also reported sucrose and cane sugar as the least appealing yogurt sweeteners with sucralose and acesulfame K (AceK) also not appealing, although less so than sucrose/cane sugar. Cluster 1 consumers were categorized as the *natural alternative sweeteners cluster*. Cluster 2 (n=516) consumers found honey the most appealing sweetener in yogurt and were identified as the *honey cluster*. The third cluster 3 (n=390) reported cane sugar and sucrose as the most appealing sweeteners. This cluster was categorized as the *traditional sweetener cluster*.

Iso-Sweetness Values

Results from MES and power function curves confirmed that stevia was the most potent sweetener followed by sucrose, allulose, and honey powder (Table 6). These results are consistent with previous literature that have reported that stevia can be 150 to 300 times sweeter than sucrose (Cardello et al., 1999; Ashwell, 2015). It was also expected for allulose to be less potent than sucrose. Allulose has been documented to be approximately 70% as sweet as sucrose (Zhang et al., 2021), similar to the results of this study (relative sweetness of 0.6 in the current study). An interaction ($p<0.05$) was noted for vanilla flavor and allulose in 1% milkfat yogurt (Table 5). Less allulose was needed in yogurts with allulose that had added vanilla compared to yogurts that did not have vanilla. Studies performed previously have investigated the role of vanilla flavor to increase perception of sweet taste intensity. Oliveira et al. (2021) observed that vanilla flavoring increased sweet taste perception in reduced sugar vanilla yogurt and Wang et al., (2018) also noted increased sweet taste perception in reduced sugar skim milk with added vanilla flavoring. In this study, interactions with vanilla were not noted for other sweeteners ($p>0.05$). Minor adjustments to sweetener concentrations were required following descriptive analysis and 2-AFC tests (Table 7).

Descriptive Analysis

Descriptive analysis was performed on vanilla yogurts with the selected sweeteners and sweetener blends in conjunction with consumer testing. As expected, sensory attributes were generally similar with a few exceptions (Table 8). Cooked/milky flavor was highest in the SUC yogurt and detected at lowest intensity in the STE yogurt. Diacetyl was only detected in the SUC, ALL, and ALL blend yogurts. SUC yogurt had the highest vanilla flavor intensity and STE yogurts had the lowest. Bitter taste was detected in STE and ALL blend yogurts, and metallic was detected in STE, ALL and ALL blend yogurts. Yogurts with STE were also more astringent than other yogurts. These results are consistent with previous studies. Li et al. (2015) observed higher bitter taste and astringency in chocolate milk sweetened with stevia compared to chocolate milks with sucrose, and Keefer et al. (2020) noticed protein bars sweetened with stevia and also monk fruit had increased bitterness and metallic taste compared to bars sweetened with sucrose, fructose, and sucralose. Recent studies with allulose have reported bitter, metallic, and chemical side tastes in aqueous solutions of 13.31% w/v (Tan et al., 2019) and in 6%, 7.5%, 9%, 10.5%, and 12% w/v solutions (Jung et al., 2021).

Consumer Acceptance Testing

Interactions between priming and consumer liking of yogurts with different sweeteners were not detected ($p>0.05$) except for appearance and color liking. Priming increased ($p<0.05$) appearance liking for the ALL, STE, HP blend, and the ALL blend yogurts, and increased color liking for the ALL and HP blend yogurts (results not shown). For all other liking attributes, main effects were noted ($p<0.05$) (Table 9). Yogurt with SUC was the most liked yogurt receiving the highest scores for overall liking, vanilla flavor liking, sweet taste liking, and sourness/tartness liking (Table 8). Yogurt with STE was the least liked. Priming consumers with the specific sweetener increased all liking scores compared to no priming (Table 10). Priming consumers has been found to influence liking scores. Oltman et al. (2015) identified that priming with declaration of great flavor and amount of protein increased product concept liking of protein beverages, while Parker et al., (2018) observed that priming with type of sweetener increased overall liking scores for protein beverages made with natural sweeteners for label conscious consumers and increased overall liking scores for flavor driven consumers for beverages sweetened with sucralose.

Consumer JAR percentages were generally consistent with liking scores (Tables 11, 12). Yogurt with SUC had the fewest penalties and was the most liked yogurt while yogurts that were less liked had more penalties. All of the yogurts were penalized for not enough vanilla flavor, regardless of priming. Fewer penalties were documented among the yogurts sweetened with other sweeteners when consumers were primed compared to when they were not. As an example, unprimed consumers indicated that the ALL yogurt flavor was too weak and too strong, was both not sweet enough and was too sweet, and was too sour/tart. Primed consumers specified that the flavor too strong, was both not sour/tart enough and too sour/tart. The yogurts sweetened with other ALL, STE, HP blend or ALL blend were penalized for being too sweet and too sour when unprimed. Yogurt with STE was penalized for being too sweet and too sour, regardless of priming. These results possibly reference that consumers can detect sweetener-specific sensory attributes (e.g. these yogurts were not sweetened with sucrose) and when unprimed, more and/or conflicting JAR penalties were documented. The HP blend yogurt had penalties for the flavor being too strong and too sweet for both primed and unprimed consumers. Unprimed consumers noted this yogurt was too dark and had too strong of an aroma, but this these attributes were not penalized when consumers were aware that the yogurt was sweetened with a honey blend.

Purchase intent scores for primed consumers (Figure 5) were not impacted by tasting for the SUC, ALL and ALL blend yogurts, while purchase intent scores decreased for yogurts sweetened with STE and HP blend following tasting and this decrease was largest for STE yogurts. Primed consumers found that the taste of the SUC and HP blend yogurts more natural than unprimed consumers (Figure 6). Both primed and unprimed consumers found the SUC sample to be the most natural, suggesting that at iso-sweetness, yogurts with nonnutritive sweeteners are not identical to a sucrose sweetened yogurt, consistent with trained panel results. Additionally, both groups of consumers indicated that the ALL, ALL blend, and STE yogurts did not taste natural with the STE sample receiving the lowest (most artificial) scores.

Consumers differentiated the yogurts using (CATA) ($p<0.05$) with all attributes except for 'fermented' significant (Figures 7, 8). Primed and unprimed consumers selected similar attributes. Both primed and unprimed consumers found the SUC yogurt to be 'creamy and indulgent.' In addition, both groups of consumers found the HP blend to be 'natural,' 'healthy,' and 'good-for-me.' For the ALL yogurt, both primed and unprimed consumers found this yogurt to be 'bitter.' Primed consumers also indicated that the ALL yogurt was 'sour' and 'astringent,' while unprimed consumers described this sample as 'metallic. The STE yogurt was described as 'astringent' by both consumers groups, and 'bitter' for primed consumers and 'sour' and 'astringent' for unprimed consumers. The ALL blend for primed consumers was characterized as 'metallic' and by unprimed consumers as 'creamy'.

DISCUSSION

From the online survey, respondents conceptually preferred naturally sweetened, reduced sugar yogurt, and found yogurt sweetened with honey the most appealing. This preference is most likely due to the idea that ‘naturally sweetened’ is perceived as healthier. The term ‘natural’ is seen by consumers as something that coincides with healthiness/low health risk, while artificial/unnatural foods are considered to be a higher health risk to consume (Bearth et al., 2014). Sipple et al. (2022) noted that naturally sweetened frozen desserts/ice creams were perceived as healthier or better-for-you by consumers than artificially sweetened frozen desserts/ice creams. A focus on natural sweeteners might also align with a desire for reduced sugar label claims. (Parker et al., 2018) observed that consumers desired protein beverages that were naturally sweetened in conjunction with reduced sugar/calories. Parker et al. (2018) also reported two segments of protein beverage consumers: label conscious consumers and flavor driven consumers. Li et al. (2014) documented that parents conceptually desired naturally sweetened chocolate milks for their children with sweetener type the most important attribute.

Familiarity of the ingredient can also impact perceived naturalness. A study conducted by Chambers et al. (2019) evaluated the perceived naturalness of 30 different ingredients. One of the factors that played a role in the perception of the naturalness of the ingredients was consumer familiarity. Consumers who were not as familiar with an ingredient were most likely to find those ingredients not natural (Chambers et al., 2019). In the present study, the statement ‘I am familiar with different ingredients that are used to sweeten yogurt’ was ranked lower than other statements implying most participants were not familiar with types of sweeteners found in yogurt (Table 2). Participants were most familiar with honey which may have led to why respondents found honey to be the most appealing sweetener. Interestingly, other than honey, respondents found cane sugar more preferred than sucrose, suggesting a gap in knowledge since cane sugar is a type of sucrose. Additionally, participants were least familiar with allulose. Allulose is a fairly new sweetener which obtained GRAS status in 2012 with the recommended maximum intake no greater than 30g per day (Tate & Lyle, personal communication). A survey conducted in 2021 determined that 66% of the 992 participants did not know what allulose was (Food Insight, 2021), consistent with the results of the current study. Consequently, a lack of familiarity may be why respondents found allulose to not be an appealing sweetener.

Consumers placed a strong emphasis on viewing nutrition information more so than label claims in the current study, which could indicate that the nutrition label and ingredient deck are the item(s) that consumers reference the most when deciding how natural a product is despite any label claims present on the package. Aligning with this trend, many consumers are also seeking products that have a clean label. There is no legal definition of clean label. However, one of the components of a clean label to many consumers is a short ingredient list with simple ingredients (Asioli et al., 2017), which is consistent with some consumer sweetener segments from MaxDiff finding a short ingredient list *attractive*.

Survey respondents demonstrated a high level of proficiency when interpreting information on a nutrition facts label, but the percentage of participants selecting the correct amount of added sugar noticeably declined compared to amount of protein. The FDA in May 2016 announced the final revised version of the nutrition facts label. These changes included a separate display of *added* sugars along with including the percent daily value (Kim et al., 2021). Kim et al. (2021) conducted a survey to understand how these changes affected consumer understanding of the nutrition facts label. One of the questions asked to participants was “What percentage (%) of the total sugars come from added sugars in one serving of this food?” Only

32.9% of respondents correctly answered the added sugar question from the single column nutrition facts label correctly (Kim et al., 2021). This evidence supports that consumers are still having difficulties understanding total sugar and added sugar information on these 2016 nutrition facts label guidelines.

Results from the MaxDiff exercises identified distinct consumer clusters for both the preferred sugar claims and preferred sweetener exercises. These clusters identified that there are various consumer segments for sweeteners. This observation is relevant to findings made by Li et al. (2014) with parental desires for chocolate milk for their children. Distinct clusters of parents were documented with different ideal chocolate milk attributes for their children. Traditional parents preferred chocolate milk sweetened with sucrose (regular sugar content), another group of parents (all natural and organic) preferred naturally sweetened chocolate milk sweetened noncaloric/nonnutritive sweeteners followed by sucrose, and the health conscious parents preferred reduced or no added sugar chocolate milk (Li et al., 2014). The current study also identified clusters of consumers that preferred traditional sweetener consumers and consumers that preferred natural sweeteners for both the sugar claims and sweetener exercises (Figures 3 and 4). Cane sugar and sucrose received the highest utility scores from the traditional sweetener consumers, while this same segment of consumers gave alternative sweeteners low utility scores (Figure 4). Conversely, stevia and monk fruit/stevia blend received the highest utility scores from the natural sweetener consumers. This group of consumers also gave the lowest utility scores for cane sugar and sucrose.

Consistent with the MaxDiff results, the Kano results from this study identified a portion of respondents that found reduced sugar *attractive*. These same respondents also found probiotics and short ingredient label attributes as *attractive*, possibly suggesting that these consumers are more likely to look at the label claims and/or the nutrition facts label on products. It is important to take note that these participants were from cluster 1 (reduced sugar/ artificial sweetener consumers) from the sugar claims MaxDiff and cluster 1 (natural alternative sweetener consumers) from the sweetener MaxDiff, which suggests that these consumer groups are more likely to accept alternative sweeteners in yogurts. Parker et al. (2018) also observed that label conscious consumers had increased liking scores when primed about the type of sweetener in their protein beverage. In the current study, most respondents found high protein an *attractive* attribute and all clusters found flavor to be a *performance* attribute. Greek yogurt remains a market leader in the yogurt category and consumers are aware that Greek yogurt contains more protein than regular yogurt (Desai et al., 2013). Li and Dando (2019) observed that consumers liked vanilla yogurts labeled with high protein and low-fat compared to no label claim, a low-fat label claim, or made with stevia label claim.

Flavor was the main driver of consumer acceptance among the yogurts. Regardless of primed status, consumers gave the SUC yogurt higher acceptance scores for each liking attribute when compared to the ALL, STE, HP blend and the ALL blend yogurts. Focusing on each sweetener individually, not many studies have examined consumer acceptance of yogurt sweetened with allulose. Notably, Mora et al. (2022) conducted a consumer acceptance test with sucrose, allulose, stevia, and sucralose in vanilla fat free Greek yogurt. Mora et al. (2022) observed no differences in overall liking and flavor liking among yogurts sweetened with sucrose, allulose, and sucralose. While these results show encouraging potential for allulose, the authors did not confirm the iso-sweetness of the yogurts with different sweeteners but relied on literature values from a previous study that focused on dose response behavior of sweeteners in a water solution. As such, differences (or lack of) in liking due to differences in sweet taste cannot be ruled out. Additionally, this test used plain fat free Greek yogurt, which has different sensory properties than low-fat plain yogurt. With this in mind, the results from this study cannot be fully applicable to the present study where vanilla yogurt sweetened with sucrose was preferred over vanilla yogurts sweetened with other sweeteners/sweetener blends at iso-sweet taste intensity.

For the current study, trained panelists documented differences among the yogurts with different sweeteners at iso-sweet taste intensities and so did consumers. Consumers differentiated yogurts with alternative sweeteners from the SUC yogurt in overall liking and provided further insights by JAR and CATA scaling. The ALL yogurt received higher scores for vanilla flavor and sweet taste liking compared to yogurts with STE and higher sweet taste liking than ALL blend yogurts. Allulose is known to be bitter and metallic when compared to sucrose, but still exhibits less bitter and metallic side tastes than other alternative sweeteners such as stevia (Tan et al., 2019). No bitter taste was detected in the ALL yogurt by DA, and only slight metallic taste was detected by DA. Additionally, when primed, consumers indicated through JAR scores that this sample had too strong of a flavor and not enough vanilla flavor, while unprimed consumers gave these attributes conflicting penalties. This possibly signifies that, while the ALL sample had lower side tastes than the STE yogurt, these side tastes were still noticeable by (at least some) consumers leading to penalties for this yogurt for primed consumers and conflicting penalties for unprimed consumers. However, since the presence of side tastes were still low in the ALL yogurt, this might explain higher consumer acceptance for vanilla flavor and sweet taste liking for this yogurt.

Respondents from the online survey indicated honey as their most preferred yogurt sweetener, but the HP blend yogurt was not as well liked as a yogurt sweetened with sucrose with or without priming (Table 8). Cano-Lamadrid et al. (2020) also obtained similar results for pomegranate/apple juice jelly candies sweetened with either sucrose or honey. Comparable to the present study, these authors also evaluated unprimed and primed consumers. Part of priming consumers involved disclosing which sweetener was used in the jelly candies. The highest overall liked jelly candy for both primed and unprimed consumers was sweetened with sucrose (Cano-Lamadrid et al., 2020). Yogurt sweetened with stevia received the lowest liking scores, also analogous to other studies. (Pereira et al., 2021a) observed that stevia sweetened mango yogurt was the least accepted yogurt among mango yogurts sweetened with sucrose, thaumatin, and fructooligosaccharide or blends of those sweeteners. Mora et al. (2022) also documented the lowest liking scores for Greek yogurt sweetened with stevia. Primed and unprimed consumers for the present study, characterized the STE yogurt as bitter, metallic, and astringent (Tables 13 and 14), consistent with trained panelists (Table 8). Similarly, trained panelists characterized stevia sweetened mango yogurts as having bitter taste, bitter aftertaste, metallic flavor, and astringency (Pereira et al., 2021).

