THE EFFECTS OF POLYSORBATE-80 AND LECITHIN ON STABLE FROZEN DESSERT

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ABSTRACT

The texture and richness of an ice cream are wholly dependent on the precise combination of its ingredients. This experiment aimed to determine the effects of various concentrations of two emulsifiers: lecithin and polysorbate-80, and to determine if they had a synergistic effect. It was hypothesized that a 70% polysorbate-80 and 30% lecithin ratio would best meet the desired qualities. After conducting sensory evaluations, it was determined that in the low fat ice cream, the emulsifiers had negligible effect on the taste of the final product. In the light ice cream, the 70% polysorbate-80 and 30% lecithin trial had the best texture and richness. In the regular ice cream, the emulsifier negatively impacted the taste of the sample.

INTRODUCTION

Food science is the scientific discipline that involves all aspects of food development and production. The study of food science begins with the harvesting of ingredients and ends with the consumption of a food product by the consumer. Food scientists formulate and package food products, study of shelf-life of products, conduct sensory evaluation, and have chemical testing of products. Food science has many connections to other scientific disciplines, including microbiology, chemistry, biochemistry, and chemical engineering. Thus, food scientists require an understanding of the fundamental chemical, biological, and physical properties of each of the materials they work with in order to ensure that they can manufacture a microbiologically safe and chemically shelf stable product for mass consumption [1].

To create ice cream, scientists utilize the physical chemistry of dispersion systems. Ice cream is 30% ice, 50% air, 5% fat, and 15% sugar solution [2]. Ice cream is difficult to concoct because it consists of all three states of matter: solid ice crystals and fat droplets, liquid sugar solution, and gaseous air bubbles. It also simultaneously exists as three dispersions: an emulsion, a sol, and a foam. Food emulsions, or dispersions of one liquid within another, generally consist of oil and water. Ice cream is a dispersion of milk fat within water. Emulsions are unstable because both the oil and water coalesce their smaller droplets into larger ones. A sol is a dispersion of solid particles in a liquid phase; in ice cream, the ice crystals are the solid phase. Brownian motion, or the random movement of particles, suspends the smaller ice particles within the mixture. The larger ice particles, being less dense than the matrix of the ice cream, rise to the top. This may result in freezer burn after a long period of time. Foam is a gas dispersed in a liquid. In a foam, gas bubbles are separated by thin liquid films. Foams are only possible in the presence of surface active molecules such as emulsifiers, stabilizers, and proteins which maintain the bubbles. Ice cream's whipped, smooth texture is attributed to the many air bubbles within it [2].

The complex nature of ice cream necessitates the inclusion of substances that can help stabilize the mixture so that it can exist as all three colloid dispersions [2]. Two substances that are essential to the quality of ice cream are stabilizers and emulsifiers. Stabilizers are an essential component of ice cream manufacturing, although they are used in small amounts. They are water-soluble biopolymers that are generally polysaccharides obtained from plants. Made up of branched or straight polymers, stabilizers have the ability to form hydrogen bonds with water molecules within foods through their hydroxyl groups. The strength of these hydrogen bonds increases the viscosity of substance containing the stabilizer [3].

In ice cream, stabilizers extend the shelf-life by limiting ice recrystallization, which occurs as the structure of the stabilizer prevents water from migrating to a larger crystal and forces the water to refreeze into the original crystal. A decrease in ice recrystallization also results in a smoother texture and reduces detection of ice crystals [4]. Stabilizers possess many other functional advantages. During aeration, stabilizers improve the ice cream's ability to be whipped. They increase the viscosity of the mixture, which ensures a uniform distribution of gas bubbles during the whipping process [5]. In addition, stabilizers reduce the melting rate of the ice cream as they affect fat agglomeration by altering the structure of the fat network [6]. Research shows that ice cream without stabilizers melt at the quickest rate, due to the lack of fat aggregates. The greater the amount of fat aggregates, the lower the melting rate of the ice cream [7]. Stabilizers help maintain the flavors of the ice cream. Furthermore, the molecular interactions of proteins and stabilizers with solvents ensure that the ice cream mixture does not separate into its various phases [2].

