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DEPARTMENT OF FOOD SCIENCE

SENSORY DRIVEN OPTIMIZATION OF DR. BOB'S LOW FAT STRAWBERRY YOGURT SMOOTHIE

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ABSTRACT

Dr. Bob's Low Fat Strawberry Smoothie is currently sold in the Penn State University Creamery. The objective of this project was to determine what attributes contribute most to "liking" of the product as part of a comprehensive program to improve overall liking, under the assumption that liking is a major driver of repeat sales. The original smoothie was tested using untrained participants who evaluated overall liking and provided Just About Right ratings for sweetness, sourness, thickness, strawberry flavor, and color. Mean drop analysis was used on the JAR data to determine which attributes caused the greatest drop in overall liking. Analysis of the original product indicated a need to boost strawberry flavor. In the second test, the original product was re-tested as a control, along with a reformulated product that contained added natural strawberry flavor (0.20% wt/wt). Results indicated the number of participants who rated the reformulated product as "Not Enough Strawberry" decreased substantially, but the number of participants who rated the flavor added product as "Too Much Strawberry" also increased substantially. A third round of testing was conducted with 0.10% and 0.15% (w/w) added flavor in order to determine a concentration of added strawberry flavor that would keep "Not Enough Strawberry" ratings sufficiently low while driving the number of "Too Much Strawberry" ratings closer to the level found in the original product. The 0.10% flavor added product showed the lowest percent of respondent ratings for "Not Enough Strawberry" while maintaining a very low level of ratings for "Too Much Strawberry." The reformulated product containing 0.1% added strawberry flavor fared better with respect to the attribute "strawberry flavor" than any of the other treatments. However, for all of the flavor added treatments, overall liking was not significantly greater than any of the original treatments.

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Chapter 1

Introduction

1.1 Review of Literature

Yogurt drink retail sales reached $395 million in 2011 according to the "Yogurt and Yogurt Drinks—August 2012" Mintel Report. Although sales of yogurt drinks is forecasted to fluctuate over the next five years, more and more consumers are realizing the health benefits associated with yogurt, especially as a good source of calcium and vitamin D (Mintel 2012). The International Dairy Foods Association claims sales of yogurt now represent over half the volume of cultured dairy product sales (Laaman 2011). Many people choose yogurt beverages as a quick, on-the-go snack, with perceptions that drinkable yogurt "has more vitamins and minerals than other beverages (including milk)," is "healthy," and contains "more beneficial protein." As shown by Thompson, Lopetcharat, and Drake, natural strawberry flavor and strawberry aroma in yogurt products were shown to have a high association with liking. On the other hand, some consumers find drinkable yogurt to have excessive sweetness and to be too high in calories and/or sugar (Thompson, Lopetcharat, and Drake 2007). Yogurts, including drinkable yogurts, are often used as a vehicle to deliver probiotics (Mintel 2012). The increase in popularity of yogurt drinks suggests the potential to increase sales of a currently produced yogurt beverage, Dr. Bob's Low Fat Strawberry Yogurt Smoothie, if it is reformulated to better match consumer preferences. The following literature review details the components of milk as the main ingredient in yogurt, the processing of yogurt and of yogurt beverages specifically, incorporation of probiotics into yogurt products, sensory analysis, and the product development process—all of which are necessary to understand before considering reformulation of Dr. Bob's Low Fat Strawberry Yogurt Smoothie.

Composition of Milk

Cow's milk is a lacteal secretion containing numerous macro- and micronutrients. Typically, cow's milk contains 87.5% water and 12.5% solids: 3.9% fat, 3.4% protein, 4.8% lactose, and 0.8% ash, however the composition varies greatly among breeds, season, stage of lactation, cow age, and other factors. The average pH of cow milk is around 6.5-6.7. Although it also varies among breeds and other factors, milk contains numerous vitamins and minerals. Vitamins A and D are soluble in the fat, while B_1, B_2, and C are present in the aqueous phase. As for minerals, while potassium and calcium salts are the most prevalent, sodium and magnesium are found in milk. These minerals are present mainly in the forms of caseinates, citrates, chlorides, and phosphates (Bylund, 2003).

The fat in milk exists as an oil in water emulsion, and is a mixture of saturated and unsaturated fats. Fat globules are approximately 1-10 μm in diameter, with the outer surface known as the milk fat globule membrane. Milk fat is 98% triglycerides, but also contains di- and mono-glycerides, fatty acids, sterols, carotenoids, phospholipids, and the fat-soluble vitamins A and D. Although phospholipids only make up approximately 0.8% of milk lipids, they play a major role in functionality due to their amphiphilic nature (MacGibbon and Taylor 2003). The presence of relatively high levels of butyric and caproic fatty acids characterize the sensory attributes of cow milk fat, while myristic, palmitic, stearic, and oleic acids comprise the majority of the fatty acids by percentage (Bylund 2003). Although most of them are present in very small quantities, over 400 fatty acids have been identified in milk, making it one of the most complex naturally-occurring fats. Due to the lower density of milk fat globules as compared to the serum phase, the fat naturally separates and rises to the top. To prevent creaming, high pressures are used in a process known as homogenization to decrease the size of the fat globules (MacGibbon and Taylor 2003).

The proteins in milk exist as a colloidal suspension and are divided into two main types: caseins and whey proteins. Caseins (α_{s1}, α_{s2}, β, and κ-casein) comprise approximately 80% of the nitrogen in milk, and due to their amphiphilic nature, exist in the form of micelles. There are approximately 10^{14}-10^{16} micelles per milliliter of milk, and micelles rely on hydrophobic interactions, hydrogen bonding, and electrostatic interactions to maintain structure (O'Regan, Ennis, and Mulvihill 2009). The isoelectric point of casein is 4.6. When the pH is lowered to 4.6, casein micelles coagulate, resulting in formation of a gel-like consistency, which is the basis for yogurt production (Tamime and Robinson 2007). Whey proteins (α-lactalbumin, β-lactoglobulin, blood serum albumin, and immunoglobulins), which are also sometimes referred to as milk serum proteins, account for about 15% of the nitrogen in milk. Whey proteins have a near-biologically optimum amino acid profile, containing all nine essential amino acids. Thus, whey protein and its derivatives are extensively used in many applications in the food industry. The remaining 5% of the nitrogen in milk is made up of non-protein nitrogenous compounds (Bylund 2003).

Milk also contains a variety of enzymes, which are highly affected by temperature and pH of the milk. Four of the main enzymes of significance are lipase, peroxidase, catalase, and phosphatase. Most enzymes are denatured and inactivated during thermal processing of milk, which extends the shelf life of the milk from a chemical standpoint. However, if the enzymes act on their respective substrate prior to a heat-treating step, or if the heat treatment is not severe enough to inactivate the enzymes, off-flavors will occur and can be significantly detrimental to the flavor of further processed products like yogurt (Bylund 2003).

Yogurt Processing

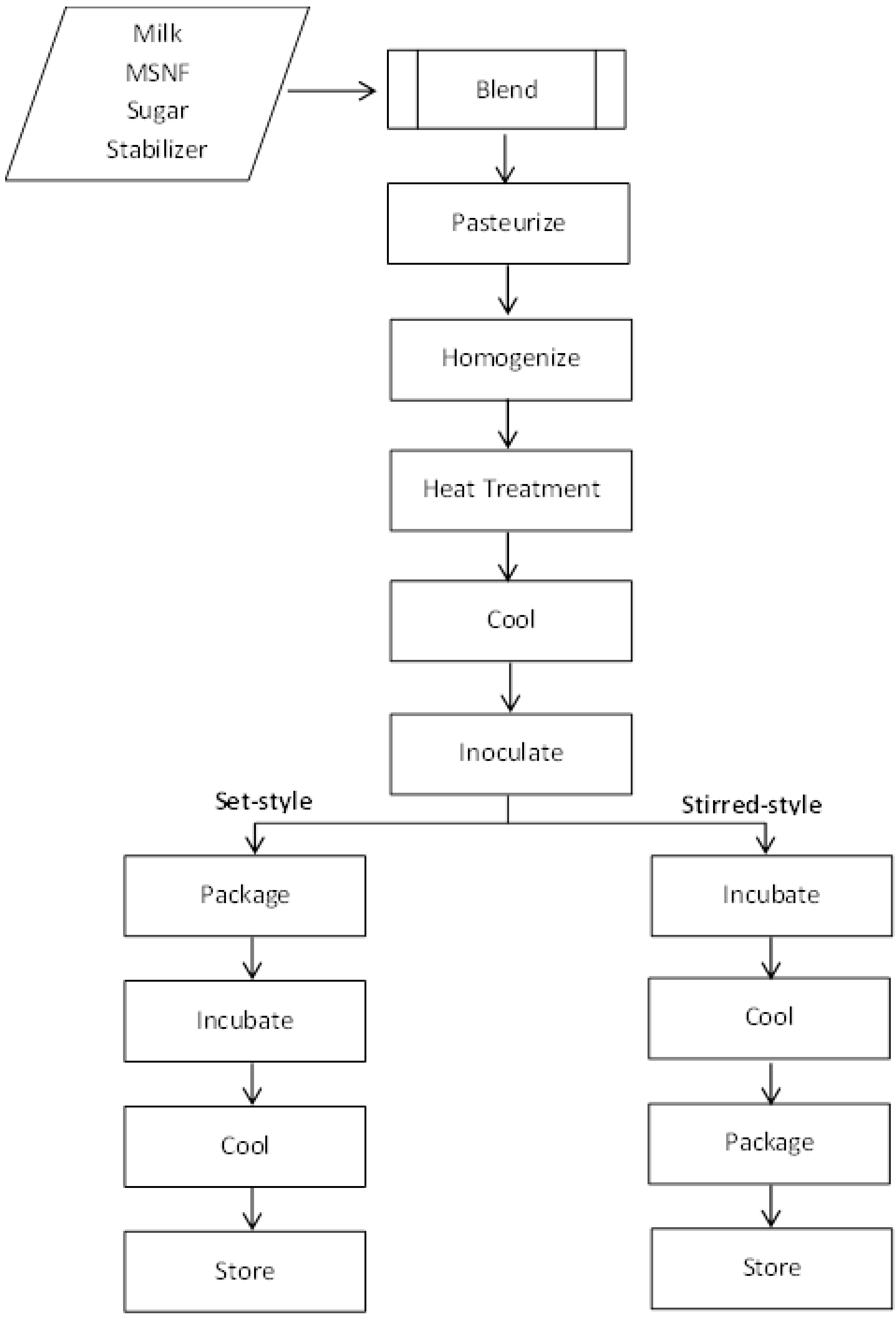

Figure 1-1. Simple Yogurt Processing Flow Diagram (Tamime and Robinson 2007)