Stevia received GRAS status in 2008, which is why more people are most likely more familiar with stevia than allulose (Table 3). Primed consumers also indicated through purchase prior to tasting, that they were open to purchasing yogurt with stevia. However, after tasting the STE yogurt, purchase intent scores significantly decreased demonstrating that the sensory experience of yogurt with stevia as not consistent with expectations. Other studies have also noticed similar findings. Sipple et al. (2022) observed that there were no significant differences in purchase scores for primed consumers prior to tasting frozen desserts sweetened with sugar, acesulfame k and sucralose, stevia and erythritol, and monk fruit and allulose. After tasting though, purchase intent scores decreased for the desserts sweetened with stevia and erythritol and monk fruit and allulose. Parker et al. (2018) also observed that primed consumers gave high concept liking scores for protein beverages sweetened with stevia before tasting indicating a high theoretical acceptance of this sweetener. However, after tasting with or without priming, overall liking scores suggested a decrease in consumer acceptance compared to concept liking. These consistent results illustrate that the concept of stevia is appealing to consumers, but stevia does not meet consumer expectations.

The ALL blend yogurt received an overall liking score from consumers that was not different from the ALL or HP blend yogurt, but the sweet taste liking of this yogurt was lower than that of ALL or HP blend yogurts (Table 9). Trained panelists also documented differences from this yogurt compared to the SUC yogurt (Table 8). These side tastes were not as prominent as the side tastes in the STE yogurt (Table 8). Blends have been utilized to help mask side tastes from alternative sweeteners (Heikel et al., 2012; Parker et al., 2018; Pereira et al., 2021a). As a result, in the current study, a blend containing sucrose was favorable to use to assist in masking the side tastes of allulose and stevia. Additionally, BYO results suggested that consumers were accepting of low amounts of added sugar even though 'no added sugar' was preferred for the sugar claims MaxDiff. Though the ALL blend yogurt scored higher than the STE yogurt for all liking attributes, the ALL blend yogurt underperformed for sweet taste liking compared to the ALL and HP blend yogurts.

Purchase intent decreased after tasting for all yogurts except the SUC yogurt. The decrease in PI following tasting when primed suggests that yogurts sweetened with sweeteners other than sucrose did not meet expectations (Figure 5), and this decrease was most marked for yogurts sweetened with stevia. These results demonstrate that while conceptually alternative sweeteners may be appealing, in actuality, consumers remain driven by flavor of the product. Sipple et al. (2022) noted similar results in better-for-you frozen dairy desserts sweetened with alternative sweeteners. Prior to tasting, primed consumers gave the frozen desserts sweetened with stevia or with monk fruit/allulose purchase intent scores greater than a 3 on a 5-point scale. Following tasting, purchase intent decreased significantly for the frozen desserts with either of these sweetener/sweetener blends. Interestingly, even though purchase intent for primed consumers decreased once they tasted vanilla yogurt with honey, primed consumers still believed the HP yogurt to taste as natural as the SUC yogurt (Figure 6) confirming that consumers believe that honey is a natural sweetener. Perhaps consumers like the natural concept of honey as a sweetener but do not like how it actually tastes in yogurt.

A potential limitation of this study was the texture/viscosity of the yogurts. To keep uniformity among yogurts, powdered/granulated versions of the sweeteners were used. However, this process impacted texture of the HP blend yogurt. The HP blend received the lowest texture liking score along with consumers indicating that this yogurt was not thick enough. Additionally, it would be interesting to perform a study with alternative sweeteners in conjunction with different varieties of honey as different varieties of honey are known to have diverse flavors (Farooq et al., 2020). Popa and Ustunol (2011) performed a consumer acceptance test with sage honey, alfalfa honey, sourwood honey, high fructose corn syrup, and sucrose sweetened strawberry yogurts. Differences in liking were documented among yogurts sweetened with different honeys. At iso sweetness, differences remained among the yogurts with alternative sweeteners compared to sucrose. Future studies with temporal sensory evaluations might assist with clarification of specific sensory attributes for sensory optimization of yogurts with alternative sweeteners.

CONCLUSIONS

Online survey respondents indicated that naturally sweetened reduced sugar yogurts were preferred. Stevia was the non nutritive sweetener that consumers were most familiar with while allulose was the least. Priming with the sweetener source increased liking for vanilla yogurts, regardless of sweetener type. Vanilla yogurts sweetened with sucrose were preferred over yogurts with honey/sucrose, allulose, stevia or allulose/stevia/sucrose blends. Yogurts sweetened with allulose or allulose/stevia/sucrose blends were liked more than yogurts sweetened with stevia alone suggesting that further studies should explore the utilization of allulose alone or with blends. Consumers remain interested in sugar reduction and/or replacement in yogurts. However, the flavor of the product remains the main driver for consumer acceptance

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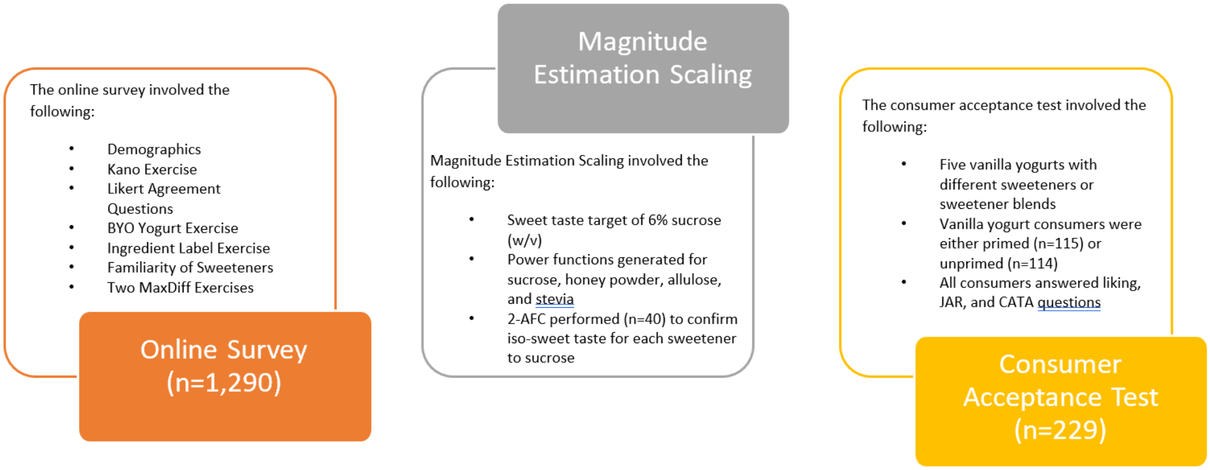

Figure 2.1: Overview of experimental design.

Figure 2.2: Conceptual nutrition label used for online survey.

Table 2.1: Priming statements shown to consumers in the consumer acceptance test (n=115).

Item	Priming Statement
SUC	The vanilla yogurt you are about to taste is naturally sweetened with SUCROSE (table sugar/ cane sugar)
ALL	The vanilla yogurt you are about to taste is naturally sweetened with ALLULOSE, a natural very low calorie sweetener.
STE	The vanilla yogurt you are about to taste is naturally sweetened with STEVIA, a natural non-caloric sweetener.
HP Blend (50:50 sucrose and honey powder)	The vanilla yogurt you are about to taste is naturally sweetened with a blend of HONEY AND SUCROSE (table sugar/ cane sugar)
ALL Blend (50:10:40 allulose, sucrose, and stevia)	The vanilla yogurt you are about to taste is naturally sweetened with a blend of SUCROSE (table sugar/ cane sugar), ALLULOSE (a natural very low calorie sweetener), and STEVIA (a natural non-caloric sweetener).

Table 2.2: Agreement scores of yogurt statements from online survey (n=1,290).

Summarized Agree/disagree statements	Agreement Score
I consume yogurt because I enjoy the flavor or texture	4.2a
I enjoy trying new flavors and varieties of yogurts	4.0b
I consume yogurt because it supports my digestive or gut health	3.9bc
I am interested in trying novel or unusual yogurt products	3.8cd
Most yogurts available today contain too much sugar	3.7def
reducing the sugar content of yogurt makes it a healthier product	3.7de
I would prefer to buy an all-natural yogurt product that has a higher total sugar content	3.6ef
I consume yogurt because it supports my bone health	3.5f
I typically read the ingredient list when purchasing yogurt	3.5ef
I am familiar with different ingredients that are used to sweeten yogurt	3.2g
I always buy the same brand of yogurt	3.1gh
Organic contains less sugar than conventional yogurt	3.0hi
I would prefer to buy an all-natural yogurt product that has a higher total sugar content	2.9i
Most yogurts today have similar nutritional value	2.9i
Plant-based yogurts are healthier than those made with dairy milk	2.8ij
Healthier yogurts have worse flavor and texture than indulgent yogurts	2.6j
When purchasing yogurt I am willing to sacrifice flavor and texture for health benefits	2.6j
I would prefer to buy a yogurt product that a lower total sugar content and contains artificial non-nutritive sweeteners	2.4k

Table 2.3: Familiarity scores of sweeteners from online survey (n=1,290).

Sweetener	Familiarity Score
Honey	4.6a
Sucrose (Table Sugar)	4.3b
Corn Syrup	4.1c
Cane Sugar	4.0c
Fructose	3.7d
Stevia Leaf Extract	3.3e
Agave Nectar	3.2e
Sucralose	2.5f
Monk Fruit	2.2g
Erythritol	1.8h
Acesulfame Potassium (AceK)	1.5i
Allulose	1.3j

Means in column followed by a different letter are significantly different ($p < 0.05$). Familiarity was scored on a 5-point scale where 1=not at all familiar, 2= slightly familiar, 3= somewhat familiar, 4= moderately familiar, and 5= extremely familiar

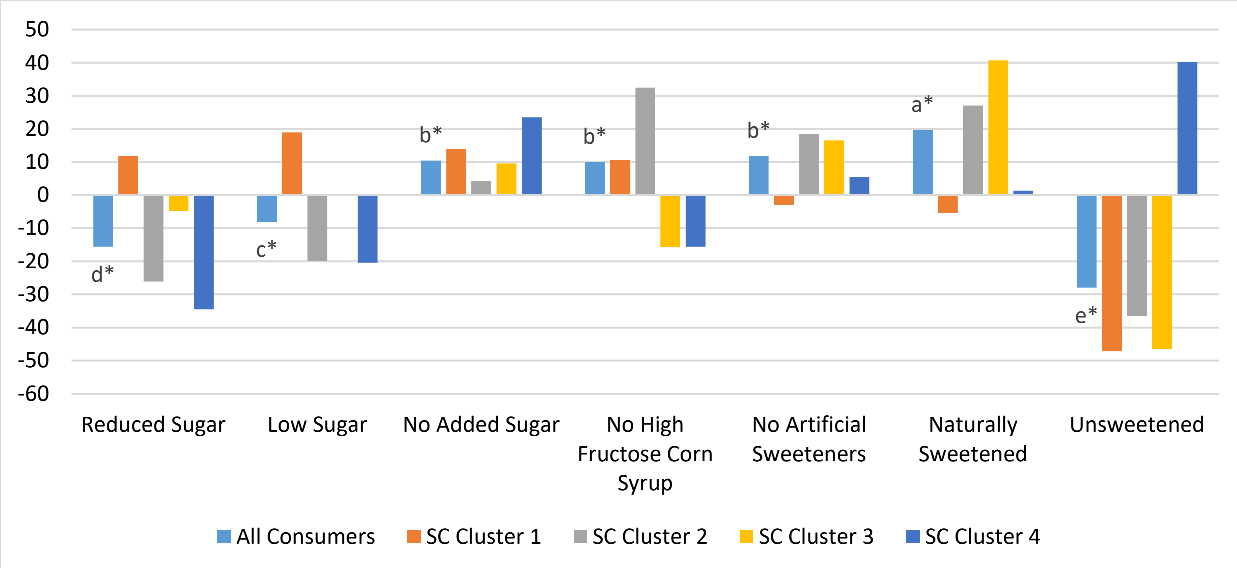

Figure 2.3: Clustered and overall maximum difference scores for preferred sugar claims (SC) MaxDiff exercise from online survey. Maximum difference scores are zero-centered, and higher (more positive) scores are representative of more appealing levels within an attribute, while lower (more negative) scores represent less appealing characteristics. Cluster 1: reduced sugar/ artificial sweetener consumers (n= 247), Cluster 2: traditional sweetener consumers (n=551), Cluster 3: natural sweetener consumers (n=279), and Cluster 4: unsweetened/ no sweeteners consumers (n=213). All consumers are all respondents who completed the online survey (n=1,290). *Different letters indicate significant differences among all consumers (p<0.05).

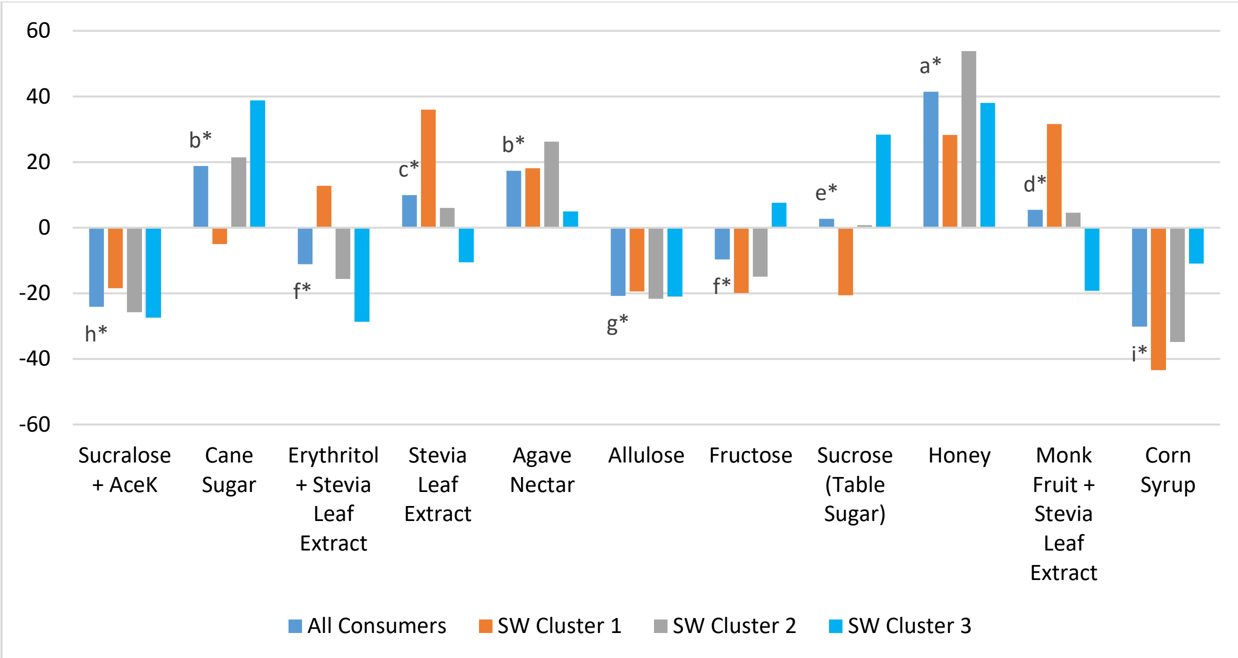

Figure 2.4: Clustered and overall maximum difference scores for preferred sweetener (SW*)* MaxDiff exercise from online survey. Maximum difference scores are zero-centered and, higher (more positive) scores are representative of more appealing levels within an attribute, while lower (more negative) scores represent less appealing characteristics. Cluster 1: natural alternative sweetener consumers (n= 384), Cluster 2: honey consumers (n= 516), Cluster 3: traditional sweetener consumers (n=279). All consumers are all respondents who completed the online survey (n=1,290). *Different letters indicate significant differences among all consumers (p<0.05).

Table 2.4: Kano results of the total population and clustered responses from sugar label claims MaxDiff.