There are various types of stabilizers available in the food industry, all with particular properties necessary for ice cream manufacturing. Some common examples of stabilizers used in ice cream manufacturing are guar gum, xanthan, pectin, sodium alginate, carrageenan, and gelatin. Locust bean gum, one of the most commonly used stabilizers, is produced from the endosperm of seeds of *Ceratonia siliqua* [8]. Locust bean gum is extracted from the kernels of the carob tree. Locust bean gum is a polysaccharide containing a mannose backbone (Figure 1). Compared to other stabilizers, the structure of locust bean gum contains relatively few galactose branch points off the mannose spine. This results in decreased solubility and viscosity of the locust bean gum. Therefore, it requires heating in order to be activated within the material in which it has been applied. Locust bean gum also reduces ice crystal growth by creating a gel at a solid/liquid interface. The gel formation is attributed to its ability to form hydrogen bonds between areas of the mannose spine. Locust bean gum is therefore the best choice for a stabilizer in the creation of ice cream [9].

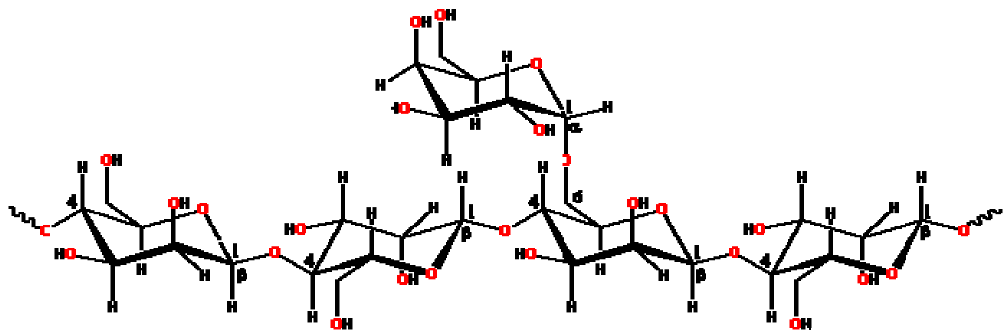

Figure 1. Structure of Locust Bean Gum [9]

Like stabilizers, emulsifiers are crucial in achieving the desired texture and richness in ice cream. Common types of emulsifiers utilized in the food science industry include monoglycerides and diglycerides, sorbitan esters of fatty acids, and phospholipids. In the case of ice cream, the fat globules from milk and the ice crystals form an emulsion; the fat globules disperse within the ice crystals [8]. Each molecule of emulsifier consists of both hydrophilic and hydrophobic sections, which allows the molecule to be positioned directly between the fat region and the water region. They then act to reduce the tension between the two phases, which in turn destabilizes the emulsion. The reduction of the fat emulsion is specifically accomplished by replacing proteins on the fat surface. This destabilizes the fat and allows the fat globules to mix with the water. This in turn causes air bubbles beaten into the mix to be properly stabilized and allows the ice cream to have a smooth texture. A reduction in the creaming of the fat globules results from homogenization of the milk, a process in which the volume of fat droplets is decreased while the surface area is increased through increasing pressure on milk streamed through a small hole [3].

Two types of emulsifiers commonly used in ice cream are polysorbate-80 and lecithin. These emulsifiers, while ultimately performing the same function, work in different ways. Polysorbate-80 is a sorbitan ester of a fatty acid. Its structure, comparable to that of monoglycerides, consists of a sorbital molecule with an attached fatty acid (Figure 2) [10]. Polysorbate-80 functions as an emulsifier by preventing milk proteins from completely coating the fat globules, which are present in the ice cream, thus encouraging the destabilization of the fat emulsion. The addition of polysorbate-80 to ice cream, when added in levels from 0.02% to 0.04%, has been proven to retain the shape of the ice cream, as well as decrease its melting rate [6]. This is accomplished through the structure of polysorbate-80, which allows for its molecules to join in nets and chains. By creating a more extensive fat network, these nets and chains maintain the shape of the ice cream as it melts, providing a firmer texture and holding air in the mixture [2].