As can be seen in Figure 1-1, standard yogurt processing begins with the blending of milk with milk solids not fat (MSNF), sugar, and stabilizer. The raw milk has been standardized to a pre-determined fat and MSNF content, usually between 0-3.0% and 8.25-12%, respectively. Although traditionally to concentrate the milk solids the milk was boiled to reduce the volume to approximately two-thirds its original volume, it is now more common to add milk protein or milk solids non-fat. Milk powder can be added at a rate anywhere between 1-6%, but 3-4% is recommended in order to produce a desirable texture in the final product. Most yogurts currently on the market are low-fat, and thus skim milk powder is commonly added (Tamime and Robinson 2007).

The addition of stabilizers to the fortified milk base is significant to gel formation in the yogurt. Common stabilizers that aid in building viscosity in yogurt include pectin, locust bean gum, guar gum, modified food starch, and carrageenan (Laaman 2011). These stabilizers maintain and enhance texture, body, viscosity, mouthfeel, and appearance of the yogurt (Tamime and Robinson 2007). Sweetening agents are also added to the milk base. The amount of sweetener is dependent upon many factors, including the solids content of the milk base, the type of sweetener used, consumer liking, level of fruit used later in the process, economic restrictions, and legal restrictions. Sucrose, invert sugar, high fructose corn syrup, and corn syrup solids are common nutritive sweetening agents in yogurt, while sucralose and aspartame are common non-nutritive sweeteners (Tamime and Robinson 2007).

As shown in Figure 1-1, once the milk and dry ingredients are blended, the milk base is pasteurized and homogenized. The purpose of pasteurization is to destroy the majority or all of the vegetative pathogens in the mix. The minimum pasteurization time and temperature for yogurt in the US is 72°C for 15 seconds. Holding the mix at 72-74°C for 15-30 seconds sufficiently reduces the microbial load enough to provide a suitable environment for growth of the starter cultures, although it does not destroy bacterial spores (Chambers 2002). The homogenization step is designed to decrease fat globule size to prevent agglomeration and separation of the fat, but the process can also cause some serum proteins to denature, and whey/casein interactions (Tamime and Robinson 2007). Since low fat yogurt milk does not need an intense homogenization treatment due to its low fat content, a single stage homogenizer at 65-70°C (149-158°F) and a pressure of 15-20 MPa is recommended. Homogenization of the milk has been shown to impart significant characteristics on milk components that ultimately improve yogurt viscosity, including improving the water-holding capacity of the milk proteins and limiting syneresis (Schkoda *et al.* 2001a,b).

In yogurt processing a heat treatment of the mix follows pasteurization and homogenization. A typical time-temperature combination ranges from 85°C (180°F) for 30 minutes to 95°C for five minutes. The heat treatment causes the denaturation of whey proteins and many of the enzymes present in the system. Although some proteinases and lipases are not denatured, the likelihood for rancidity and bitter off-flavors is still decreased. Additionally, the denaturation of whey proteins onto casein molecules significantly increases the gel stability and viscosity of the yogurt, and minimizes syneresis (Tamime and Deeth 1980).

Once the mix is homogenized and heat treated, it is cooled to around 40-45°C: the optimum growth temperature for the starter cultures. The two bacterial cultures that must be used in yogurt manufacture, according to the Code of Federal Regulations Standard of Identity for yogurt, are the thermophilic, lactic acid producing cultures *Lactobacillus delbrueckii* subspecies *bulgaricus* and *Streptoccus thermophilus* (CFR Title 21, 2013). Different ratios of each organism, in addition to the exact temperature of fermentation, affects the resulting flavor, aroma, and texture characteristics in the finished product. (Tamime and Robinson 2007).

Once the mix is inoculated, the yogurt can be processed as either “set-style” yogurt or “stirred-style.” For set-style yogurt, the inoculated mix is deposited into containers, where it is incubated for approximately 3-5 hours, until the pH drops to around 4.6. If fruit is to be included in set-style yogurt, it is deposited in the container before the yogurt is added, to produce a "fruit on the bottom" or FOB product. The containers with yogurt are then cooled to approximately 15-22°C (60-70°F) to arrest acid production by the starter cultures, and are ready for shipment. The shelf life of yogurt is typically between 20-50 days (Tamime and Robinson 2007).

For stirred-style yogurt, the inoculated mix is fermented in large tanks until the pH drops to around 4.6. Once the yogurt has reached the desired pH, it is cooled to prevent further acid development. Fruit or other flavorings can be put into the cup or blended into the yogurt white mass in line. Subsequently the yogurt is packaged and ready for shipment (Tamime and Robinson 2007). The final yogurt, either set- or stirred-style, must meet the requirements in the Code of Federal Regulations standard of identity for yogurt.

The CFR specifies "yogurt" must contain not less than 8.25% milk solids not fat, not less than 3.25% milk fat (with the exception of "low fat yogurt"), and have a titratable acidity of at least 0.9% lactic acid (Code of Federal Regulations Title 21, 2013). Although not regulated, carbohydrate levels in finished yogurt can be as high as 20% (wt/wt) (Tamime and Robinson 2007), as fruits can add a significant amount of sugars—strawberries have an average natural carbohydrate content of 6.2% (wt/wt) (Shallenberger and Birch 1975).

Yogurt Drink Processing

Processing of yogurt drinks is similar to stirred style yogurt processing. Once the mix is inoculated and fermented in a batch-size tank to a pH of 4.6, the yogurt is agitated while being cooled, and often a pasteurized slurry is mixed in. The slurry contains fruit and or flavoring, more sugar, water, and the stabilizer. For yogurt drinks, the stabilizer used is often pectin (Tamime and Robinson 2007). A combination of high methoxy (HM) pectin, an optimum pH for pectin functionality, and shear treatment results in an ideal texture for a yogurt beverage. The optimal pH for pectin to enhance protein stability is between 3.8 and 4.1 (Laaman, 2011). The resulting product is often homogenized once again to ensure a thin, drinkable consistency. The yogurt beverage is then deposited into bottles and is ready for consumption (Bylund 2003).

There is no federal standard of identity for “drinkable yogurt,” however, if the product has “yogurt” on the label, it must abide by the requirements for yogurt—as stated previously. On the other hand, smoothies do not have any standard of identity, which creates a marketplace full of very different products, some without even containing yogurt, all with similar names. This can cause confusion to consumers in the marketplace, or misconceived perceptions of certain products (Thompson, Lopetcharat and Drake 2007).

Probiotics

The human intestinal tract is filled with over 400 species of bacteria, at a level that grows from 0 at birth to 10^{12} colony forming units/gram of intestinal contents in the large intestine as an adult (FAO, 2006). These bacteria help maintain homeostasis in the gastrointestinal tract and may play a role in immune system regulation. It is proposed that the microbes in the gut protect against pathogens by outcompeting pathogens for resources, producing anti-microbial substances, and by competitive exclusion of binding sites (O'Flaherty & Klaenhammer, 2010).

Probiotics are defined as “Live microorganisms which when administered in adequate amounts confer a health benefit on the host” (FAO, 2006). Currently there is insufficient research to determine the number of probiotic bacteria needed in certain foods to confer a health benefit, but it is recommended that the daily dose be between 10^7-10^{10} CFU (Lee and Salminen 2009). However, it is known that the amount to be delivered is highly dependent on the strain of probiotic and on the health benefit being pursued. The most common strains of probiotic bacteria are in the genera *Bifidobacterium* and *Lactobacillus*. While many of the health benefits conferred by probiotics are associated with the digestive system, some studies show other benefits as well. Probiotics can aid with pediatric intestinal diseases, infectious gastroenteritis, antibiotic-associated diarrheal, necrotizing enterocolitis, allergic and atopic diseases in children, and respiratory infections, in addition to digestive effects such as bloating and stool inconsistencies (Aureli, et al., 2011). Dr. Bob's Low Fat Strawberry Yogurt Smoothie, containing *Bifidobacterium animalis* subspecies *lactis* (*B. lactis*), BB-12, was originally formulated to deliver children ages 2-4 with a minimum of 10^{10} CFU of BB12 per day, to determine if consumption of this level of BB-12 would reduce school absences due to illness. Although this study did not find a significant improvement in number of school absences due to illness with consumption of the BB-12 product, it is still hypothesized that had a larger sample size been used, the data would have shown that the addition of probiotic to the smoothie would have a significant positive effect on the child consumers. Additionally the study did show that the BB-12 probiotic remained viable in the acidic yogurt product for over 50 days (Merenstein, et al., 2011).