Feature	Total pop. (n=1,290)	Cluster 1 (n=247)	Cluster 2 (n=551)	Cluster 3 (n=279)	Cluster 4 (n=213)
Reduced Sugar	Indifferent	**Attractive**	Indifferent	Indifferent	Indifferent
High Protein	**Attractive**	**Attractive**	**Attractive**	**Attractive**	Indifferent
Low Fat	Indifferent	Indifferent	Indifferent	Indifferent	Indifferent
High Calcium	Indifferent	Indifferent	Indifferent	Indifferent	Indifferent
Fortified	Indifferent	Indifferent	Indifferent	Indifferent	Indifferent
Probiotics	Indifferent	**Attractive**	Indifferent	Indifferent	Indifferent
Tastes Good	**Performance**	**Performance**	**Performance**	**Performance**	**Performance**
Indulgent	Indifferent	Indifferent	Indifferent	Indifferent	Indifferent
Natural Ingredients	Indifferent	Indifferent	Indifferent	Indifferent	Indifferent
Short Ingredient Label	Indifferent	**Attractive**	Indifferent	Indifferent	Indifferent

Kano classification was calculated by previously described methods (Kano, 1984; Erto et al., 2011; Oltman et al., 2015).
Indifferent indicates that the consumer does not care about that attribute.
Attractive indicates that the attribute is unexpected by the consumer; consumers are satisfied if this attribute is present.
Performance (one-dimensional)- indicates that as the attribute increases, so does consumer liking.
Bolding indicates that the attribute is either an attractive or a performance attribute.

Table 2.5: Kano results of the total population and clustered responses from sweetener MaxDiff.

Feature	Total pop. (n=1,290)	Cluster 1 (n=384)	Cluster 2 (n=516)	Cluster 3 (n=390)
Reduced Sugar	Indifferent	**Attractive**	Indifferent	Indifferent
High Protein	**Attractive**	**Attractive**	**Attractive**	Indifferent
Low Fat	Indifferent	Indifferent	Indifferent	Indifferent
High Calcium	Indifferent	Indifferent	Indifferent	Indifferent
Fortified	Indifferent	Indifferent	Indifferent	Indifferent
Probiotics	Indifferent	**Attractive**	Indifferent	Indifferent
Tastes Good	**Performance**	**Performance**	**Performance**	**Performance**
Indulgent	Indifferent	Indifferent	Indifferent	Indifferent
Natural Ingredients	Indifferent	Indifferent	Indifferent	Indifferent
Short Ingredient Label	Indifferent	**Attractive**	Indifferent	Indifferent

Kano classification was calculated by previously described methods (Kano, 1984; Erto et al., 2011; Oltman et al., 2015).
Indifferent indicates that the consumer does not care about that attribute.
Attractive indicates that the attribute is unexpected by the consumer; consumers are satisfied if this attribute is present.
Performance (one-dimensional)- indicates that as the attribute increases, so does consumer liking.
Bolding indicates that the attribute is either an attractive or a performance attribute.

Table 2.6:. Effect of vanilla flavor on the iso-sweet point of each sweetener to a 6% sucrose solution in 1% milkfat yogurt. Results are reported in g of sweetener per 500g of total product.

Item	Iso-sweet point (g of sweetener)
Honey Powder	139.5 a
Honey Powder w/ Vanilla	137.6 a
Allulose	99.3 b
Allulose w/ Vanilla	80.6 c
Sucrose w/ Vanilla	51.0 d
Sucrose	47.8 d
Stevia w/ Vanilla	0.49 e
Stevia	0.31 e

Means in column followed by a different letter are significantly different ($p < 0.05$).

Table 2.7: Formulations of sweeteners and blends in yogurt with and without vanilla flavoring (per 500g of total product).

Item	Sucrose (g)	Honey Powder (g)	Allulose (g)	Stevia (g)	Vanilla Flavoring (g)
Sucrose	47.7	-	-	-	-
Honey Powder	-	139.4	-	-	-
Allulose	-	-	99.5	-	-
Stevia	-	-	-	0.325	-
SUC	46.60	-	-	-	3.75
ALL	-	-	80.48	-	3.75
STE	-	-	-	0.510	3.75
HP Blend	23.30	68.70	-	-	3.75
ALL Blend	4.30	-	33.51	0.211	3.75

SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations that proceeded to consumer testing.

Table 2.8: Descriptive analysis means of yogurt formulations used in consumer acceptance testing.

Item	SUC	ALL	STE	HP Blend	ALL Blend
Aroma Intensity	3.0a	3.0a	3.0a	3.1a	3.0a
Visible Whey	ND	ND	ND	ND	ND
Surface Gloss	13.8a	13.8a	13.8a	13.7a	13.7a
Smoothness	12.8a	12.8a	12.8a	12.8a	12.8a
Firmness	2.2a	2.4a	2.2a	2.0a	2.1a
Cooked/milky	3.8a	3.4b	3.3b	3.5b	3.6b
Dairy Sour	2.5a	2.6a	2.5a	2.5a	2.5a
Diacetyl	0.7a	0.6a	ND	ND	0.6a
Vanilla	3.5a	3.1b	2.5c	1.6d	3.2b
Honey Aromatic	---	----	---	2.4	---
Acetaldehyde	1.4a	1.1b	1.1b	1.4a	1.4a
Milkfat	1.5a	1.3b	1.2b	1.5a	1.5a
Sweet	6.0a	6.0a	5.9a	6.0a	6.0a
Sour	1.8a	1.9a	2.0a	1.9a	1.9a
Bitter	ND	ND	1.0a	ND	0.5b
Astringent Mouthfeel	1.8c	1.9b	2.4a	1.8b	1.8b
Metallic	ND	0.6b	1.6a	ND	0.6b
Aftertaste Intensity	ND	0.6c	1.3a	ND	1.0b

Means in a row followed by a different letter are different ($p < 0.05$). Attributes were scored on a 0 to 15 point universal intensity scale (Meilgarrd et al., 2007). SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations that proceeded with consumer testing.
Lexicon was adapted from Desai et al., 2013.
ND = Not Detected

Table 2.9: Liking means for vanilla yogurt with different sweeteners for all consumers.

Sample	Aroma Liking	Overall Liking	Flavor Liking	Vanilla Flavor Liking	Sweet Taste Liking	Sourness/ Tartness Liking	Texture Liking
SUC	6.8a	7.3a	7.2a	7.0a	6.9a	6.7a	7.3a
ALL	6.7a	5.9b	6.0b	6.1b	5.9b	5.7bc	6.6b
STE	6.8a	4.8c	4.5c	5.2d	4.4d	5.0d	6.9b
ALL Blend	6.7a	5.9b	5.8b	6.1b	5.4c	6.0b	6.9b
HP Blend	6.3b	5.9b	5.9b	5.7c	6.0b	5.6c	6.0c

Data represents all consumers (n=229).
Means within a column followed by a different letter are significantly different ($p < 0.05$)
SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia).
Liking attributes were scored on a 9-point hedonic scale, where dislike extremely = 1 and like extremely =
Interactions were detected for appearance and color liking ($p < 0.05$). Main effects were significant ($p < 0.05$) for other consumer liking attributes.

Table 2.10: Liking means for vanilla yogurt for unprimed and primed consumers.

Priming	Aroma Liking	Overall Liking	Flavor Liking	Vanilla Flavor Liking	Sweet Taste Liking	Sourness/ Tartness Liking	Texture Liking
Unprimed	6.5b	5.8b	5.7b	5.9b	5.5b	5.7a	6.6b
Primed	6.8a	6.1a	6.0a	6.2a	5.9a	5.9a	6.9a

Data represents unprimed consumers (n=114) and primed consumers (n=115).
Means within a column followed by a different letter are significantly different ($p < 0.05$) between primed and unprimed consumers.
SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations that proceeded with consumer testing.
Liking attributes were scored on a 9-point hedonic scale, where dislike extremely = 1 and like extremely = 9
Interactions for primed status by sweetener type were not significant ($p < 0.05$).

Table 2.11: JAR scores for primed consumers (n=115).

Variable	Level	SUC	ALL	STE	HP Blend	ALL Blend
Color JAR	Too Light	4.3%a	5.2%a	7.0%a	2.6%a	7.0%a
	Just About Right	89.6%a	79.1%a	88.7%a	60.9%b	89.6%a
	Too Dark	6.1%bc	15.7%b	4.3%bc	36.5%a	3.5%c
Aroma JAR	Too Weak	**20.0%a**	12.2%a	15.7%a	11.3%a	8.7%a
	Just About Right	71.3%a	73.9%a	68.7%a	73.9%a	77.4%a
	Too Strong	8.7%a	13.9%a	15.7%a	14.8%a	13.9%a
Flavor JAR	Too Weak	13.0%a	13.0%a	10.4%a	17.4%a	7.8%a
	Just About Right	77.4%a	61.7%ab	33.0%c	53.0%b	61.7%ab
	Too Strong	9.6%c	**25.2%b**	**56.5%a**	**29.6%b**	**30.4%b**
Vanilla Flavor JAR	Not Enough Vanilla Flavor	**24.3%b**	**33.0%ab**	**42.6%ab**	**50.4%a**	**29.6%b**
	Just About Right	71.3%a	57.4%ab	42.6%b	45.2%b	57.4%ab
	Too Much Vanilla Flavor	4.3%a	9.6%a	14.8%a	4.3%a	13.0%a
Sweetness JAR	Not Sweet Enough	6.1%a	15.7%a	11.3%a	7.0%a	4.3%a
	Just About Right	76.5%a	68.7%a	31.3%c	60.0%ab	44.3%bc
	Too Sweet	17.4%cd	15.7%d	**57.4%a**	**33.0%bc**	**51.3%ab**
Sourness/Tartness JAR	Not Sour/Tart Enough	15.7%a	**21.7%a**	27.0%a	**31.3%a**	18.3%a
	Just About Right	77.4%a	56.5%bc	44.3%c	59.1%abc	66.1%ab
	Too Sour/Tart	7.0%c	**21.7%ab**	**28.7%a**	9.6%bc	15.7%abc
Thickness JAR	Too Thin	12.2%bc	**23.5%ab**	4.3%c	40.0%a	16.5%b
	Just About Right	86.1%ab	71.3%bc	88.7%a	58.3%c	78.3%ab
	Too Thick	1.7%a	5.2%a	7.0%a	1.7%a	5.2%a

Different letters in rows following means signify significant differences ($p < 0.05$).
SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations.
JAR questions were scored on a 5-point scale where 1 or 2 = too little, 3 = just about right, and 4 or 5 = too much.
Percentage of consumers that selected these options are presented.
Bolding indicates a significant mean drop.

Table 2.12: JAR scores for unprimed consumers (n=114).

Variable	Level	SUC	ALL	STE	HP Blend	ALL Blend
Color JAR	Too Light	7.0%a	5.3%a	10.5%a	1.8%a	9.6%a
	Just About Right	86.0%a	78.9%a	86.0%a	41.2%b	83.3%a
	Too Dark	7.0%ab	15.8%b	3.5%c	**57.0%a**	7.0%ab
Aroma JAR	Too Weak	18.4%a	34.2%a	22.8%a	21.1%a	28.9%a
	Just About Right	65.8%a	56.1%a	64.9%a	57.9%a	57.9%a
	Too Strong	15.8%a	9.6%a	12.3%a	**21.1%a**	13.2%a
Flavor JAR	Too Weak	13.2%a	**20.2%a**	**20.2%a**	17.5%a	14.9%a
	Just About Right	74.6%a	46.5%b	30.7%b	47.4%b	48.2%b
	Too Strong	12.3%b	**33.3%a**	**49.1%a**	**35.1%a**	**36.8%a**
Vanilla Flavor JAR	Not Enough Vanilla Flavor	**25.4%b**	**37.7%ab**	**54.4%a**	**48.2%a**	**36.8%ab**
	Just About Right	67.5%a	50.0%ab	32.5%b	36.0%b	46.5%a
	Too Much Vanilla Flavor	7.0%a	12.3%a	13.2%a	15.8%a	16.7%a
Sweetness JAR	Not Sweet Enough	12.3%a	**21.1%a**	**27.2%a**	18.4%a	12.3%a
	Just About Right	71.9%a	52.6%ab	30.7%c	50.9%b	51.8%b
	Too Sweet	15.8%b	**26.3%ab**	**42.1%a**	**30.7%ab**	**36.0%a**
Sourness/Tartness JAR	Not Sour/Tart Enough	10.5%a	16.7%a	19.3%a	21.1%a	11.4%a
	Just About Right	68.4%a	56.1%ab	41.2%b	57.0%ab	66.7%a
	Too Sour/Tart	21.1%b	**27.2%ab**	**39.5%a**	**21.9%ab**	**21.9%ab**
Thickness JAR	Too Thin	15.8%ab	29.8%b	4.4%c	**57.9%a**	16.7%b
	Just About Right	75.4%a	67.5%a	78.9%a	40.4%b	72.8%a
	Too Thick	8.8%ab	2.6%b	16.7%a	1.8%b	10.5%ab

Different letters in rows following means signify significant differences ($p < 0.05$).
SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations.
JAR questions were scored on a 5-point scale where 1 or 2 = too little, 3 = just about right, and 4 or 5 = too much. Percentage of consumers that selected these options are presented.
Bolding indicates a significant mean drop.

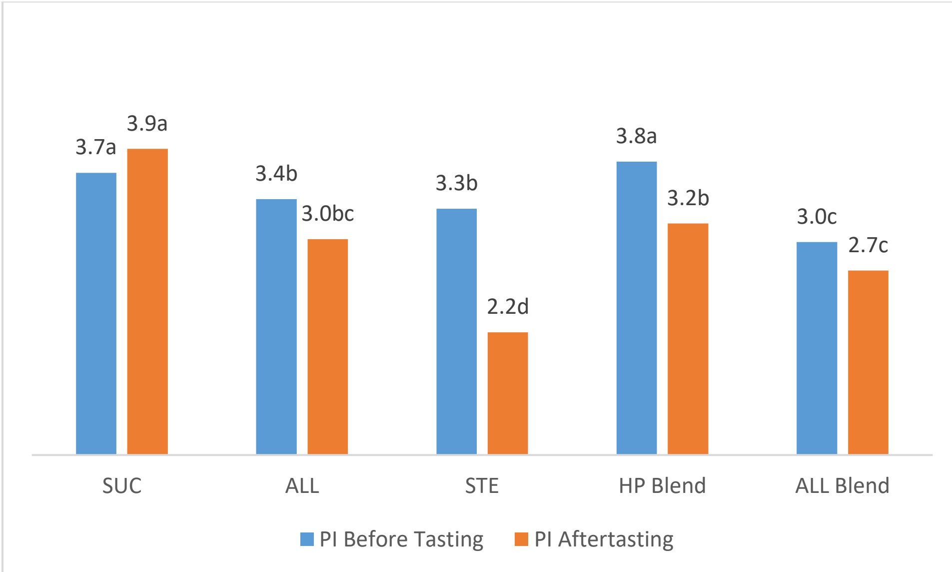

Figure 2.5: Mean purchase intent scores of primed consumers (n=115) before and after tasting each yogurt sample. Different letters among samples indicate difference ($p < 0.05$). Purchase intent was scored on a 5-point scale where 1 and 2 = would not purchase, 3 = maybe/ maybe not purchase, and 4 and 5 = would purchase. SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations.

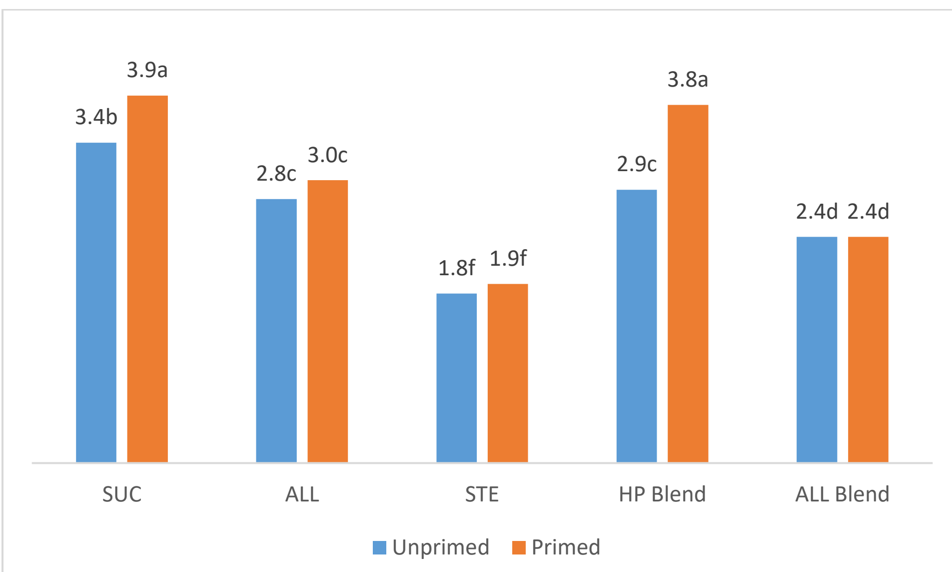

Figure 2.6: Mean perceived artificial sweetness scores for unprimed (n=114) and primed (n=115) consumers. Different letters among samples indicate difference ($p < 0.05$). Perceived artificial sweetness was scored on a 5-point scale where 1 and 2 = tastes artificial, 3 = unsure, 4 and 5 = tastes natural. SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations.