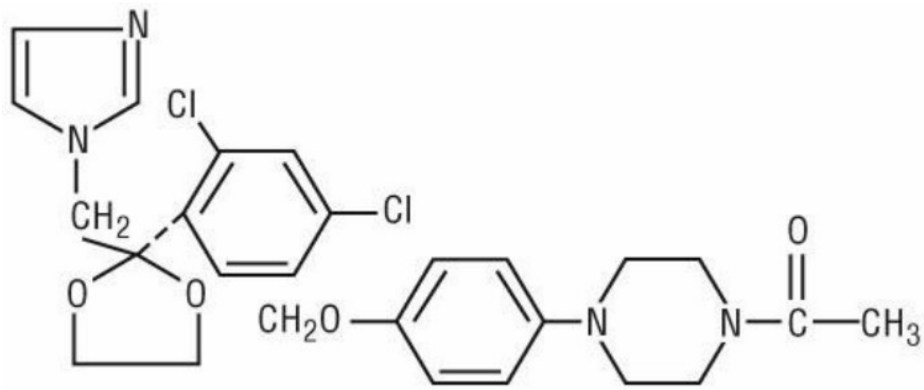

Figure 2. Structure of Polysorbate-80 [10]

Lecithin is a type of phospholipids found in oil that acts as a natural emulsifier to keep fats and oils dispersed and in suspension (Figure 3). Lecithin also partially adds to the creamy texture of the ice cream. It allows the oil-water emulsion to stabilize by forming a micelle, or a cluster of molecules that lower surface tension. The non-polar tail of lecithin is attracted to the nonpolar fat, and so the fat globule can be dissolved in the lecithin. The polar phosphate head of the lecithin molecule is dissolved in the polar ice crystals. Lecithin contributes to the richness of the ice cream the micelle can blend in and create the creamy texture. Lecithin is also considered to be a surfactant, which lowers both the surface tension of a liquid as well as the interfacial tension between two liquids. However, in other studies of ice cream samples that compared emulsifiers of polysorbate-80, α-monoglyceride, monoglyceride, the samples containing lecithin resulted in lower flavor scores [2].

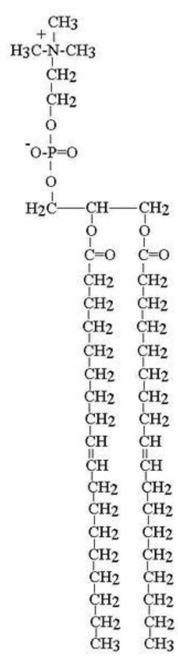

Figure 3. Structure of Lecithin [11]

Emulsifiers are necessary due to the differences in physical properties of the other components of ice cream, which include water, sugar, fats, and proteins. Water is the most abundant ingredient in ice cream. It is used to dissolve or disperse the other particles in the ice cream. It is a highly polar molecule due to its atoms partial charges. The attraction between water molecules makes it a good solvent for ionic and polar compounds, but not for hydrophobic molecules such as fats. In ice cream, water dissolves sugars and proteins [2].

Like water, sugar plays several major roles in the structure of ice cream. Sugar is a necessary component of ice cream, not only to sweeten, but also to add body, add texture, and decrease the rate of melting. Sweetness is desirable because it appeals to the consumer. The viscosity of the sugar solutions helps decrease ice crystal size and provides a smoother texture to the ice cream. As a solute, the sugars help decrease the freezing point of the water, which in turn decreases the rate of melting and retains some unfrozen water droplets to keep the ice cream soft. Sugars generally found in ice cream include lactose, a disaccharide found naturally in milk, and sucrose, a disaccharide extracted from sugar beet or sugar cane, commonly called table sugar [2].