Sensory Analysis

Sensory analysis is used to quantify the consumer acceptability of foods (Moskowitz, Beckley, and Resurreccion 2012). It is a combination of techniques to collect consumer perceptions about products with minimal bias. The results contain highly pertinent information regarding sight, smell, touch, taste, and sound of the food product, and can assist in determining product success. Samples are served under highly controlled conditions to minimize variation among products, and to remove bias from external information. Samples are served with random blinding codes, in random order, and with counterbalancing to ensure that judgments are made based on sensory properties and not preconceived opinions from labels or product information, and to account for effects caused by testing products sequentially (Lawless and Heymann 2010).

The three major classes of sensory tests are difference testing, descriptive analysis, and affective testing. Difference testing looks to find a perceivable difference among products. There are several different methods to conduct descriptive analysis, but all are aimed to quantify the intensity of sensory properties in a product, typically utilizing trained panelists. Affective testing uses untrained panelists, and aims to quantify the level of liking or disliking of a product. A very common affective or hedonic test is an overall liking test, which generally utilizes a nine-point hedonic scale. A particular type of affective testing is acceptability testing. Scales known as Just About Right (JAR) scales test products on a symmetrical scale from “Not Enough [X]” to “JAR” to “Too Much [X]” (Lawless and Heymann 2010). These scales intentionally conflate intensity and hedonic perceptions. The resulting directional judgments of specific attributes are very beneficial when reformulating products. Additionally, by combining JAR testing with overall liking, penalty analysis or “mean drop analysis” can be performed (Rothman and Parker 2009).

In mean drop analysis, the “drop” value is calculated by first averaging the overall liking scores for participants who scored the attribute as above or below JAR. This average from above or below JAR is then subtracted from the average overall liking score of those who rated the attribute as JAR. Drop values for each attribute (for example, -1.2 for “Not Sweet Enough”) are plotted against percentage of participants who rated the product as such (Lawless and Heymann 2010). Benefits of using mean drop analysis are that the data is easy to interpret, and it links specific product attributes to the impact on overall liking of not being JAR. Additionally, it separates attributes that have an effect on overall liking versus mere complaints that have no major impact on overall liking. Disadvantages include that no clear action is specified when data appears bimodal—in other words, when “not X enough” and “too X” both have a large percentage of respondents with a large mean drop. Mean drop analysis also does not specify the amount of adjustment needed to correct a certain attribute with a high mean drop, and it does not take into account the possible alteration to ratings of other attributes when the targeted attribute is adjusted (Rothman and Parker 2009).

Lovely and Meullenet used JAR scales with mean drop analysis to determine an optimal strawberry yogurt. This study concluded that the most highly liked strawberry yogurt had a strong strawberry flavor with high sweetness (Lovely and Meullenet 2008). In a 2007 study by Thompson, Lopetcharat, and Drake on sensory analysis of strawberry yogurt beverages, results show that natural fruit flavor and sweet taste were the highest drivers of liking in the product. The results of this study also indicate that participants were divided into clusters of overall liking for variable products, suggesting that there may not be a single product that can be optimized to the preferences of all consumers in every attribute (Thompson, Lopetcharat, and Drake 2007).

Product Development

If a company wishes to remain competitive and viable in the marketplace, innovation in product development is imperative (Mishra 2008). The fundamental role of product development is to understand and then fulfill consumer wants and needs while maintaining profitability. A general model for product development, as described by Earle, et al, has four stages: product strategy, product design and process development, product commercialization, and product launch and evaluation (Earle, Earle, & Anderson, 2001).

The product strategy stage involves defining and designing the product concept, identifying how other sectors such as marketing and manufacturing should be taken into account, developing specifications for the product and its design, and predicting the financial scope of the project. Numerous factors must be taken into account when designing the product, including composition, packaging, safety, nutrition, shelf-life, usability, costs, and product quality. Overall, the product development process relies heavily on collaboration between marketing research, consumer research, production and manufacturing research, technology, and food product design, while taking into account consumer trends and technological trends (Earle, Earle, & Anderson, 2001).

Of the thousands of innovative products introduced to the marketplace every year, it is well-known that about 88% of new products fail and are removed from store shelves within one year (Rudder, Ainsworth, and Holgate 2001). However, continued innovation is a must for any successful business. There are a number of types of innovation, such as “me-too products” which are imitations of existing products, line extensions which introduce new flavors or novel methods of delivery, and repositioned existing products which have a new use for an existing product. New forms of existing products offer just that—for example soup in a powdered form; while new packaging of existing products can improve ease-of-use for an existing product. New products can also be reformulations of existing products, and finally, creative or true new products which have never before existed. Each form of innovation varies in extensiveness of the product development process and associated costs. Associated risks also vary between type of new product, as do potential benefits and profits (Mishra 2008).

1.2 Objective

The intention of this study was to improve overall liking (*liking*) of Dr. Bob's Low Fat Strawberry Yogurt Smoothie. The main objectives were to determine the factors most important in driving *liking* of Dr. Bob's smoothie, and to assess how varying the main driver of *liking* influences overall liking of the product. Mean drop analysis was used, utilizing a nine point hedonic scale for overall liking with attribute specific JAR scales for five distinct attributes: sweetness, sourness, thickness, strawberry flavor, and color. The attribute with the greatest percentage of participants and the greatest mean drop in overall liking was addressed via reformulation of the original product. The original product was tested, along with several variants, to determine if a significant difference exists in overall liking between the original product and modified versions.

Chapter 2

Materials and Methods

2.1 Yogurt Production

Original Dr. Bob's Low Fat Strawberry Yogurt Smoothie is produced according to the formulation presented in Tables 2-1 and 2-2, and the flow diagram shown in Figure 2-1. The following steps are outlined in the flow diagram:

1. Mix the yogurt ingredients: skim milk, sugar, cream, and non-fat dry milk.
2. Pasteurize the mix at 80°C (177°F) for 25 seconds.
3. Homogenize the mix at 2000 psi first stage and 500 psi second stage. The mix is then pumped to the yogurt tank.
4. Heat treat the mix at 82°C (180°F) for 30 minutes.
5. Cooling the mix to 41-43°C (106-110°F).
6. Inoculate the mix with starter culture (YF-L702, CHR Hansen, Milwaukie, IL, USA), added at 0.02% wt/wt. Agitate for 20 minutes.
7. Incubate to a pH of 4.5.
8. Cooled with low-speed agitation to 21°C (70°F).
9. To make the slurry, water is combined with corn syrup solids, sugar, and pectin dry-blended with sugar, and heated to 82-88°C (180-190°F) until the pectin is dissolved. The slurry is then mixed for a minimum of 1 hour.
10. The slurry is cooled to 38°C (100°F); the strawberry puree is mixed into the slurry.

11. The slurry, with strawberry puree, is mixed into the yogurt white mass for at least 10 minutes.
12. The product is homogenized at 500/1000 psi and sent to a storage tank prior to bottling.
13. The final product is bottled in a machine that deposits 16 ounces of yogurt into a single bottle, and caps, labels, and stamps the time and sell by date on the bottle.
14. Samples are taken from the bottling machine at the beginning, middle, and end of the run to test for coliforms, yeasts, and molds.
15. All product is stored. If the microbial tests from step 14 are positive, the product is not released for sale.

Table 2-1. Original Smoothie and Component Formulations

Component	% in Yogurt	% in Slurry	% in Strawberry	% in Smoothie
MSNF	9.00	0.00	0.00	6.80
Fat	1.30	0.00	0.00	0.98
Sucrose	3.00	18.00	36.00	7.22
36DE CSS	0.00	29.80	0.00	6.41
Pectin	0.00	1.86	0.00	0.40
Total Solids	13.30	49.66	38.00	21.80

Table 2-2. Original Smoothie Components and Example Recipe

Smoothie Component	% of Smoothie (wt/wt)	Ingredient Component	% of Smoothie Component (wt/wt)
Yogurt White Mass	75.5	**Skim Milk**	93.6
		Cream	3.2
		NFDM	0.3
		Sucrose	3.0
Slurry	18.5	**Water**	50.3
		36DE CSS	29.9
		Sucrose	18
		Pectin	1.9
Strawberry Puree	6.0	**Strawberry**	100.0