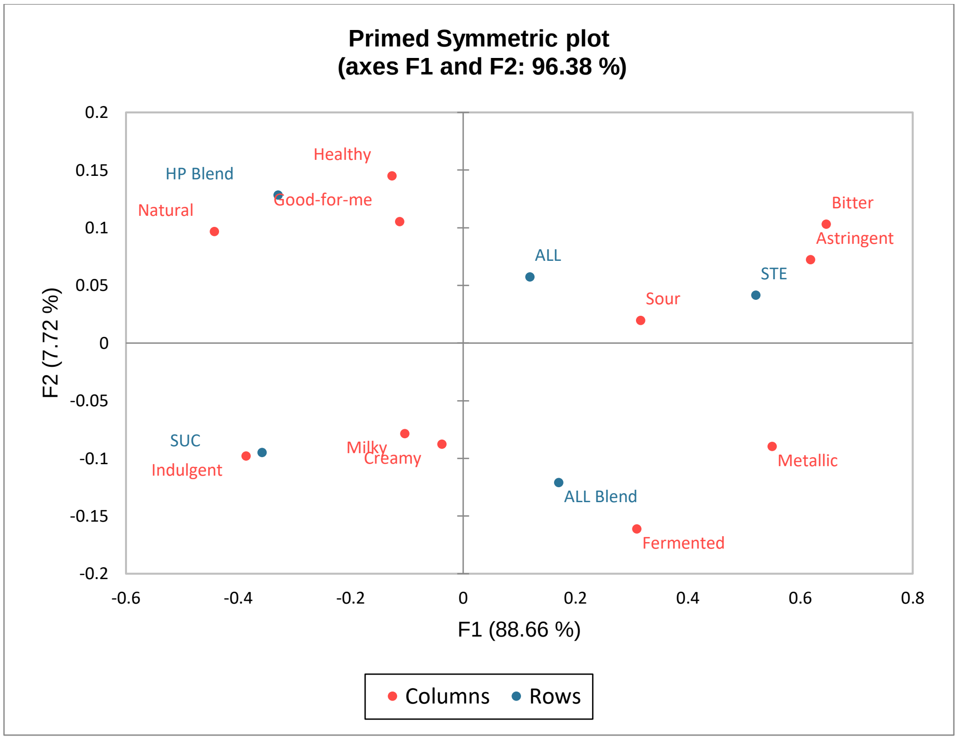

Figure 2.7: Symmetric row plot from check-all-that-apply yogurt attribute results for primed consumers (n=115). SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations that proceeded with consumer testing and are shown in blue. Yogurt attributes are shown in red.

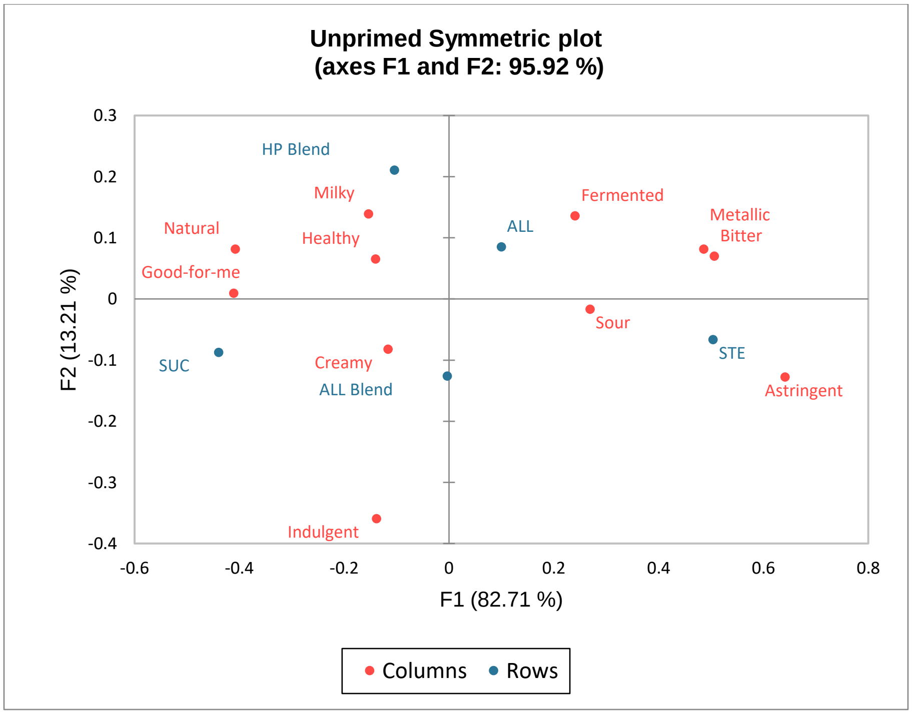

Figure 2.8: Symmetric row plot from check-all-that-apply yogurt attribute results for unprimed consumers (n=114). SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations that proceeded with consumer testing and are shown in blue. Yogurt attributes are shown in red.

Table 2.13: Frequency of selection of attributes from primed consumers (n=115).

Item	SUC	ALL	STE	HP Blend	ALL Blend
Creamy	26.9%a	22.3%a	21.3%a	20.8%a	24.5%a
Milky	16.6%a	14.6%a	10.3%a	14.5%a	16.1%a
Sour	5.7%ab	9.8%ab	12.4%a	5.0%b	8.4%ab
Fermented	1.6%a	1.8%a	2.8%a	0.9%a	2.5%a
Bitter	1.4%c	6.8%ab	12.8%a	3.0%bc	6.85ab
Astringent	1.1%c	6.0%ab	10.3%a	2.7%bc	6.5%ab
Healthy	9.8%a	10.4%a	8.5%a	13.6%a	8.0%a
Indulgent	10.6%a	3.6%b	3.5%b	9.2%ab	6.2%ab
Natural	16.8%c	11.0%bc	3.9%a	19.3%c	8.0%ab
Good-for-me	7.9%a	8.3%a	6.4%a	9.2%a	5.9%a
Metallic	1.6%b	5.4%ab	7.8%a	1.8%b	7.1%a

Means in a row followed by a different letter are significantly different ($p < 0.05$). SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations.

Table 2.14: Frequency of selection of attributes from unprimed consumers (n=114).

Item	SUC	ALL	STE	HP Blend	ALL Blend
Creamy	26.7%a	21.7%a	18.0%a	19.9%a	26.1%a
Milky	13.3%ab	13.3%ab	7.8%b	16.5%a	12.4%ab
Sour	7.3%a	12.0%ab	16.3%b	9.6%ab	10.6%ab
Fermented	3.0%a	6.1%a	6.7%a	5.5%a	3.9%a
Bitter	1.8b%	8.7%a	12.0%a	5.9%ab	5.7%ab
Astringent	1.2%b	5.2%ab	10.2%a	2.6%b	4.6%ab
Healthy	11.2%a	10.0%a	7.1%a	11.4%a	9.5%a
Indulgent	8.8%a	3.9%ab	6.0%ab	2.9%b	8.5%ab
Natural	15.5a%	8.1%abc	3.9%c	12.5%ab	7.4%bc
Good-for-me	10.3%a	5.5%ab	2.5%b	7.0%ab	5.3%ab
Metallic	0.9%b	5.5%a	9.5%a	6.3%a	6.0%a

Means in a row followed by a different letter are significantly different ($p < 0.05$). SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations.

SUPPLEMENTAL

Table 1: Attributes and responses from BYO online survey exercise (n=1,290).

Attribute	Attribute Item	% of Respondents
Added Sugar (g)	0	30.2%
	2	35.2%
	4	27.4%
	8	5.9%
	12	1.3%
Sweetener	Sucralose + AceK	2.0%
	Cane Sugar	19.2%
	Erythritol and Stevia Leaf Extract	1.7%
	Stevia Leaf Extract	13.2%
	Agave Nectar	6.4%
	Allulose	0.2%
	Fructose	4.9%
	Sucrose (Table Sugar)	5.5%
	Honey	39.3%
	Monk Fruit and Stevia Leaf Extract	6.7%
	Corn Syrup	0.9%
Protein (g)	4	15.7%
	10	52.2%
	15	32.0%
Total Fat	0	28.1%
	2	55.5%
	4	16.4%
Label Claims	Organic	17.6%
	GMO Free	7.6%
	All Natural	49.4%
	None of the Above	25.4%

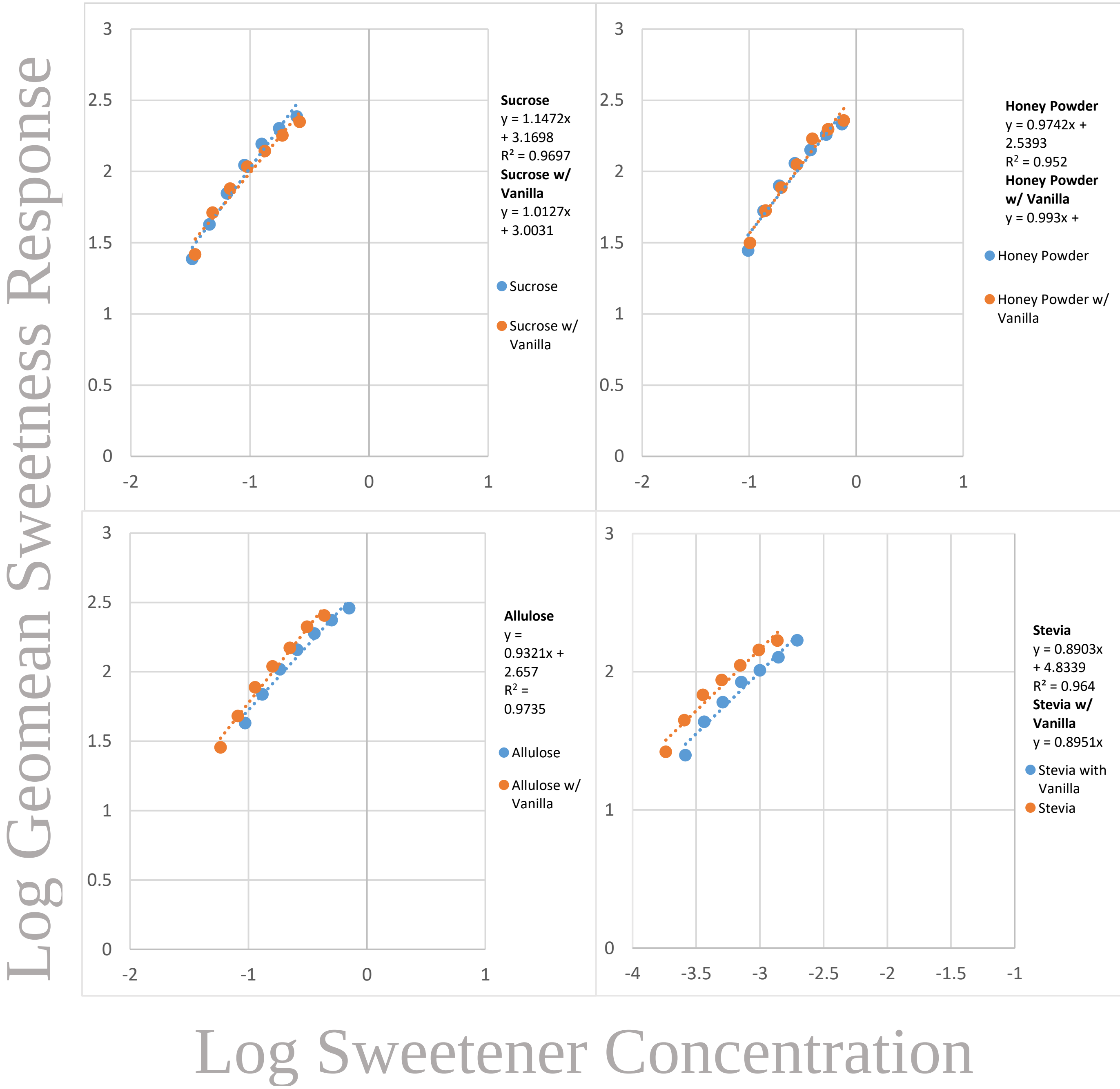

Figure 1: Magnitude estimation curves of iso-sweet amounts in yogurt with and without vanilla flavoring.

Table 2: Mean drops for primed consumers (n=115).

Variable	Level	SUC Mean Drops	ALL Mean Drops	STE Mean Drops	HP Blend Mean Drops	ALL Blend Mean Drops
Color JAR	Too Light	--	--	--	--	--
	Just About Right	--	--	--	--	--
	Too Dark	--	--	--	--	--
Aroma JAR	Too Weak	**1.5**	--	--	--	--
	Just About Right	--	--	--	--	--
	Too Strong	--	--	--	--	--
Flavor JAR	Too Weak	--	--	--	--	--
	Just About Right	--	--	--	--	--
	Too Strong	--	**2.5**	**2.6**	**2.8**	**3.0**
Vanilla Flavor JAR	Not Enough Vanilla Flavor	**1.1**	**1.3**	**1.0**	**2.1**	**1.9**
	Just About Right	--	--	--	--	--
	Too Much Vanilla Flavor	--	--	--	--	--
Sweetness JAR	Not Sweet Enough	--	--	--	--	--
	Just About Right	--	--	--	--	--
	Too Sweet	--	--	**1.7**	**2.5**	**1.8**
Sourness/Tartness JAR	Not Sour/Tart Enough	--	**0.9**	--	**1.4**	--
	Just About Right	--	--	--	--	--
	Too Sour/Tart	--	**1.8**	**1.1**	--	--
Thickness JAR	Too Thin	--	**1.3**	--	--	--
	Just About Right	--	--	--	--	--
	Too Thick	--	--	--	--	--

SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations.
JAR questions were scored on a 5-point scale where 1 or 2 = too little, 3 = just about right, and 4 or 5 = too much.

Table 3: Mean drops for unprimed consumers (n=114).

Variable	Level	SUC Mean Drops	ALL Mean Drops	STE Mean Drops	HP Blend Mean Drops	ALL Blend Mean Drops
Color JAR	Too Light	--	--	--	--	--
	Just About Right	--	--	--	--	--
	Too Dark	--	--	--	**1.1**	--
Aroma JAR	Too Weak	--	--	--	--	--
	Just About Right	--	--	--	--	--
	Too Strong	--	--	--	**1.7**	--
Flavor JAR	Too Weak	--	**1.4**	**2.8**	--	--
	Just About Right	--	--	--	--	--
	Too Strong	--	**2.8**	**3.1**	**2.7**	**2.7**
Vanilla Flavor JAR	Not Enough Vanilla Flavor	**1.0**	**1.4**	**2.7**	**2.0**	**1.5**
	Just About Right	--	--	--	--	--
	Too Much Vanilla Flavor	--	--	--	--	--
Sweetness JAR	Not Sweet Enough	--	**1.6**	**2.3**	--	--
	Just About Right	--	--	--	--	--
	Too Sweet	--	**1.2**	**2.3**	**1.5**	**1.7**
Sourness/Tartness JAR	Not Sour/Tart Enough	--	--	--	--	--
	Just About Right	--	--	--	--	--
	Too Sour/Tart	--	**2.5**	**1.8**	**2.4**	**1.9**
Thickness JAR	Too Thin	--	--	--	**0.8**	--
	Just About Right	--	--	--	--	--
	Too Thick	--	--	--	--	--

SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations.
JAR questions were scored on a 5-point scale where 1 or 2 = too little, 3 = just about right, and 4 or 5 = too much.