Another ingredient that contributes to the flavor of ice cream is fat. It adds to the creamy texture of the ice cream and decrease the melting point of the ice cream. However, fats are high calorie molecules, which is unfavorable to the consumer. Because of this, there must be a balanced amount of fat in order to provide creaminess while limiting the calories in the product. By US Regulation, regular ice cream contains 10 percent fat; light ice cream contains at least 50% less fat than regular fat ice cream; low-fat ice cream has a maximum of 3 grams total fat per half-cup serving of ice cream [12]. The fat in ice cream comes from milk and cream. The fat cannot be derived from vegetable sources in order for the final product to be classified as ice cream.

Proteins are essential in the function and properties of ice cream. Proteins generally compose approximately four percent of the ice cream mix in the form of milk solids non-fat (MSNF). These play major roles in creating a stable ice cream that is acceptable to the consumer. Proteins aid in the emulsifying of the ice cream mix due to their surface activity. This consequently bolsters the whipping properties of ice cream. In addition, proteins have a water-holding capacity that affects both the viscosity and iciness of the mix [3]. Proteins also provide a dairy flavor that is characteristic of ice cream. Proteins are obtained from liquid milk, skimmed milk powder, whey powder, or buttermilk. They are a significant portion of ice cream that must be carefully used to create an optimal product; it is quite easy to create a flawed product due to improper use of protein [3].

The two major types of protein that are added to the ice cream mix via milk are casein and whey protein. Casein composes approximately eighty percent of all protein in milk, with whey proteins composing the other twenty percent. Casein is generally found as a colloidal particle in the ice cream mix, the casein micelle. Enzymes in milk are another source of protein in the ice cream mix [2].

Whey is the more common of the milk proteins. However, it comes with a disadvantage as well. Whey increases the amount of lactose in the ice cream mix because whey protein concentrate contains 5-6% lactose. This high amount of lactose forms crystals on the surface of the ice cream that create a sandy texture [13].

The production of ice cream involves a number of complex processes before an end product is reached. There are several very important steps in the production of ice cream. These include pasteurization, homogenization, aging, freezing, and hardening. The purpose of the pasteurization of ice cream is to kill any pathogens present in the mixture as well as hydrate the proteins and stabilizers [14].

The mixture is homogenized with the purpose of forming a fat emulsion. This emulsion is created through the process of breaking down and decreasing the volume of the fat globules, which are found in the milk and cream ingredients in ice cream. Homogenization reduces them to a size of less than 1 μm, increases the surface area of fat globules, adds to the smoothness of ice cream, and provides for better air stability and resistance to melting through the alteration in the fat structure [15].

Aging ice cream improves the body and texture of the ice cream and its ability to whip effectively. Fat molecules are also given more time to cool down and form crystals. In addition, aging allows for the full hydration of the proteins and polysaccharides [15].

The next step in the creation of ice cream is freezing. A “dynamic freezing process” is used where about 50% of the water in an ice cream mixture is frozen. Air is also whipped into the mix through this process [14]. After any additional ingredients are added, the completed ice cream mixture is placed into the freezer which allows for the remaining water present in the ice cream to freeze. This hardening process is also important to keep the product stable without risk of ice crystal formation. If the ice cream is not kept at low enough temperatures, ice crystal growth is possible, which restricts the length of an ice cream’s shelf life [14].

While the procedure of the ice cream formulation greatly affects the product, the quality can be controlled most finely through the manipulation of emulsifiers. The benefits of polysorbate-80 as an emulsifier have been thoroughly evidenced by multiple sources. It is also believed that a combination of polysorbate-80 and lecithin result in a better end product, perhaps due to synergistic effects [8]. However, lecithin, as previously stated, often received low scores in consumer sensory evaluations [16]. Thus, a hypothesis was proposed stating that a mixture of 70% polysorbate-80 and 30% lecithin would provide the best combination of emulsifiers among other ratios of polysorbate-80 and lecithin for a regular, light, and low fat ice cream exhibiting universally desired qualities.

EXPERIMENTAL DESIGN

Materials

In a group discussion, a S’mores flavored ice cream was selected. The ice cream flavor consisted of a chocolate base ice cream with marshmallow swirl fluff and chocolate-covered graham crackers mixed in.