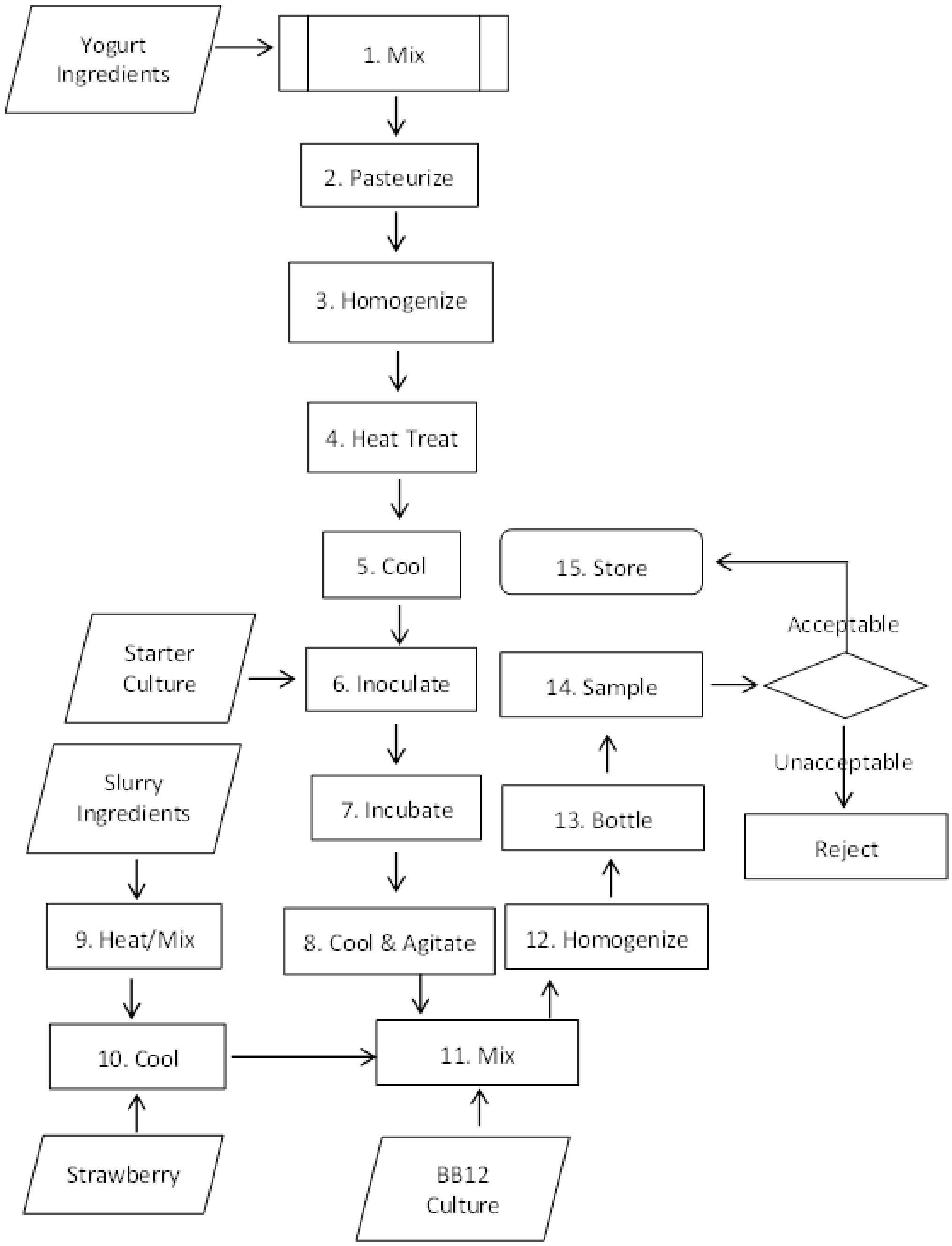

Figure 2-1. Process Flow Diagram for Original Dr. Bob's Low Fat Strawberry Smoothie

2.2 Analytical Testing

Total solids and total fat were measured in triplicate using the CEM SMART TRAC, as specified in AOAC method 990.20 (AOAC 1995) and AOAC PVM 1:2004 (Journal of AOAC 2005), respectively. Coliforms were enumerated for according to AOAC Official Method 989.10 (AOAC 2010). An electronic pH meter was used to take pH values of the finished product as stated in Method 15.022, section 9 of the Standard Methods for the Examination of Dairy Products (Wehr and Frank 2004).Viscosity was measured using a Zahn cup (#2, Boekel Scientific, Feasterville, PA). The Zahn cup was dipped into a beaker with 300 mL of the product at 10°C; timing was started immediately as the cup reached the surface of the product, and was stopped when the steady flow of liquid from the cup hole stopped. This test was performed in triplicate. Color of the products was measured using a L*a*b* colorimeter, covered with a clear plastic bag for protection. The color-reading sensor, covered with a single layer of plastic, was dipped into the surface of the product to measure L*a*b* values in triplicate.

2.3 Sensory Testing

Participants

Participants were recruited from the campus and community surrounding the Pennsylvania State University. Participants were selected based off their reported consumption of strawberry flavored yogurt or a strawberry flavored yogurt drink product within the last month. Participant demographic information is shown in Table 2-3. Participants received five dollars compensation for their participation. Procedures were exempted from Institutional Review Board review by the Penn State Office of Research Protections under the wholesome foods/approved food additives exemption in 45 CFR 46.101(b)(6).

Table 2-3. Demographic Breakdown of Participants

Trial	Total Participants	Gender (%)		Age (%)				
		Male	Female	18-25	26-35	36-45	46-55	55+
1	75	17.5	82.5	23.8	22.5	22.5	30	1.3
2	68	32.4	67.6	35.3	27.9	11.8	25	0
3	80	28	72	38.7	40	8	13.3	0

Stimuli

In Trial 1, the original product was the only product tested. In Trial 2, flavoring (Natural Strawberry Flavor WONF #32462, David Michael, Inc., Lynchburg, VA, USA) was added to half the sample batch at the recommended rate of 0.20% using an electronic balance, micropipette, and fork for stirring. In Trial 3, the same flavoring was added but at a rate of 0.15% to one third of the sample batch, and a rate of 0.10% to another third of the sample batch.

Presentation

Two ounce samples were labeled with three digit blinding codes and served at approximately 7°C. In Trials 2 and 3, samples were served in counterbalanced order. All samples were presented on a single tray, and participants were asked to first rinse with water before tasting the first sample. Re-tasting was allowed. A 10 second rinse period was given between samples for Trials 2 and 3. Testing was carried out in individual booths in the Sensory Evaluation Center at the Pennsylvania State University Department of Food Science.

Scaling

To analyze liking of specific attributes of each product, five point just about right (JAR) scales were used for sweetness, sourness, thickness, strawberry flavor, and color. An example of the JAR ballot screen for sourness is shown in Figure 2-2. Category labels for each of the specified attributes were as shown in Table 2.4.

Figure 2-2. Example of JAR Ballot Screen

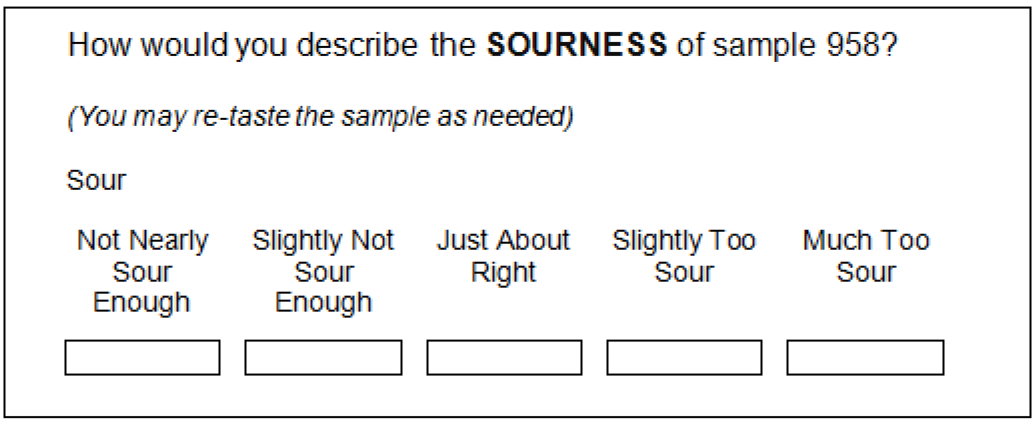

Table 2-4. Category Labels for JAR Scale Ratings

	Rating				
	1	2	3	4	5
Sourness	Not Nearly Sour Enough	Slightly Not Sour Enough	Just About Right	Slightly Too Sour	Much Too Sour
Sweetness	Not Nearly Sweet Enough	Slightly Not Sweet Enough	Just About Right	Slightly Too Sweet	Much Too Sweet
Thickness	Much Too Thin	Slightly Too Thin	Just About Right	Slightly Too Thick	Much Too Thick
Strawberry Flavor	Much Too Weak	Slightly Too Weak	Just About Right	Slightly Too Strong	Much Too Strong
Color	Much Too Light	Slightly Too Light	Just About Right	Slightly Too Dark	Much Too Dark

A nine point hedonic scale was used to test for overall liking in each product—1 being "Dislike Extremely" and 9 being "Like Extremely" (Peryam and Pilgrim 1957). Results were collected and summarized using Compusense *five* computer software (Compusense Inc., Guelph, Ontario, Canada). The ballot was designed to first ask participants for their overall liking, then more specifically about their perceptions of the five specified product attributes. When there is only one sample (as in Trial 1), this ensures that participants' overall liking scores aren't influenced by introducing analysis of specific attributes. However when multiple samples are tested, JAR scales from the first sample can affect overall liking scores of later samples (Popper, Schraidt, and Kroll 2004), as examined in the Results and Discussion section.

Statistical Analysis

Analysis of Variance was used with Tukey's test to determine if significant differences (α=0.05) existed between products in sweetness, sourness, thickness, strawberry flavor, color, or overall liking. Mean drop analysis was used to analyze the effect of ratings other than JAR on overall liking (Lawless and Heymann 2010). Points plotted in the upper right hand corner of the mean drop analysis plots were considered to have a large impact on overall liking scores.

2.4 Design

The original Dr. Bob's Low Fat Strawberry Yogurt Smoothie was first analyzed using all aforementioned analytical and sensory tests. Mean drop analysis was used to assess the factors critical in liking. The original product was then modified with respect to the determined factors. The modified product was analyzed according to the same sensory analysis. Mean drop analysis was again used to determine the effect of modification on the factors critical in liking. A second round of modifications ensued, consisting of two new treatments. Mean drop analysis was conducted a final time to determine if the identified factors critical in liking were altered. The overall process consisted of three trials, each trial including the original product as a control. ANOVA was used to determine if a single treatment had significantly greater overall liking. Analytical results were also compared using ANOVA to demonstrate that all products were statistically similar in the physical attributes of total solids, total fat, and viscosity.