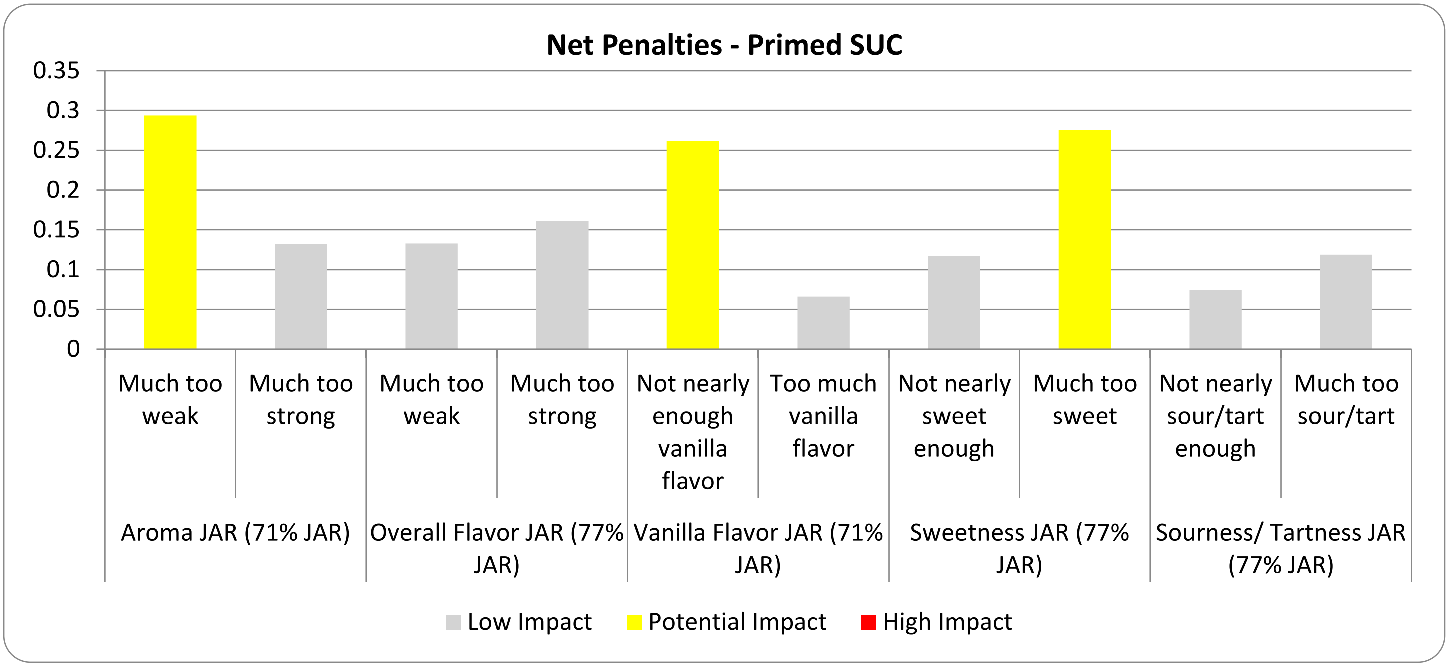

Figure 2: Net penalties from JAR questions from consumer acceptance test. JAR questions included: color, aroma, overall flavor, vanilla, sweetness, sourness/ tartness, and thickness JAR. JAR questions not present indicate that the net penalty was below the established threshold of 0.25. Net Penalty = [Proportion Indicated] * [Mean Drop], Net Penalty < 0.25 = Low Impact (Grey), Net Penalty > 0.25 & < 0.5 = Potential Impact (Yellow), and Net Penalty > 0.5 = High Impact (Red).

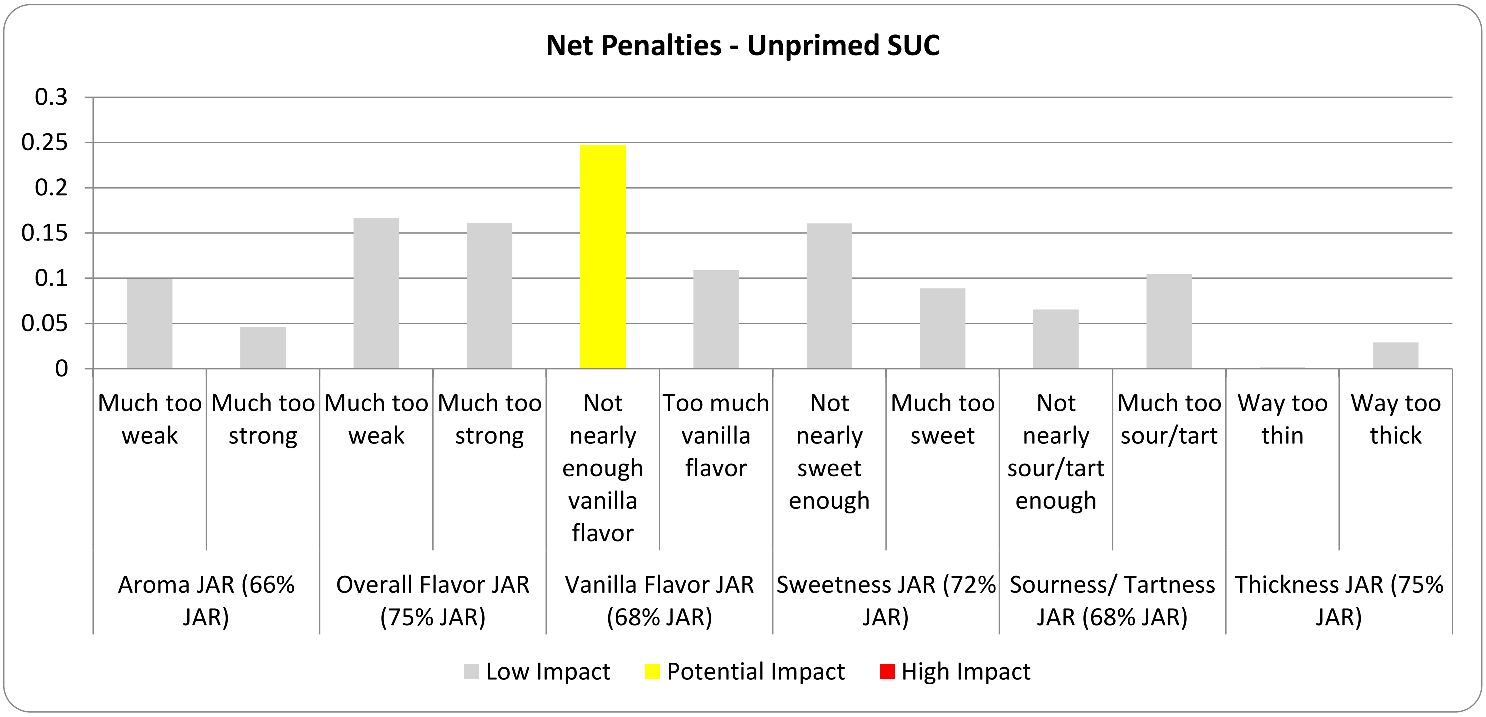

Figure 3: Net penalties from JAR questions from consumer acceptance test. JAR questions included: color, aroma, overall flavor, vanilla, sweetness, sourness/ tartness, and thickness JAR. JAR questions not present indicate that the net penalty was below the established threshold of 0.25. Net Penalty = [Proportion Indicated] * [Mean Drop], Net Penalty < 0.25 = Low Impact (Grey), Net Penalty > 0.25 & < 0.5 = Potential Impact (Yellow), and Net Penalty > 0.5 = High Impact (Red).

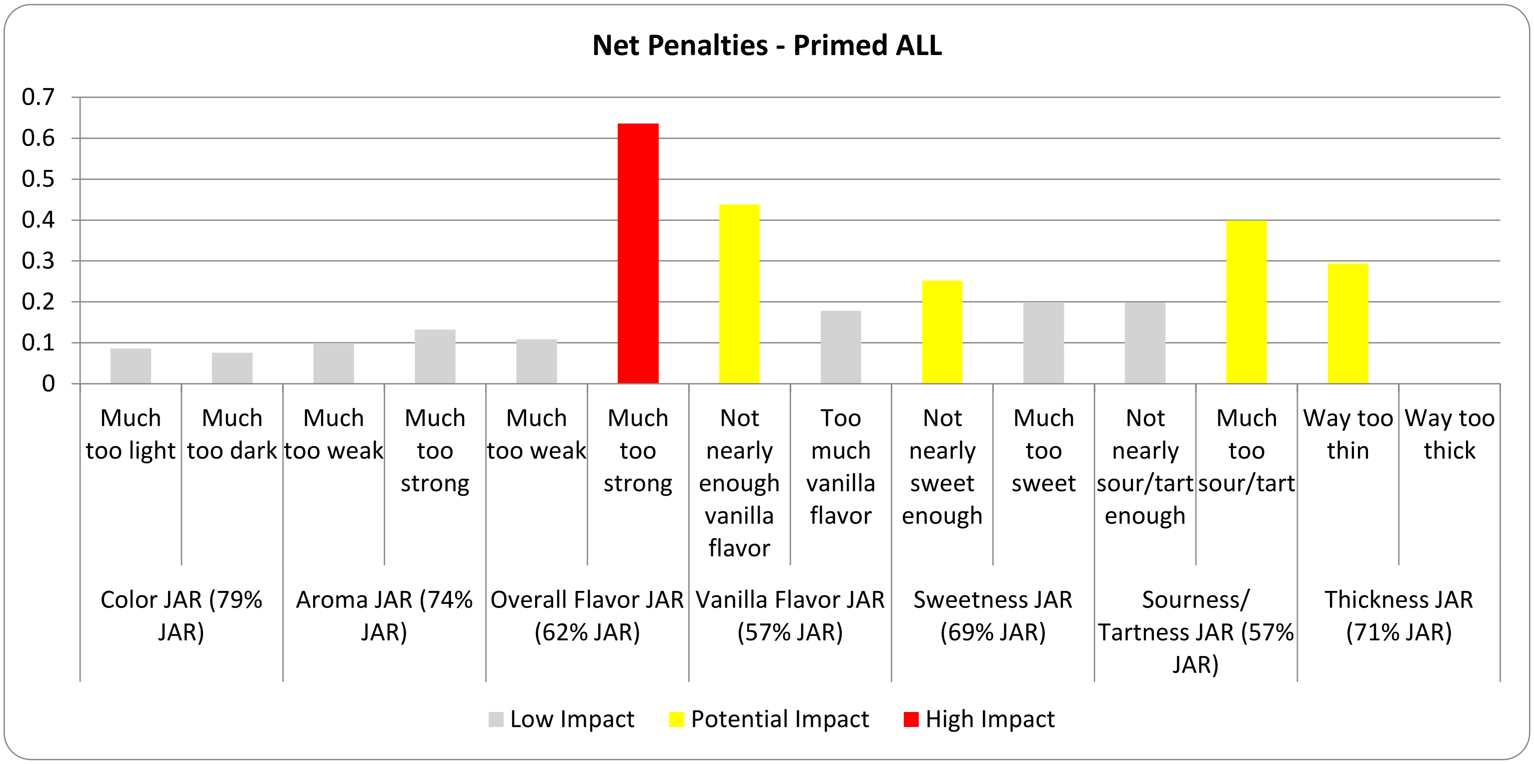

Figure 4: Net penalties from JAR questions from consumer acceptance test. JAR questions included: color, aroma, overall flavor, vanilla, sweetness, sourness/ tartness, and thickness JAR. JAR questions not present indicate that the net penalty was below the established threshold of 0.25. Net Penalty = [Proportion Indicated] * [Mean Drop], Net Penalty < 0.25 = Low Impact (Grey), Net Penalty > 0.25 & < 0.5 = Potential Impact (Yellow), and Net Penalty > 0.5 = High Impact (Red).

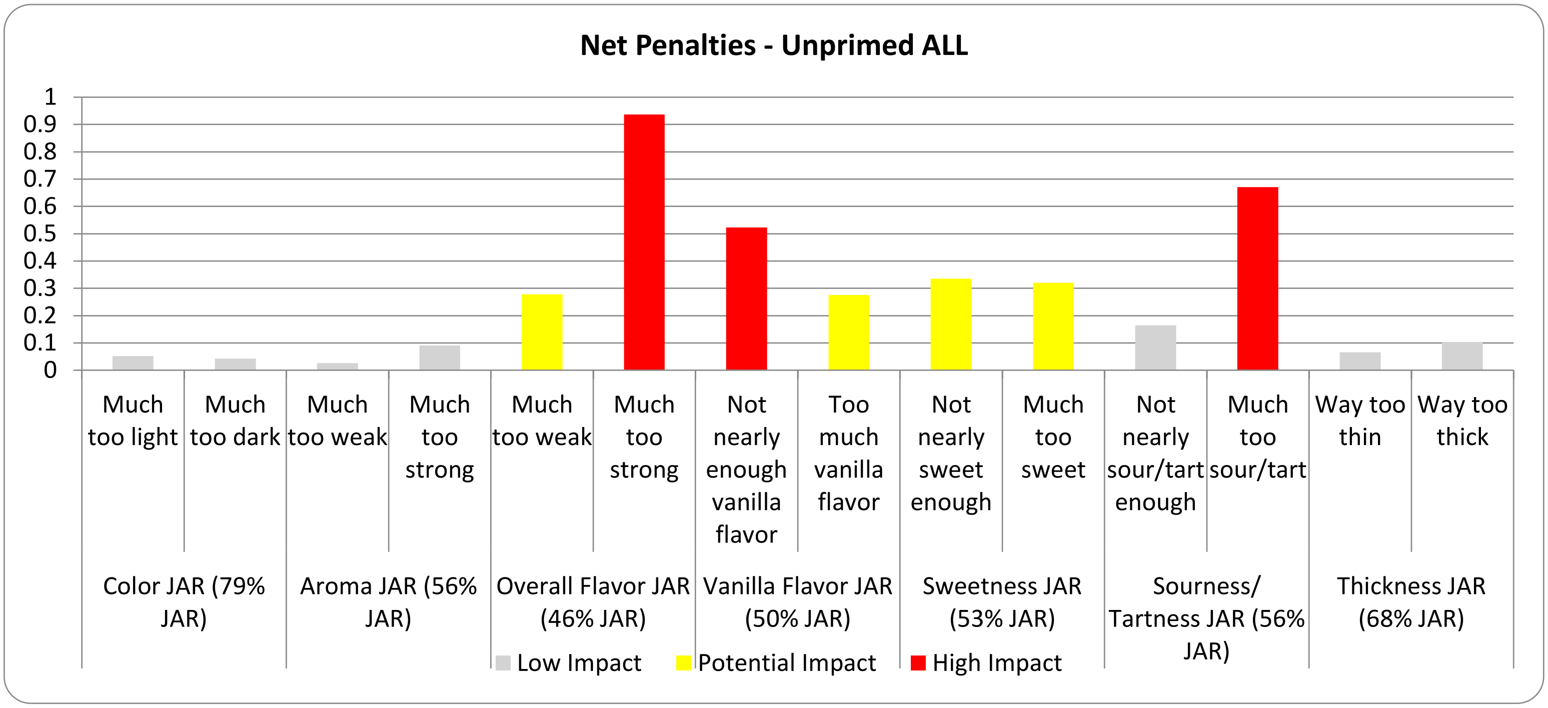

Figure 5: Net penalties from JAR questions from consumer acceptance test. JAR questions included: color, aroma, overall flavor, vanilla, sweetness, sourness/ tartness, and thickness JAR. JAR questions not present indicate that the net penalty was below the established threshold of 0.25. Net Penalty = [Proportion Indicated] * [Mean Drop], Net Penalty < 0.25 = Low Impact (Grey), Net Penalty > 0.25 & < 0.5 = Potential Impact (Yellow), and Net Penalty > 0.5 = High Impact (Red).

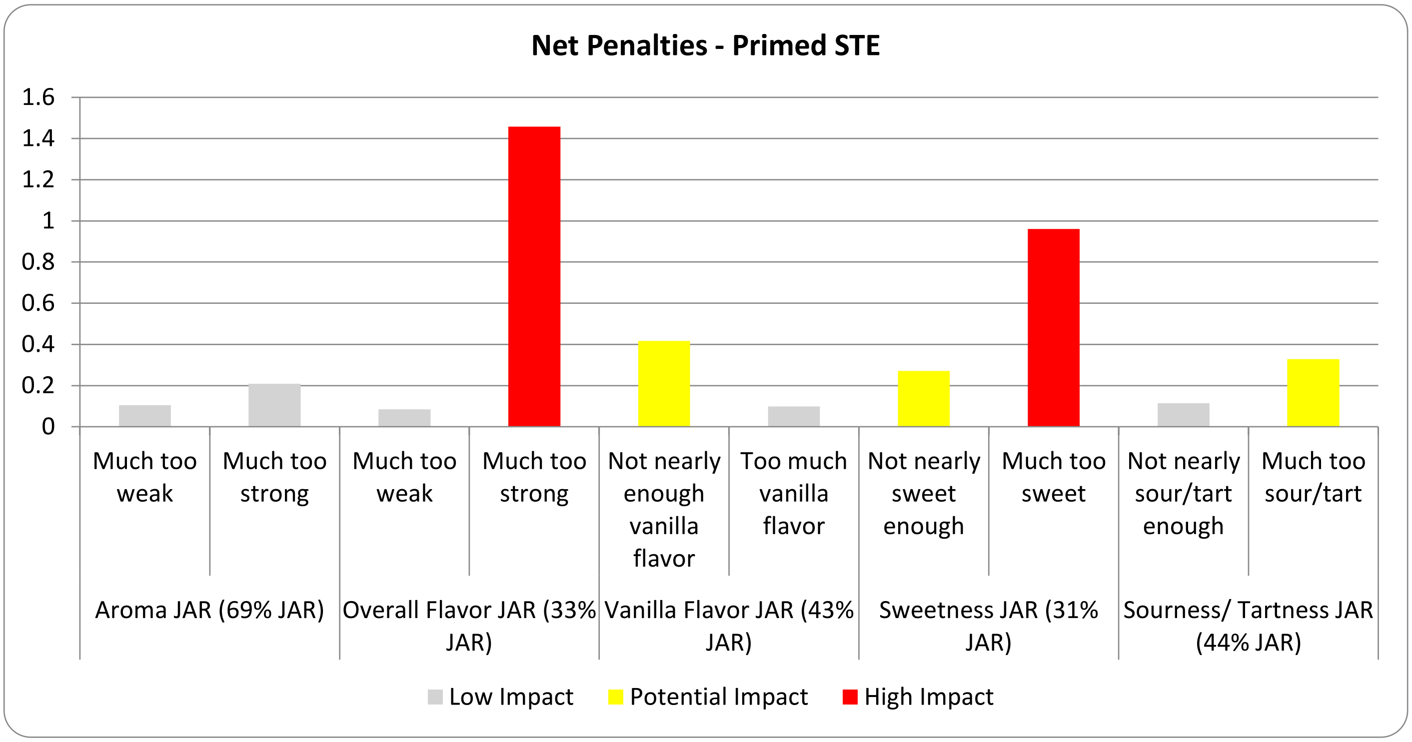

Figure 6: Net penalties from JAR questions from consumer acceptance test. JAR questions included: color, aroma, overall flavor, vanilla, sweetness, sourness/ tartness, and thickness JAR. JAR questions not present indicate that the net penalty was below the established threshold of 0.25. Net Penalty = [Proportion Indicated] * [Mean Drop], Net Penalty < 0.25 = Low Impact (Grey), Net Penalty > 0.25 & < 0.5 = Potential Impact (Yellow), and Net Penalty > 0.5 = High Impact (Red).

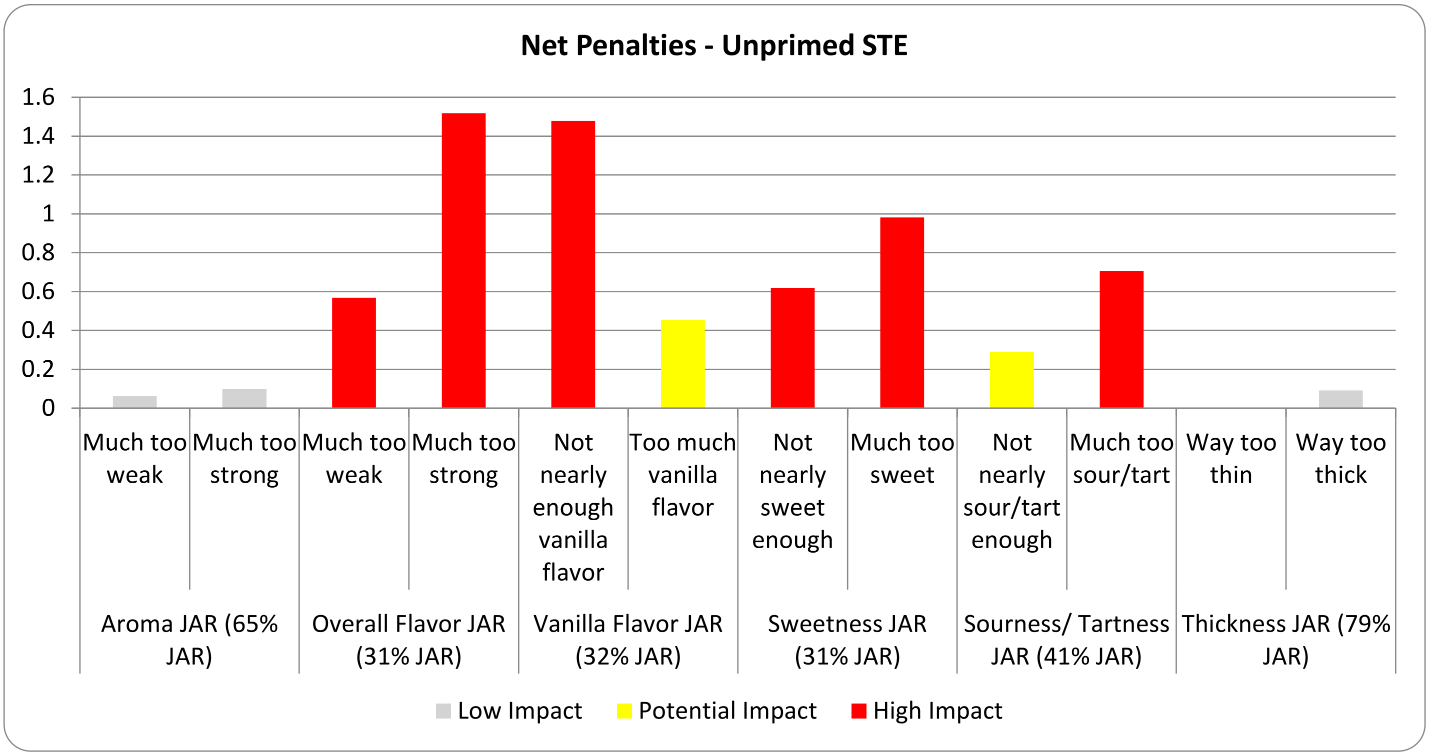

Figure 7: Net penalties from JAR questions from consumer acceptance test. JAR questions included: color, aroma, overall flavor, vanilla, sweetness, sourness/ tartness, and thickness JAR. JAR questions not present indicate that the net penalty was below the established threshold of 0.25. Net Penalty = [Proportion Indicated] * [Mean Drop], Net Penalty < 0.25 = Low Impact (Grey), Net Penalty > 0.25 & < 0.5 = Potential Impact (Yellow), and Net Penalty > 0.5 = High Impact (Red).

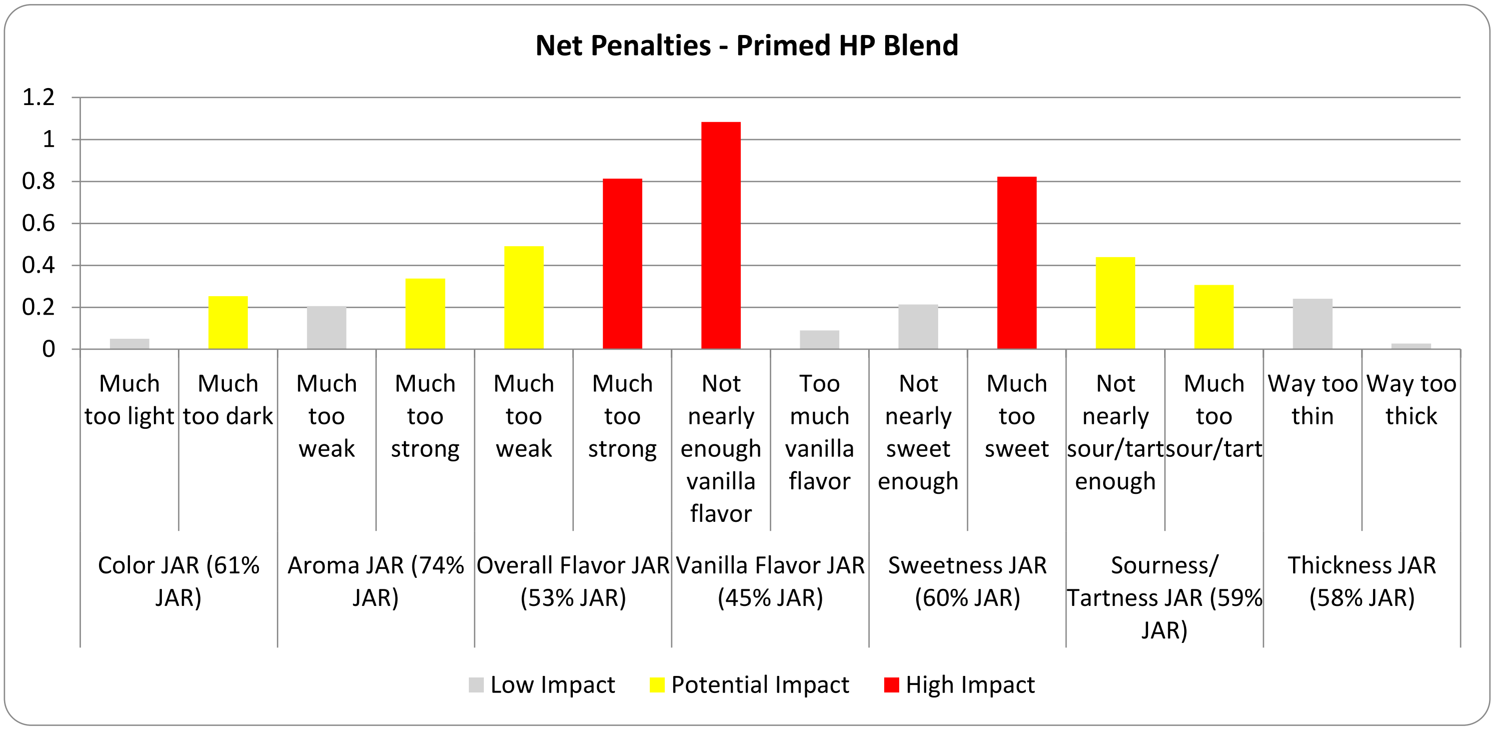

Figure 8: Net penalties from JAR questions from consumer acceptance test. JAR questions included: color, aroma, overall flavor, vanilla, sweetness, sourness/ tartness, and thickness JAR. JAR questions not present indicate that the net penalty was below the established threshold of 0.25. Net Penalty = [Proportion Indicated] * [Mean Drop], Net Penalty < 0.25 = Low Impact (Grey), Net Penalty > 0.25 & < 0.5 = Potential Impact (Yellow), and Net Penalty > 0.5 = High Impact (Red).

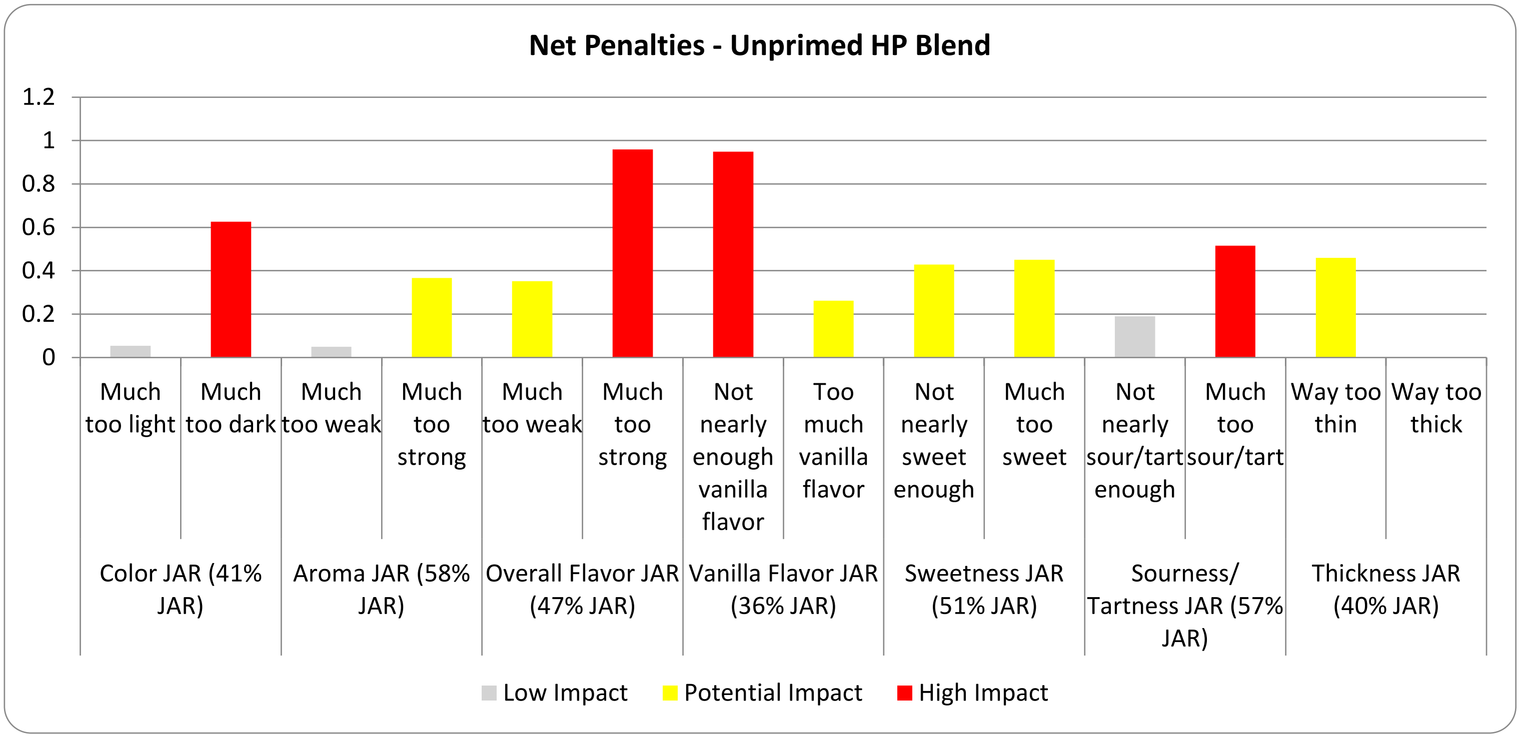

Figure 9: Net penalties from JAR questions from consumer acceptance test. JAR questions included: color, aroma, overall flavor, vanilla, sweetness, sourness/ tartness, and thickness JAR. JAR questions not present indicate that the net penalty was below the established threshold of 0.25. Net Penalty = [Proportion Indicated] * [Mean Drop], Net Penalty < 0.25 = Low Impact (Grey), Net Penalty > 0.25 & < 0.5 = Potential Impact (Yellow), and Net Penalty > 0.5 = High Impact (Red).