Chapter 3

Results and Discussion

3.1 Analytical Results

Table 3-1 shows that the analytical results for each treatment in each trial remained very constant. Using one-way ANOVA and Tukey's test, there were no statistical differences in total solids, total fat, viscosity, or L*a*b* values, and thus these were constant variables in the sensory tests. Coliform counts at < 1 HSCC/g indicate that the products were safe for human consumption.

Table 3-1: Analytical Results for All Trials

Trial	Product	Total Solids (%)	pH	Fat (%)	Coliform (HSCC/g)	Viscosity (Zahn sec)	Colorimeter Values		
							L*	a*	b*
1	Original	20.99 ± 0.11	-	0.77 ± 0.03	< 1	-	-	-	-
2	Original	21.34 ± 0.02	4.37 ± 0.02	0.80 ± 0.02	< 1	22.50 ± 0.42	80.99 ± 0.19	7.55 ± 0.05	5.09 ± 0.02
	Flavor (0.20%)	21.79 ± 0.08	4.35 ± 0.03	0.69 ± 0.03	< 1	21.80 ± 0.25	79.52 ± 0.22	9.08 ± 0.01	5.59 ± 0.08
3	Original	21.48 ± 0.02	4.31 ± 0.02	0.71 ± 0.02	< 1	22.19 ± 0.32	80.10 ± .56	8.13 ± 0.10	6.03 ± 0.09
	Flavor (0.10%)	21.48 ± 0.03	4.41 ± 0.01	0.71 ± 0.03	< 1	23.01 ± 0.33	78.98 ± 0.22	9.22 ± 0.18	5.43 ± 0.19
	Flavor (0.15%)	21.48 ± 0.04	4.40 ± 0.03	0.71 ± 0.04	< 1	22.67 ± 0.21	81.02 ± 0.31	8.67 ± 0.11	5.89 ± 0.04

[1.] indicates mean ± standard deviation
** indicates that analytical tests were not conducted

3.2 Sensory Results

Figure 3-1 contains data about overall liking for all treatments across all trials, and shows that the original product from Trial 1 had a significantly greater liking score than the original treatments in Trials 2 and 3, although it was not significantly greater in overall liking than any of the flavor added products. In Trial 3 alone, the original treatment had lower overall liking than both flavor added products, although there was no significant difference in overall liking among any of the three treatments for Trial 3.

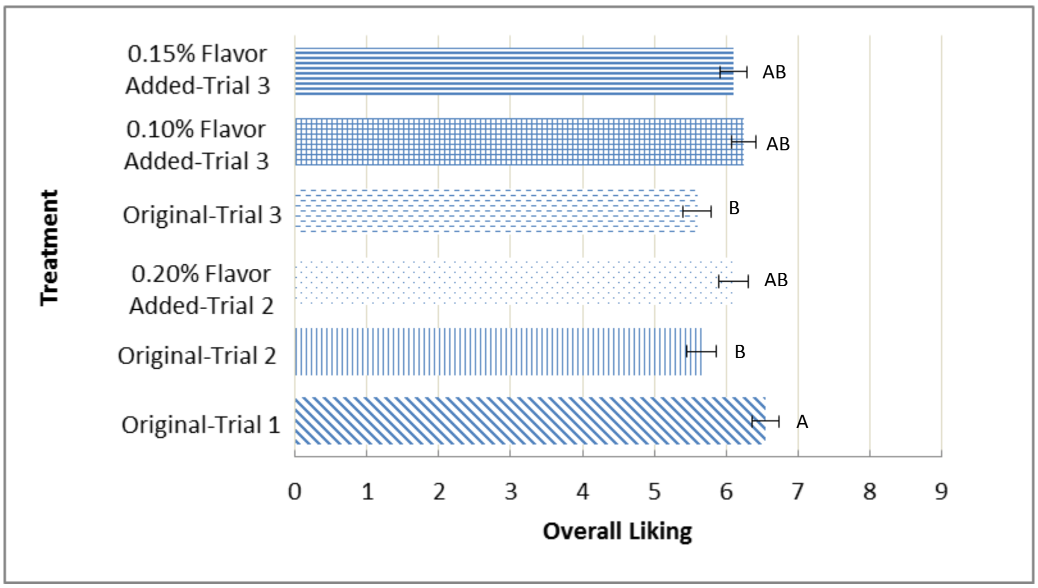

Figure 3-1. Overall liking for all treatments across all trials. Scores were rated on a nine point hedonic scale, 1 being "dislike extremely" and 9 being "like extremely." Error bars indicate standard error of the mean. Bars with no matching letters indicate a statistical difference (α=0.05).

Significant differences in JAR ratings for each tested attribute—sourness, sweetness, thickness, strawberry flavor, and color—were analyzed using one-way ANOVA and Tukey's test. Across all treatments and trials, sourness, thickness, and color did not vary significantly. For sweetness, the original product in Trial 1 had a significantly greater mean JAR sweetness rating, in the “Slightly Too Sweet” category, than the original product in Trials 2 and 3, and significantly greater than the 0.15% flavor added treatment in Trial 3. For strawberry flavor ratings, the 0.20% flavor added product from Trial 2 along with the 0.10% flavor added product from Trial 3 were significantly greater and closer to JAR than the original product in Trial 3.

Figures 3-2 through 3-6 show the frequency distribution of responses on a JAR scale for each tested attribute. For the sourness JAR scale frequency distribution (Figure 3-2), the JAR portion of the distribution is generally centered. Since sourness wasn’t directly manipulated, variability in JAR ratings among treatments is likely due to the addition of strawberry flavor. Each of the flavor added treatments has JAR ratings slightly skewed to the left, with fewer ratings than the original treatments for sourness being below JAR

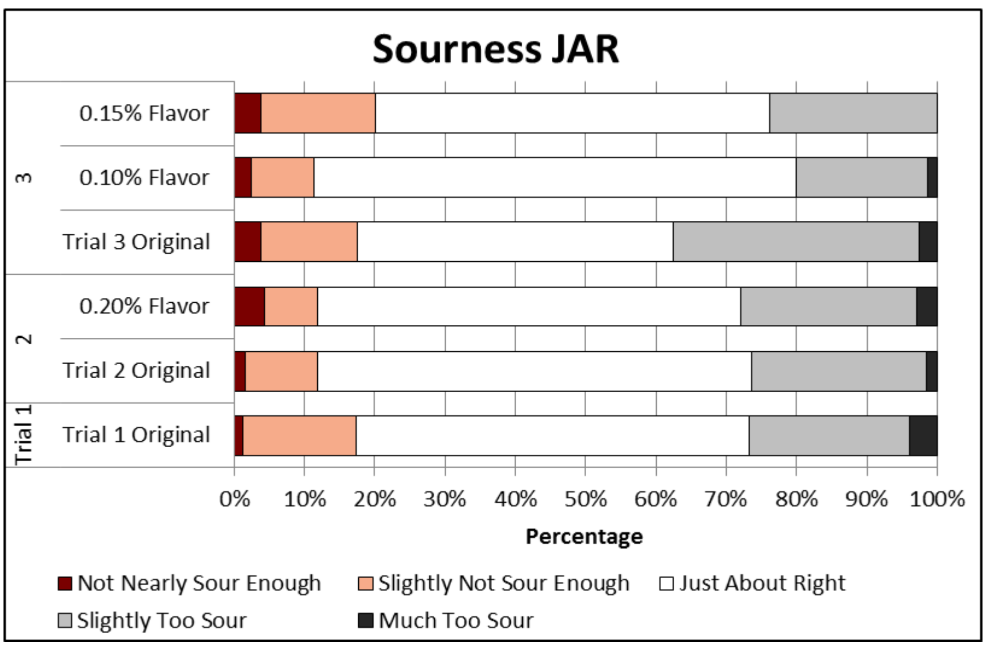

Figure 3-2. Distributions of responses for *sourness* rated on a 5 point JAR scale. The x-axis is the proportion of responses for each category on the JAR scale. Each horizontal bar is a single treatment.

For sweetness (Figure 3-3), the JAR portion is skewed slightly to the right, indicating that many of the ratings that were not JAR were on the “not sweet enough” end of the scale. In Triala 2 and 3, the original treatment had lower sweetness JAR ratings than the flavor added samples. Since all that was added was natural strawberry flavor, this difference in sweetness is likely caused by dumping.

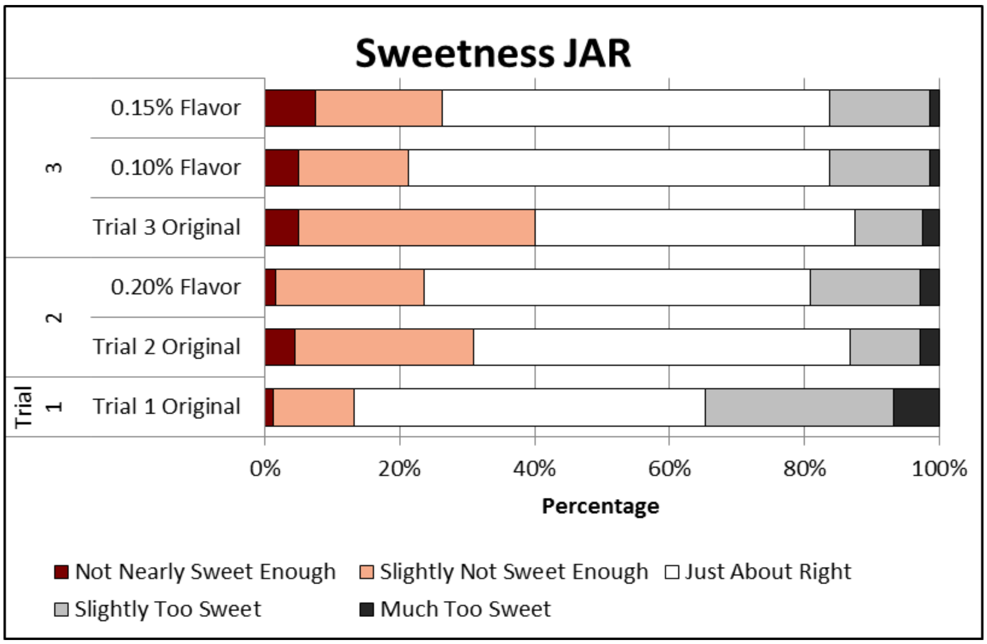

Figure 3-3. Distributions of responses for *sweetness* rated on a 5 point JAR scale. Same as Figure 3-2 but for sweetness.