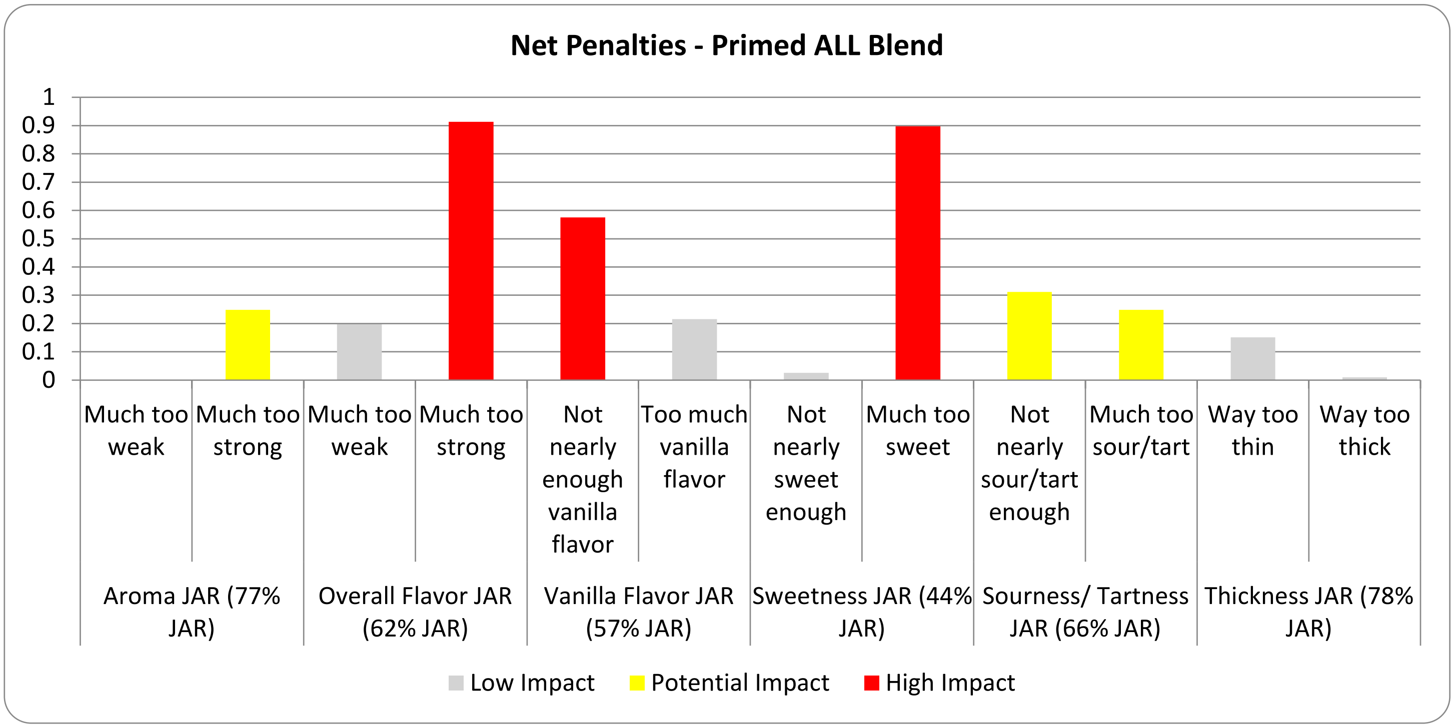

Figure 10: Net penalties from JAR questions from consumer acceptance test. JAR questions included: color, aroma, overall flavor, vanilla, sweetness, sourness/ tartness, and thickness JAR. JAR questions not present indicate that the net penalty was below the established threshold of 0.25. Net Penalty = [Proportion Indicated] * [Mean Drop], Net Penalty < 0.25 = Low Impact (Grey), Net Penalty > 0.25 & < 0.5 = Potential Impact (Yellow), and Net Penalty > 0.5 = High Impact (Red).

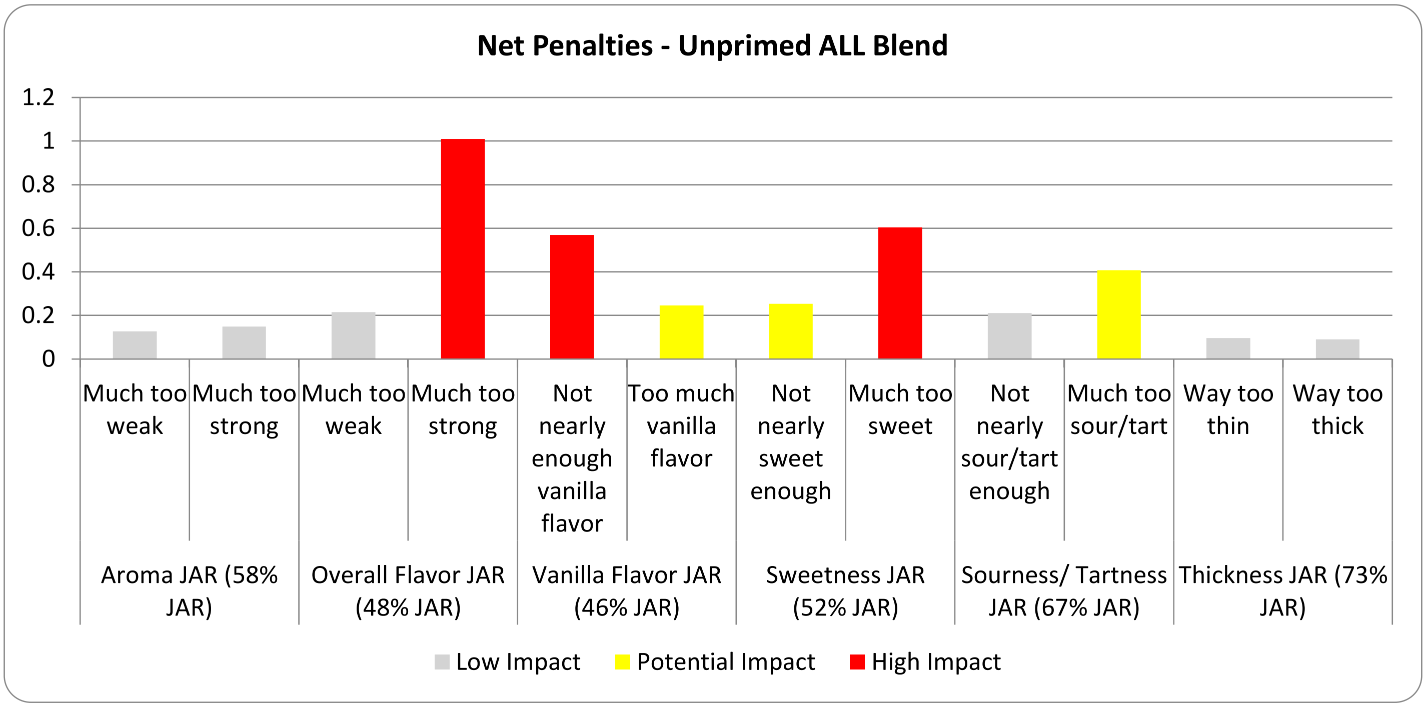

Figure 11: Net penalties from JAR questions from consumer acceptance test. JAR questions included: color, aroma, overall flavor, vanilla, sweetness, sourness/ tartness, and thickness JAR. JAR questions not present indicate that the net penalty was below the established threshold of 0.25. Net Penalty = [Proportion Indicated] * [Mean Drop], Net Penalty < 0.25 = Low Impact (Grey), Net Penalty > 0.25 & < 0.5 = Potential Impact (Yellow), and Net Penalty > 0.5 = High Impact (Red).

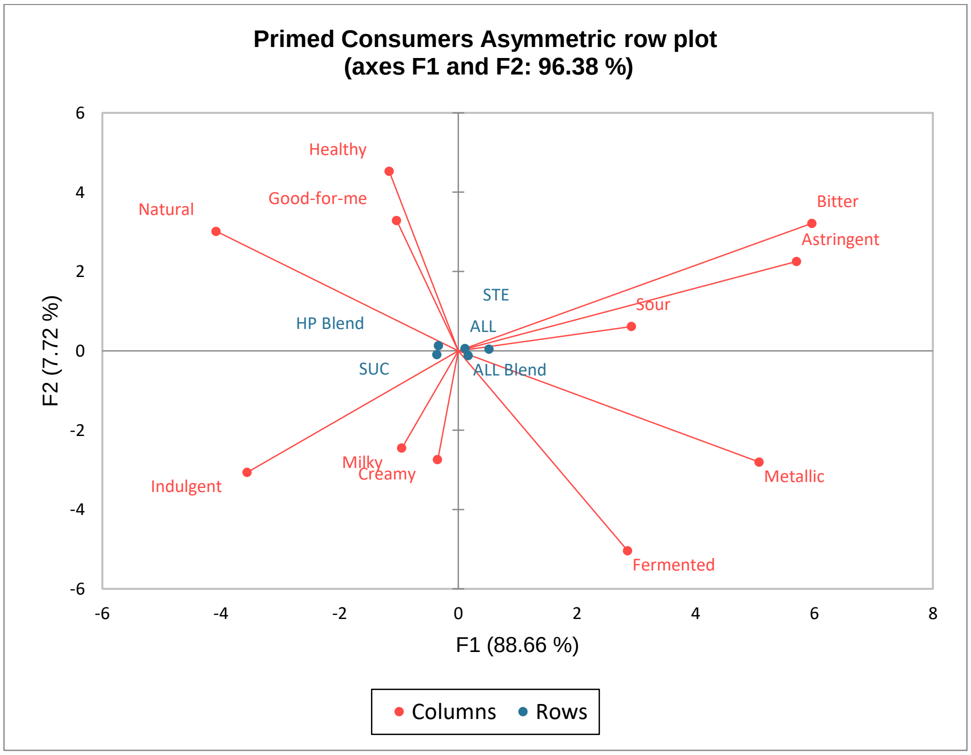

Figure 12: Asymmetric row plot from check-all-that-apply yogurt attribute results for primed consumers (n=115). SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations that proceeded with consumer testing and are shown in blue. Yogurt attributes are shown in red.

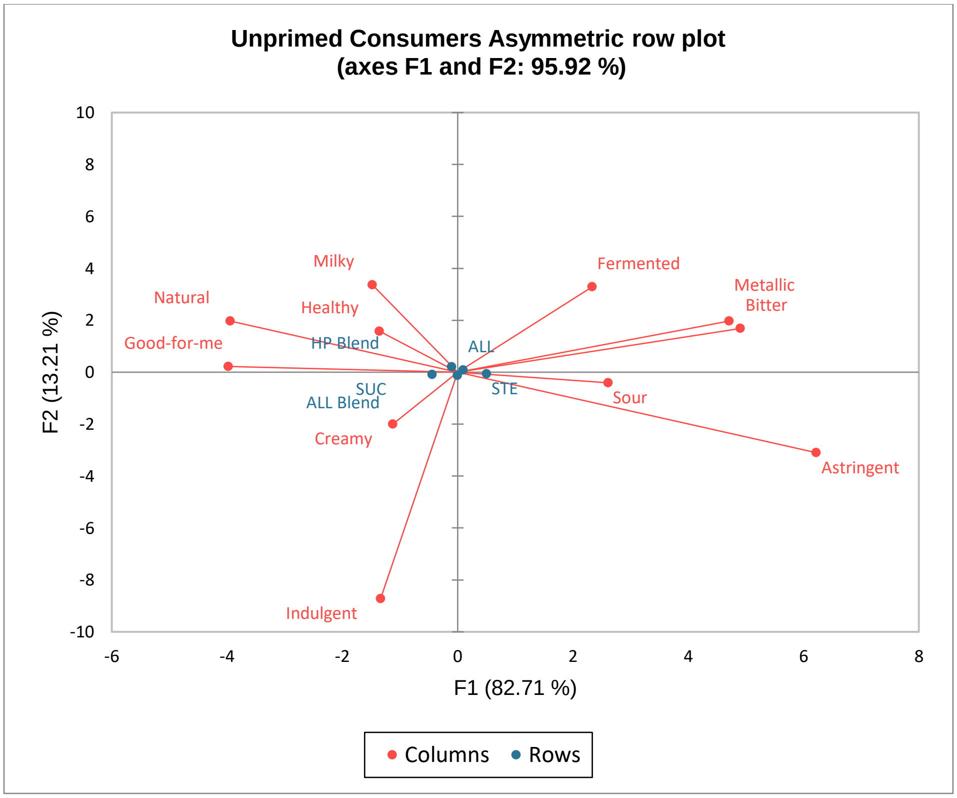

Figure 13: Asymmetric row plot from check-all-that-apply yogurt attribute results for unprimed consumers (n=114). SUC (sucrose), ALL (allulose), STE (stevia), HP Blend (50:50 sucrose and honey powder), and ALL Blend (50:10:40 allulose, sucrose, and stevia) are the formulations that proceeded with consumer testing and are shown in blue. Yogurt attributes are shown in red.

Table 4: Attributes and responses from BYO exercise. Data represents participants from the consumer acceptance test (n=229).

Attribute	Attribute Item	% of Respondents
Added Sugar (g)	0	30.6%
	2	39.7%
	4	24.9%
	8	4.8%
	12	0.0%
Sweetener	Sucralose + AceK	1.7%
	Cane Sugar	20.5%
	Erythritol and Stevia Leaf Extract	1.7%
	Stevia Leaf Extract	12.2%
	Agave Nectar	4.8%
	Allulose	0.4%
	Fructose	2.6%
	Honey	47.6%
	Monk Fruit and Stevia Leaf Extract	7.9%
	Corn Syrup	0.4%
Protein (g)	4	13.5%
	10	51.5%
	15	34.9%
Total Fat	0	24.5%
	2	55.5%
	4	20.1%
Label Claims	Organic	21.0%
	GMO Free	7.0%
	All Natural	39.3%
	None of the Above	32.8%

Table 5: Attributes and responses from BYO exercise. Data represents unprimed participants from the consumer acceptance test (n=114).

Attribute	Attribute Item	% of Respondents
Added Sugar (g)	0	28.9%
	2	43.0%
	4	21.9%
	8	6.1%
	12	0.0%
Sweetener	Sucralose + AceK	0.9%
	Cane Sugar	12.3%
	Erythritol and Stevia Leaf Extract	0.9%
	Stevia Leaf Extract	15.8%
	Agave Nectar	2.6%
	Allulose	0.9%
	Fructose	3.5%
	Honey	50.9%
	Monk Fruit and Stevia Leaf Extract	11.4%
	Corn Syrup	0.9%
Protein (g)	4	14.0%
	10	52.6%
	15	33.3%
Total Fat	0	14.0%
	2	52.6%
	4	33.3%
Label Claims	Organic	15.8%
	GMO Free	7.0%
	All Natural	43.9%
	None of the Above	33.3%

Table 6: The attribute that consumers would compromise on when choosing a yogurt. Data represents participants from the consumer acceptance test (n=229).

Compromised Attribute Item	% of Respondents
Added Sugar	9.2%
Sweetener	13.5%
Protein	26.6%
Total Fat	14.8%
Label Claims	33.2%

Table 7: The attribute that consumers would compromise on when choosing a yogurt. Data represents primed participants from the consumer acceptance test (n=115).

Compromised Attribute Item	% of Respondents
Added Sugar	6.1%
Sweetener	12.2%
Protein	27.0%
Total Fat	16.5%
Label Claims	34.8%

Table 8: The attribute that consumers would compromise on when choosing a yogurt. Data represents unprimed participants from the consumer acceptance test (n=114).

Compromised Attribute Item	% of Respondents
Added Sugar	12.3%
Sweetener	14.9%
Protein	26.3%
Total Fat	13.2%
Label Claims	31.6%

Table 9: Check all that apply exercise that demonstrates characteristics that consumers find helpful when selecting a new yogurt to purchase. Data represents participants from the consumer acceptance test (n=229).

Characteristics	% of Respondents
Nutrition Facts	78.2%
Package Size	53.7%
Flavor of Yogurt	86.5%
Ingredient List	55.0%
Type of Yogurt	73.8%
Label Claims	30.6%

Table 10: Check all that apply exercise that demonstrates characteristics that consumers find helpful when selecting a new yogurt to purchase. Data represents primed participants from the consumer acceptance test (n=115).

Characteristics	% of Respondents
Nutrition Facts	80.0%
Package Size	55.7%
Flavor of Yogurt	88.7%
Ingredient List	60.9%
Type of Yogurt	74.8%
Label Claims	30.4%

Table 11: Check all that apply exercise that demonstrates characteristics that consumers find helpful when selecting a new yogurt to purchase. Data represents unprimed participants from the consumer acceptance test (n=114).

Characteristics	% of Respondents
Nutrition Facts	75.7%
Package Size	51.3%
Flavor of Yogurt	83.5%
Ingredient List	48.7%
Type of Yogurt	72.2%
Label Claims	30.4%

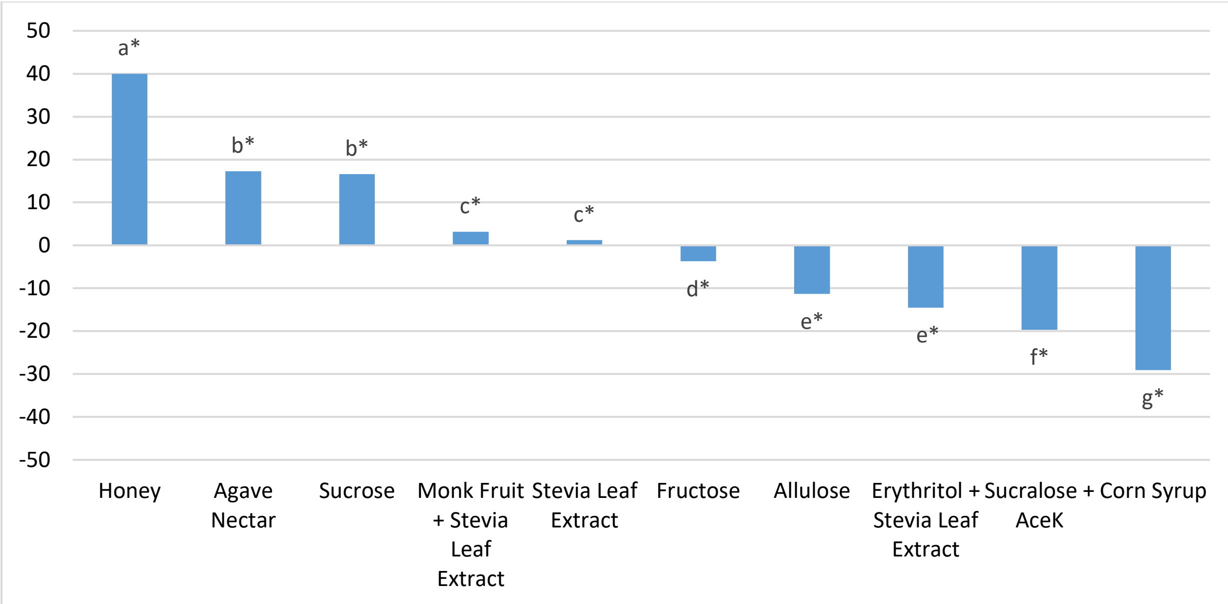

Figure 14: Overall importance scores for preferred sweetener (SW*)* MaxDiff exercise from consumer acceptance test (n=229). Importance scores are zero-centered and, higher (more positive) scores are representative of more appealing levels within an attribute, while lower (more negative) scores represent less appealing characteristics*Different letters within an attribute indicate significant differences between all consumers (p<0.05).

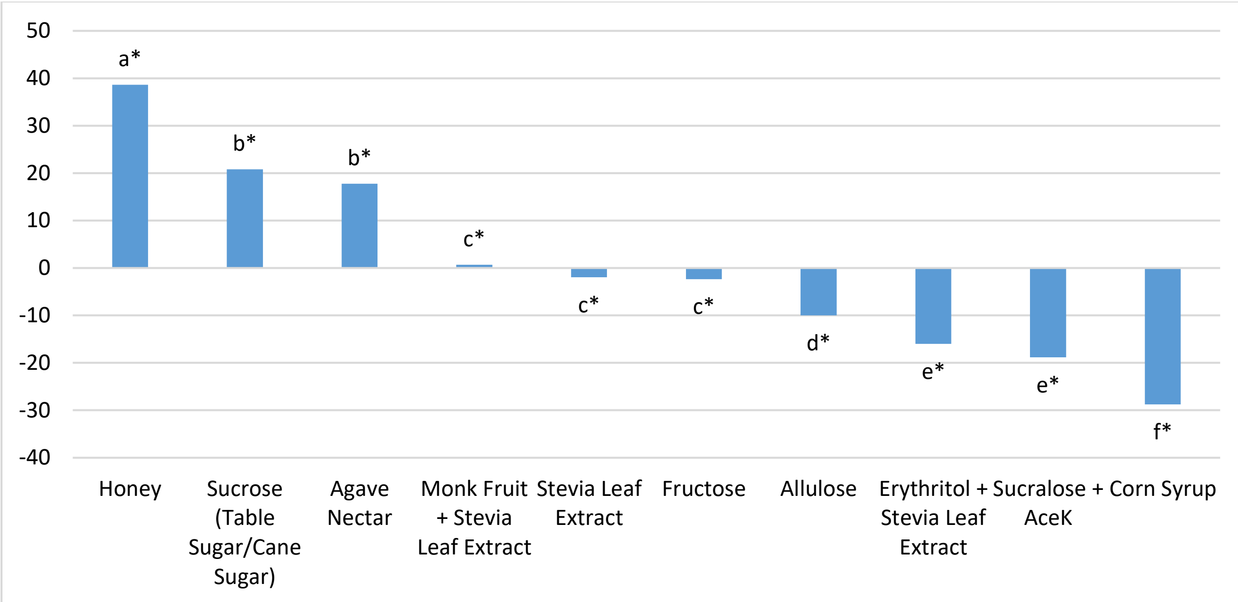

Figure 15: Overall importance scores for preferred sweetener (SW*)* MaxDiff exercise from consumer acceptance test for primed consumers (n=115). Importance scores are zero-centered and, higher (more positive) scores are representative of more appealing levels within an attribute, while lower (more negative) scores represent less appealing characteristics*Different letters within an attribute indicate significant differences between all consumers ($p<0.05$).

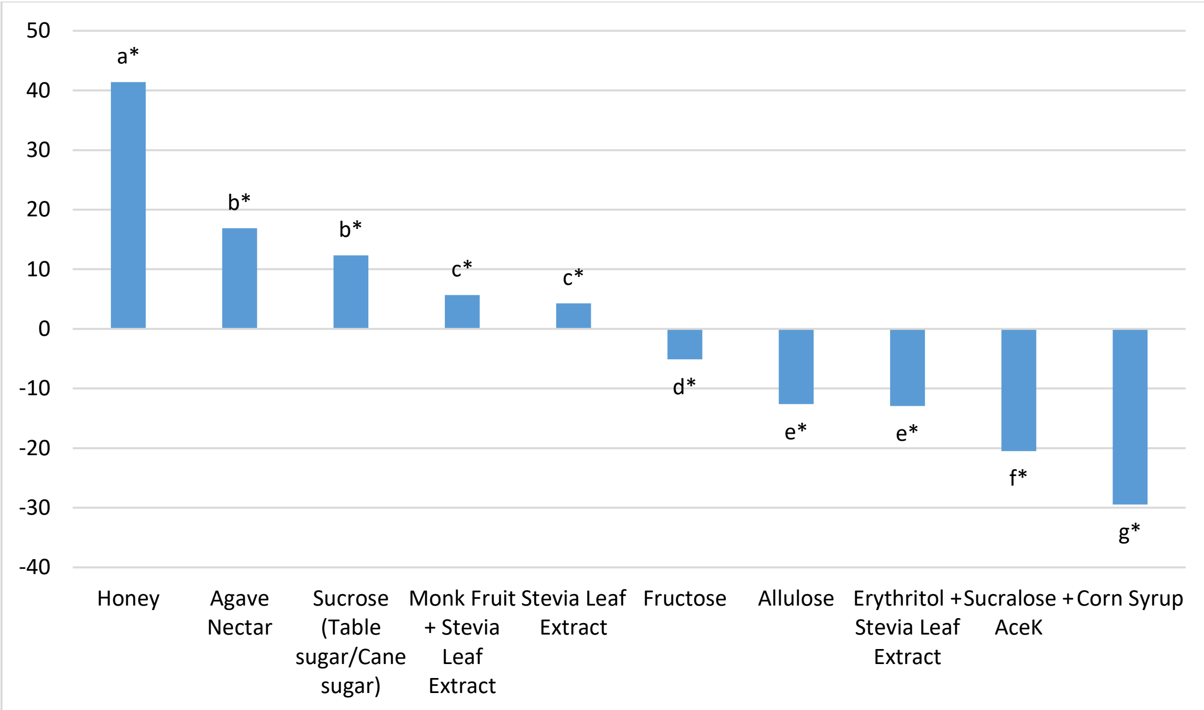

Figure 16: Overall importance scores for preferred sweetener (SW) MaxDiff exercise from consumer acceptance test for unprimed consumers (n=114). Importance scores are zero-centered and, higher (more positive) scores are representative of more appealing levels within an attribute, while lower (more negative) scores represent less appealing characteristics*Different letters within an attribute indicate significant differences between all consumers (p<0.05).

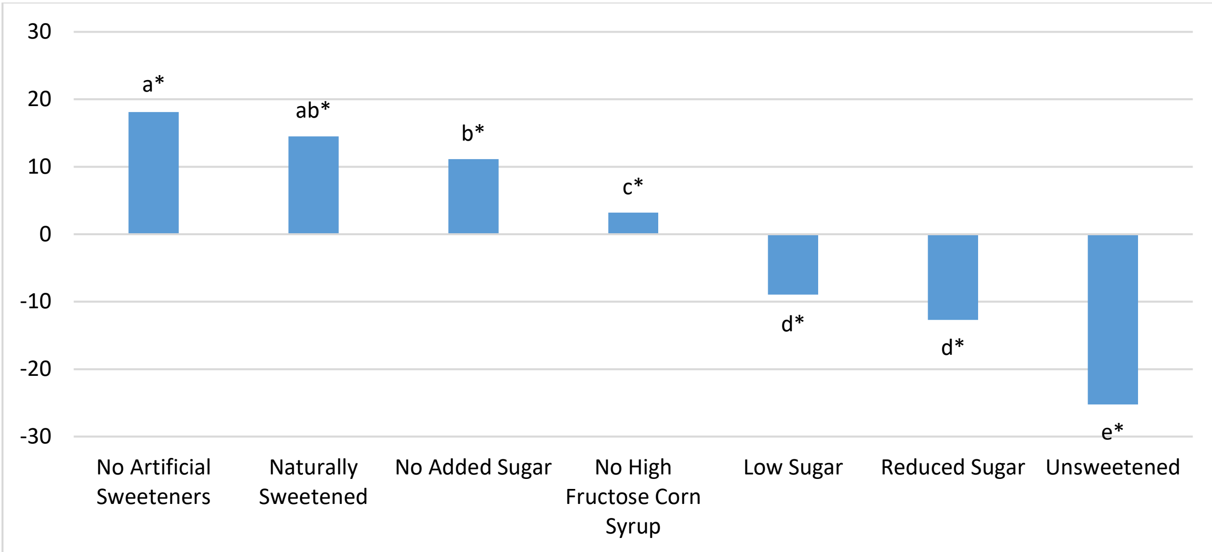

Figure 17: Importance scores for preferred sugar claims (SC) MaxDiff exercise from consumer acceptance test (n=229). Importance scores are zero-centered, and higher (more positive) scores are representative of more appealing levels within an attribute, while lower (more negative) scores represent less appealing characteristics *Different letters within an attribute indicate significant differences between all consumers (p<0.05).

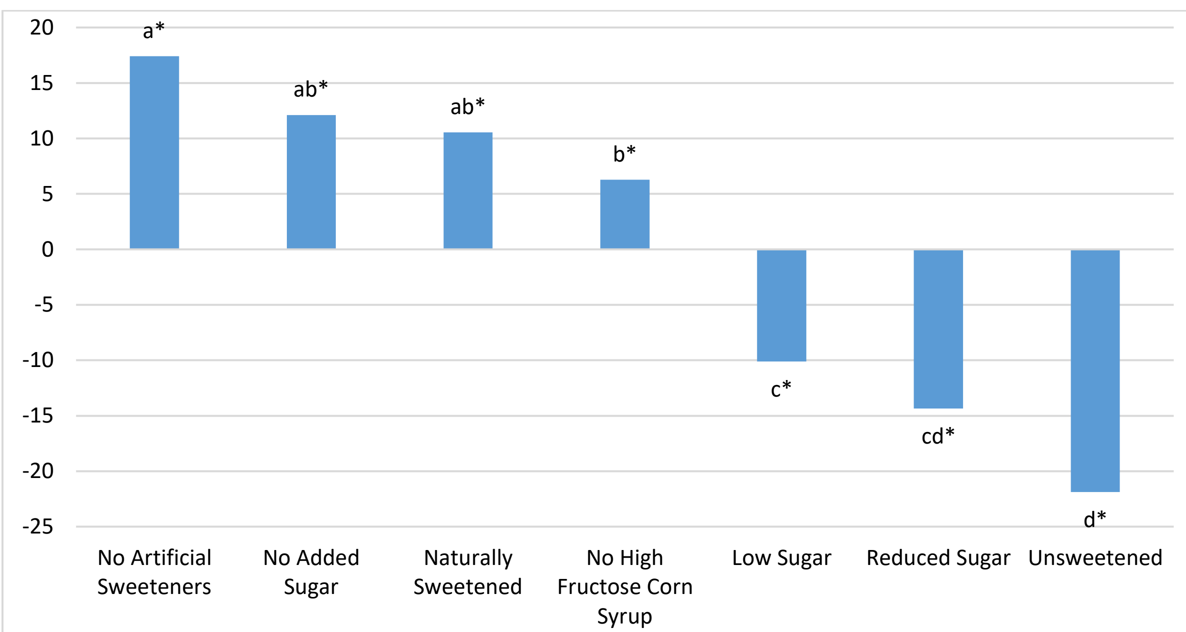

Figure 18: Importance scores for preferred sugar claims (SC) MaxDiff exercise from consumer acceptance test for primed consumers (n=115). Importance scores are zero-centered, and higher (more positive) scores are representative of more appealing levels within an attribute, while lower (more negative) scores represent less appealing characteristics *Different letters within an attribute indicate significant differences between all consumers (p<0.05).

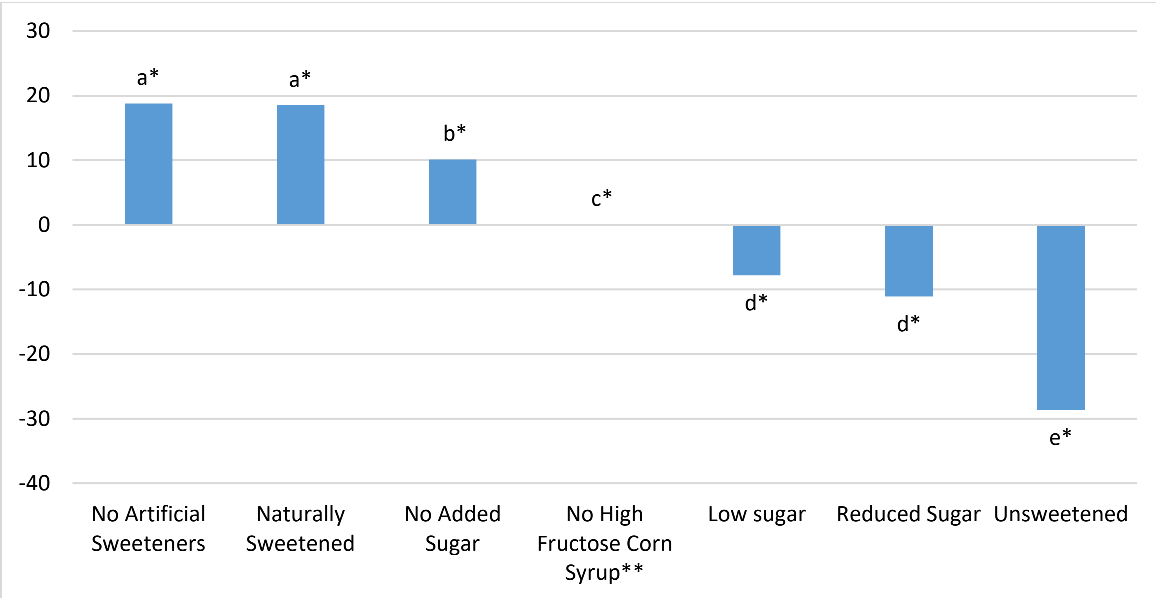

Figure 19: Importance scores for preferred sugar claims (SC) MaxDiff exercise from consumer acceptance test for unprimed consumers (n=114). Importance scores are zero-centered, and higher (more positive) scores are representative of more appealing levels within an attribute, while lower (more negative) scores represent less appealing characteristics *Different letters within an attribute indicate significant differences between all consumers ($p<0.05$). **No high fructose corn syrup equals 0.07.