The thickness JAR (Figure 3-4) scores were also skewed to the right, indicating that respondents generally thought the product was too thin.

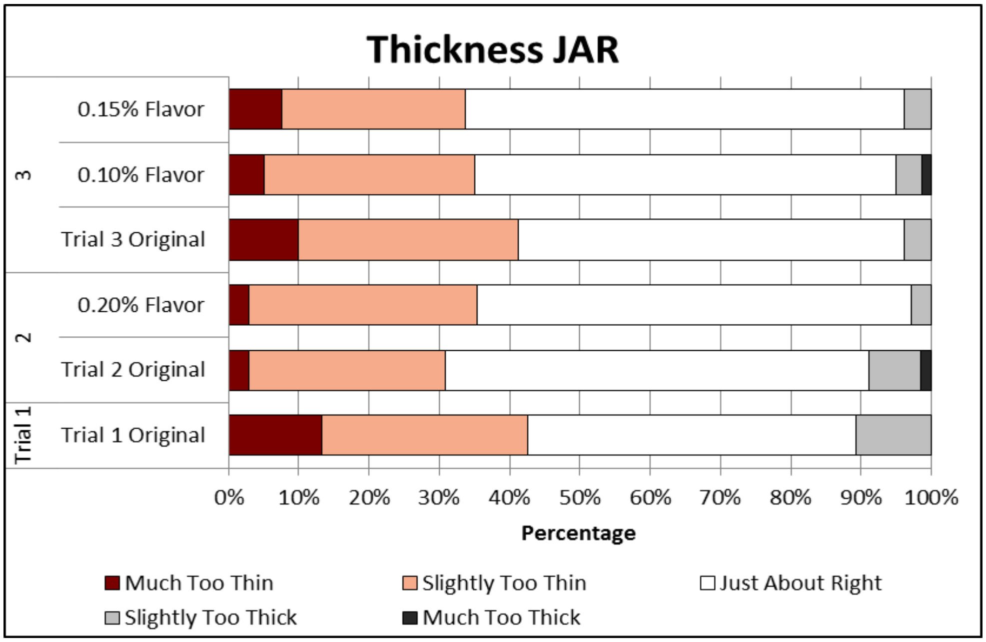

Figure 3-4. Distributions of responses for *thickness* rated on a 5 point JAR scale. Same as Figure 3-2 but for thickness.

Strawberry flavor ratings (Figure 3-5) were generally skewed to the right, indicating perceptions of "not strawberry enough." However, the original product in Trial 3 was more skewed to the right than the other treatments, and the 0.20% flavor added treatment was more centrally positioned—with a few more ratings of "too much strawberry" than other treatments. There were more "too weak" ratings for strawberry flavor for the 0.15% flavor added treatment than the 0.10% flavor added treatment, which suggests some kind of error in the analysis or data collection.

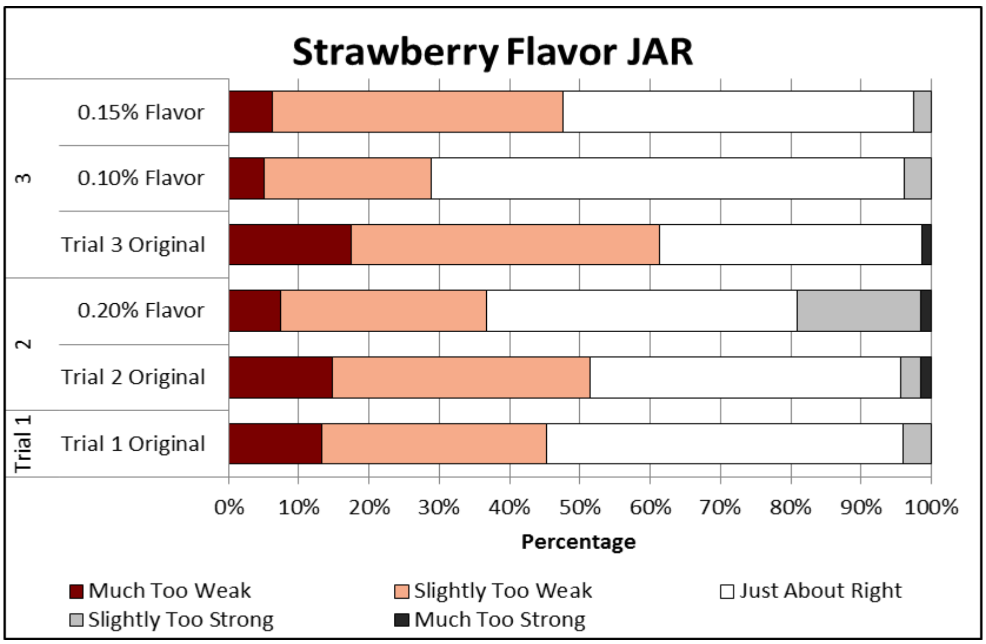

Figure 3-5. Distributions of responses for *strawberry flavor* rated on a 5 point JAR scale. Same as Figure 3-2 but for strawberry flavor.

Figure 3-6 shows that color was mostly rated as JAR, with almost all other ratings being on the "too light" end of the scale. Although consumer perceptions of color varied among treatments, L*a*b* analytical results indicate that color did not significantly vary among samples physically.

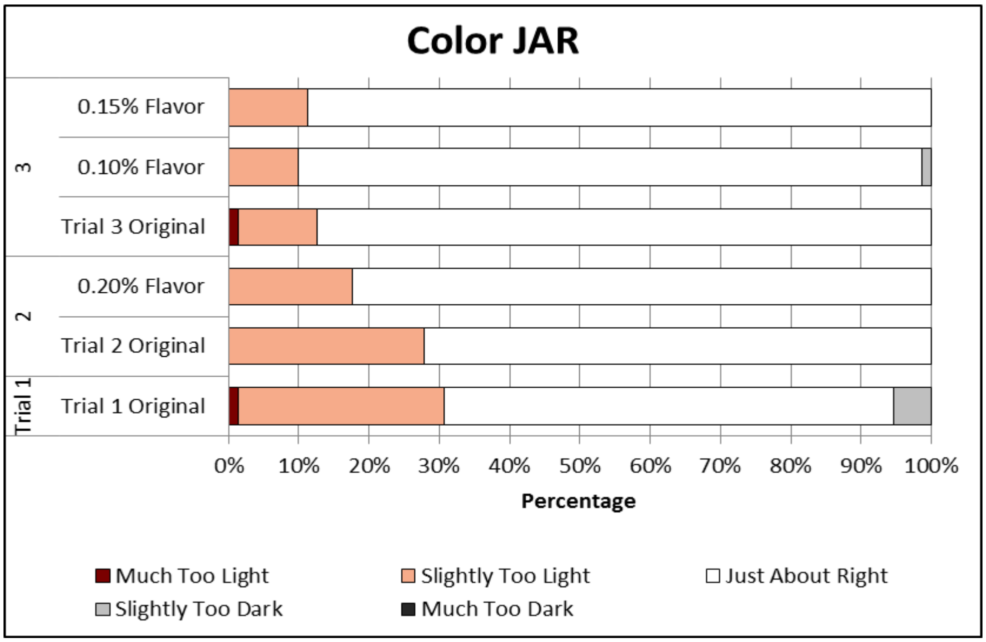

Figure 3-6. Distributions of responses for *color* rated on a 5 point JAR scale. Same as Figure 3-2 but for color.

3.3 Mean Drop Analysis

Mean drop analysis was conducted on the sensory results for the original Dr. Bob's Smoothie for Trial 1 (Figure 3-7). As can be seen in the figure, "Not Enough Strawberry" had the greatest influence on overall liking of the product, with 45.3% of respondents having a mean drop of -1.4 points on a nine point overall liking scale. Thus, in Trial 2, natural strawberry flavor was added to the original product to increase strawberry flavor. Mean drop analysis was again conducted on sensory results for the original product, and for a 0.20% (wt/wt) flavor added product (Figures 3-8 and 3-9). In Trial 3, 0.10% flavor added and 0.15% flavor added treatments were analyzed along with the original, and mean drop analysis was again conducted (Figures 3-10 through 3-12).

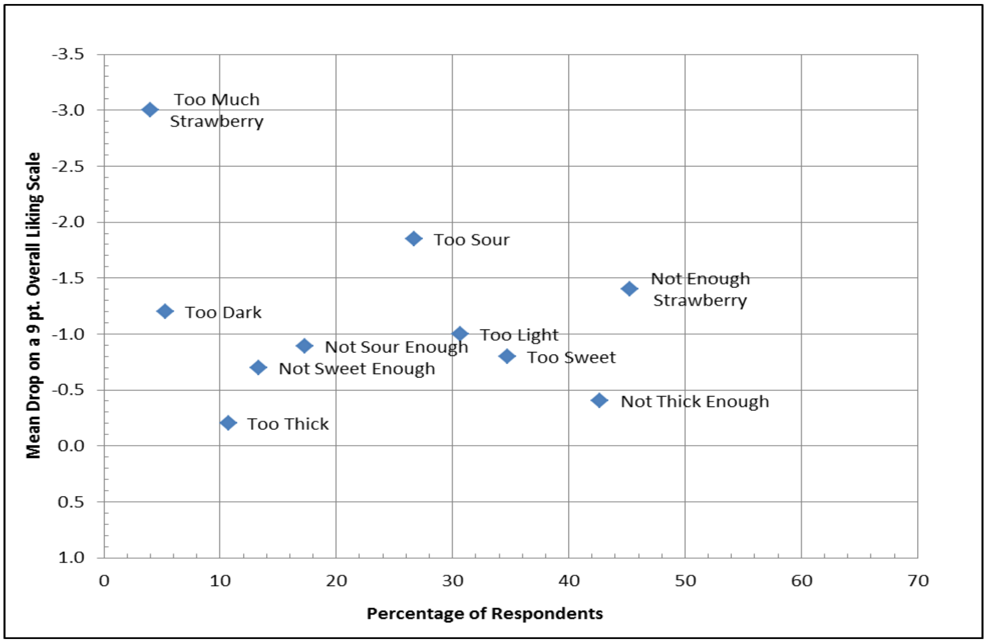

Figure 3-7. Mean Drop Analysis of Original Dr. Bob's Low Fat Strawberry Yogurt Smoothie Sensory Results in Trial 1

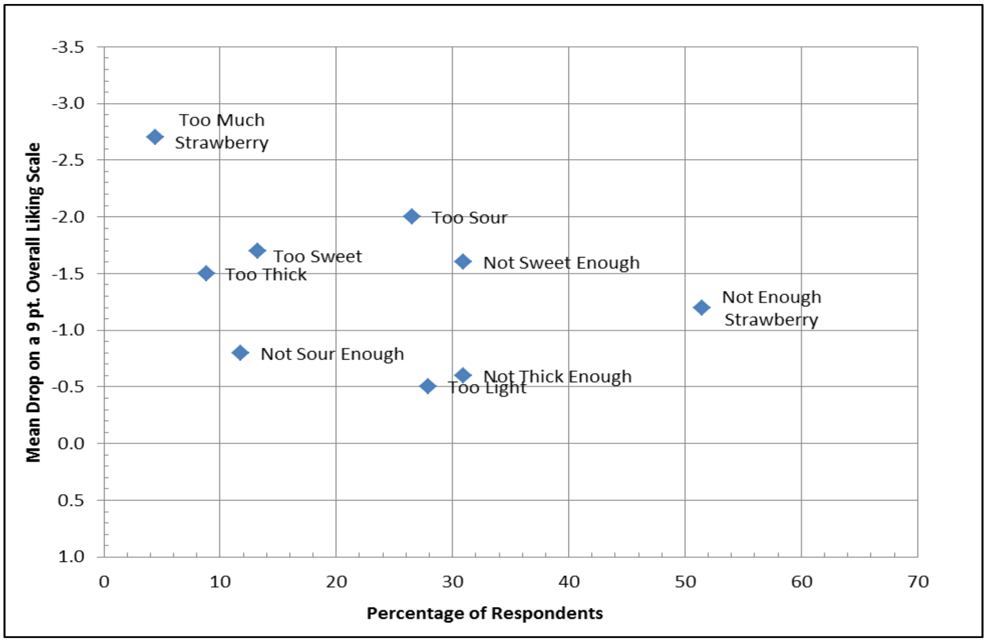

Figure 3-8. Mean Drop Analysis of Original Dr. Bob's Low Fat Strawberry Yogurt Smoothie Sensory Results in Trial 2

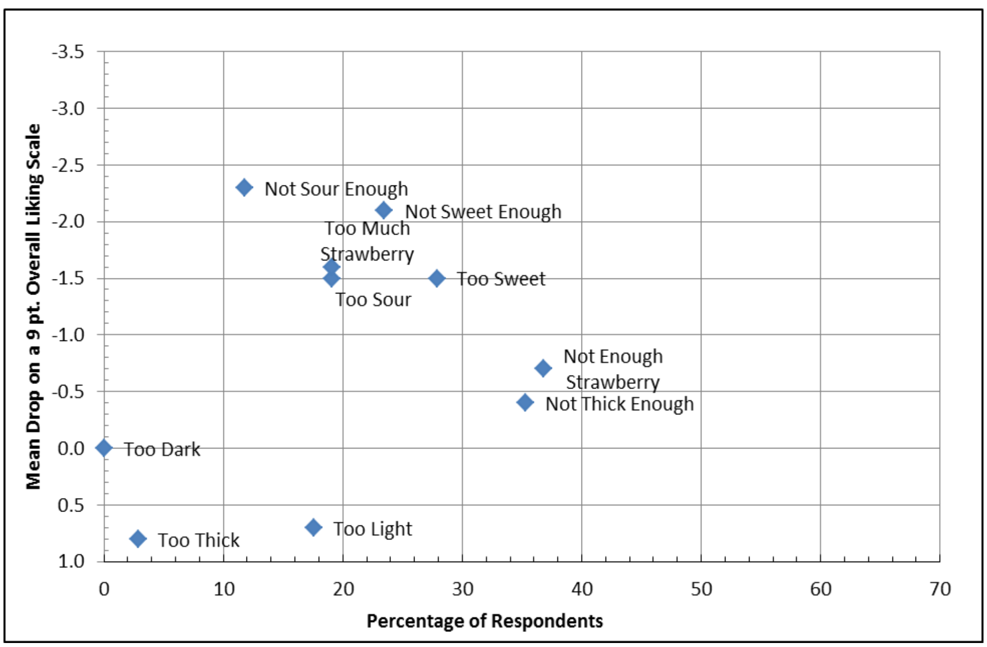

Figure 3-9. Mean Drop Analysis of 0.20% Flavor Added (% wt/wt) Strawberry Yogurt Smoothie Sensory Results in Trial 2

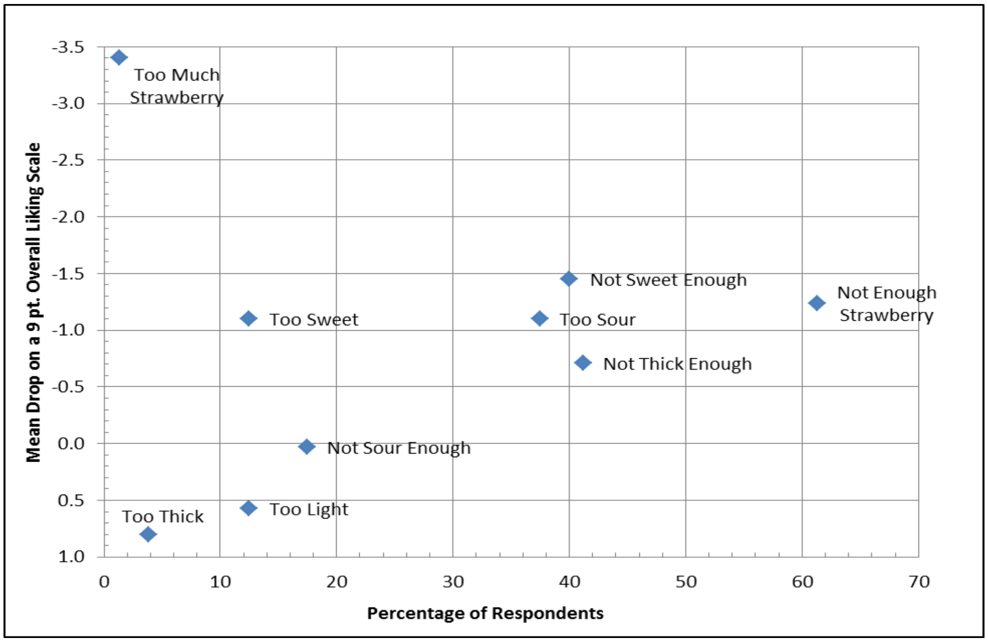

Figure 3-10. Mean Drop Analysis of Original Strawberry Yogurt Smoothie Sensory Results in Trial 3

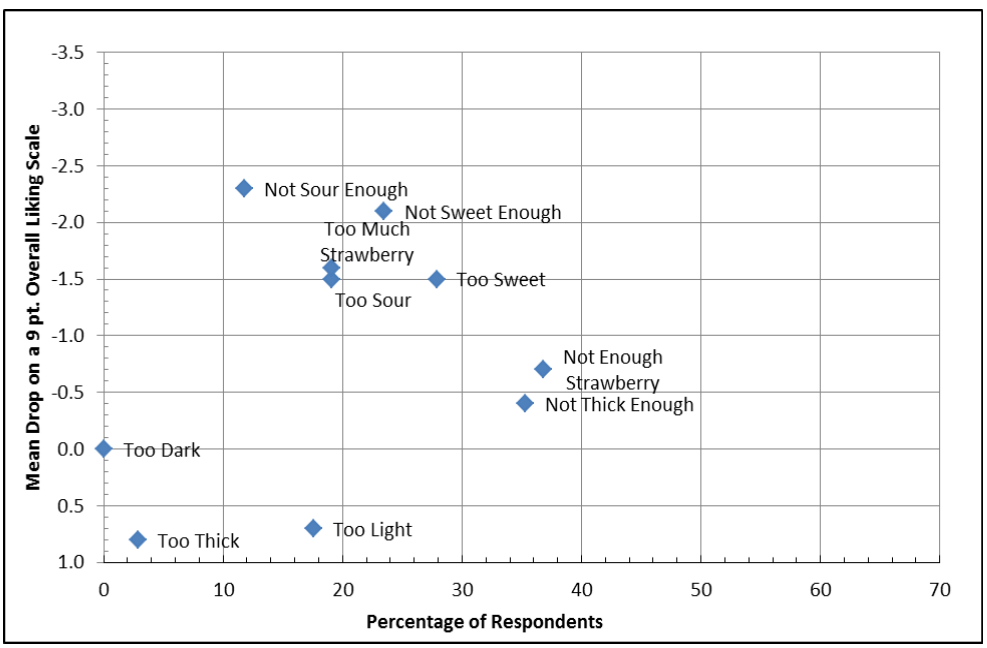

Figure 3-11. Mean Drop Analysis of 0.10% Flavor Added (% wt/wt) Strawberry Yogurt Smoothie Sensory Results in Trial 3

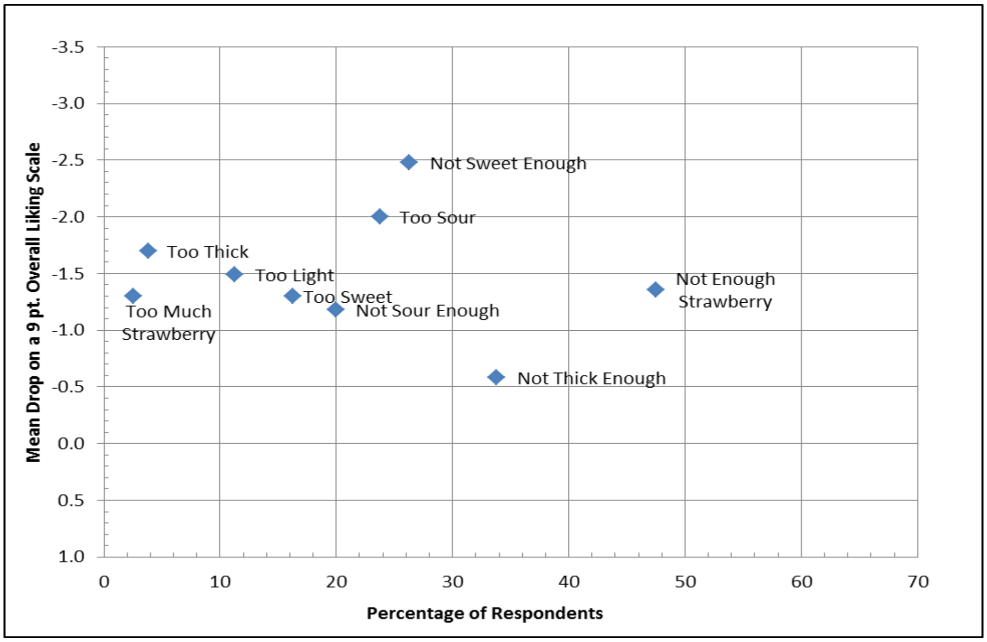

Figure 3-12. Mean Drop Analysis of 0.15% Flavor Added (% wt/wt) Strawberry Yogurt Smoothie Sensory Results in Trial 3

Although the overall liking of the original product dropped from 6.55 in Trial 1 to 5.66 in Trial 2, "Not Enough Strawberry" still had the greatest influence on overall liking of the product in Trial 2, with 51.5% of respondents having a mean drop of -1.2 on a nine point overall liking scale (Figure 3-9). In the 0.20% flavor added sample, "Not Enough Strawberry" dropped to 36.8% of respondents with a -0.7 point mean drop. Although this was a substantial improvement to those respondents who wanted more strawberry flavor, the mean drop for "Too Much Strawberry" increased from only 4.4% of respondents at -2.7 points, to 19.1% of respondents at -1.6 points. As this shows, adding a greater concentration of strawberry flavor to drive down the "Not Enough Strawberry" rating would likely increase the ratings for "Too Much Strawberry." Thus, in Trial 3, natural strawberry flavor was added to the original product at rates of 0.10% and 0.15% to ideally drive down the "Too Much Strawberry" ratings while maintaining the "Not Enough Strawberry" ratings at around 36% of respondents.

In Trial 3 alone, the original product had significantly lower overall liking than both flavor added treatments. "Not Enough Strawberry" ratings in the original product in Trial 3 were at an even greater percentage of respondents than in the Trial 2 original treatment with 61.3% of respondents, and with a -1.2 mean drop. The "Not Enough Strawberry" rating in the 0.10% flavor added treatment dropped to only 28.8% of respondents, with a mean drop of -1.4. "Too Much Strawberry" went from only 1.3% of respondents -3.4 mean drop in the original product in Trial 3 to only 3.8% of respondents with a mean drop of 0.1 for the 0.15% flavor added treatment. A positive mean drop value indicates that those who rated the product as "Too Much Strawberry" had a greater overall liking of the product by 0.1 on the 9 point hedonic scale than those who rated the product as JAR. For the 0.15% flavor added treatment, "Not Enough Strawberry" ratings were higher than for the 0.10% flavor added treatment, at 47.5% of respondents and a mean drop of -1.4. "Too Much Strawberry" ratings were still very low at 2.5% of respondents and a -1.3 mean drop. It was expected that there would be more "Not Enough Strawberry" ratings in the 0.10% flavor added treatment than in the 0.15% flavor added treatment. This illogical difference could be explained by differences in participants between trials and too few participants, which would affect the results for strawberry flavor JAR ratings, in addition to other attributes.

3.4 Limitations

When analyzing the overall liking results, it is important to note that the experimental design used did not account for ballot-based context effects in responses. When JAR scales are used on the same ballot as an overall liking scale, it identifies specific attributes for participants to analyze when they rate the product on overall liking (Popper, Schraidt, and Kroll 2004). For Trial 1, this was not an issue because overall liking was asked on the ballot before any JAR scales, and there was only one product to evaluate. In Trials 2 and 3, however, JAR scales from the first evaluated treatment are likely to have influenced overall liking ratings for the remaining treatment(s). Although counterbalancing was used to compensate for any treatment order effects, counterbalancing does not fully offset the bias and the mean overall liking was likely still affected.

It is also important to note that changes in overall liking in the original product could be due to context effects. As stated by Meilgaard, et al (2007), external factors such as atmosphere of participant testing area and temperature of samples in sensory tests must be controlled to minimize participants' bias. In the case of this test, time of year for testing could have an effect on overall liking of the product, as yogurt drinks are a more popular product in warm summer weather as opposed to cold winter weather. Trial 1 was conducted in June, and Trials 2 and 3 were conducted in February and March, respectively—thus, time of year likely had an effect on overall liking differences among trials. It is also possible that the stage of product shelf life affected overall liking scores. The products in Trial 1 and 3 were in their second week of the 30 day shelf life while the products in Trial 2 were in their fourth week of the shelf life. Sensory ratings for astringency and sourness in yogurt have been shown to change with increasing storage time (Salvador and Fiszman 2004), and thus this difference in stage of shelf life could have an impact on overall liking and JAR scores.

As far as data analysis is concerned, JAR scale ratings can be more thoroughly analyzed using the Cochran-Mantel-Haenszel (CMH) method than ANOVA. However, the CMH method requires statistical software and is highly intensive, which was outside the scope of this analysis.

Chapter 4

Conclusion and Future Work

Mean drop analysis was used to determine that "Not Enough Strawberry" was the most important factor in driving overall liking of the original Dr. Bob's Low Fat Strawberry Yogurt Smoothie. Of all the treatments, the 0.10% flavor added treatment showed the lowest percentage of respondents with a "Too Much Strawberry" rating, with only 28.8% of respondents and a -1.4 mean drop. The 0.10% flavor added treatment also kept "Too Much Strawberry" ratings to only 3.8%. Although the original product from Trial 1 had the greatest overall liking of all treatments, there was no significant difference between overall liking in the Trial 1 original product and any of the flavor added treatments. It is likely that external weather and subsequent participant preferences caused context effects that impacted the differences in ratings among trials.

Considering future work, in order to minimize bias in the sensory analysis results from context effects, all treatments should be tested during the same season, ideally on days with similar weather. Additionally, all treatments should be in the same stage of product shelf life to avoid adding another variable to the results.

It would also be interesting to analyze the concept of segmentation within the presented data. Liking of any product can be divided into segments—sometimes determined by age, gender, or lifestyle, and sometimes simply determined by taste preferences (Lawless and Heymann 2010). A study on consumer preference for drinkable strawberry yogurt among several ethnic groups shows major differences in product attribute preferences among ethnic segments (Thompson, Lopetcharat, and Drake 2010). Thus, it is possible that segmentation exists in taste preference for Dr. Bob's Low Fat Strawberry Yogurt Smoothie, as evidenced by the alteration in ratings of “Too Much Strawberry” versus “Not Enough Strawberry” with varying concentrations of added flavor. It would be interesting to investigate this possible segmentation in the future, although the university Creamery currently plans to only manufacture one yogurt drink, and thus the current yogurt drink is being optimized singularly.

The mean drop analysis charts all show that “Not Thick Enough” was also a prominent rating in all treatments. For optimal reformulation of the product, thickness should be addressed.

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Big Ten Sportsmanship Award 2011, 2013