The percentages of the basic ingredients for Type 1 ice cream, the low fat ice cream, were first determined: 3.2% fat, 10% MSNF, 0.35% stabilizer, 14% sweetener, and 0.1% emulsifier

(Figure 4). The remaining percentage was water. The fat percentage was chosen to be 3.2% in order to minimize the amount of fat within the ice cream while still maintaining the quality.

Type 2 ice cream, a light ice cream with 4.6% fat, 10% MSNF, 0.3% stabilizer, 14% sweetener and 0.15% emulsifier was also created in order to determine how closely a decrease in fat content corresponded with a decrease in the quality of the ice cream sample (Figure 4).

The percentages of the basic ingredients for the Type 3 ice cream, or the regular ice cream were first determined: 12% fat, 10% MSNF, 0.3% stabilizer, 14% sweetener and 0.15% emulsifier, in addition to the water. The fat percentage was chosen to be 12% in order to achieve the optimal texture and taste of ice cream [17]. Based on many consumer studies, it was determined that most favorable percentage of sweetener in combination with 12% fat was 14% sweetener. The percentages of solids and sweetener were held constant in order to best mimic the conditions of the original ice cream product. The percentage of stabilizer was decreased to 0.3% as the smoothness of the texture could be bolstered by the additional fat. The emulsifier was increased in accordance with the increased amount of fat.

	Fat	**Solids**	**Stabilizer**	**Sweetener**	**Emulsifier**
Type 1: Low Fat	3.2%	10%	0.35%	14%	0.1%
Type 2: Light	4.6%	10%	0.3%	14%	0.15%
Type 3: Regular	12%	10%	0.3%	14%	0.15%

Figure 4. Table of Ingredients by Percentage

The milk used in all trials was whole milk. Two types of cream were used: half and half for Types 1 and 3, and light cream for Types 2. The skim milk was used in the form of a dry powder. The stabilizer used was locust bean gum. The lecithin used was soy lecithin.

Methods

The effect of the emulsifiers was tested through six trials: Trial 1, a control trial, contained no emulsifier; Trial 2 contained 100% polysorbate-80; Trial 3 contained 100% lecithin; Trial 4 contained 70% polysorbate-80 and 30% lecithin; Trial 5 contained 30% polysorbate-80 and 70% lecithin; Trial 6 contained 50% polysorbate-80 and 50% lecithin. These trials were conducted for each of the three separate ice cream types.

To create the ice cream mixture, the dry ingredients (sugar, lecithin, cocoa powder, locust bean gum, and skim milk powder) were first measured according to the percentages of the ingredients and mixed together in order to homogenize the blend. The wet ingredients (milk, cream, polysorbate-80) were similarly measured out and mixed together. The wet ingredient blend was then placed in a pot. The dry ingredient blend was slowly added while the final mixture was continuously stirred. The mixture was heated until it reached 75°C. This temperature was maintained for thirty seconds in order to pasteurize the mixture and active the locust bean gum. The pot was then removed immediately. The mixture was poured into a container, which was then labeled and placed into the refrigerator to age for approximately three days.

The graham crackers were prepared by breaking them into pieces of approximately one sq. cm. The size of the crackers was determined as the optimal size for consumption by the average human mouth. Since chocolate is hydrophobic, the crackers were coated with a chocolate covering composed of semi-sweet dark chocolate chips, in order to prevent moisture from entering the graham crackers. This would have resulted in an unpleasant, soggy texture.

The chocolate covering on the graham cracker was first composed of pure melted chocolate chips. However, after an extensive sensory evaluation determined the resulting chocolate covering was too thick and masked the flavor of the graham cracker, a thinner chocolate coating was created. The improved chocolate coating was a mixture of four parts chocolate to one part coconut oil; this was determined to significantly thin the chocolate while still maintaining its characteristic taste [18]. The graham crackers were then frozen until use. Just as the chocolate covering was originally too thick, the marshmallow also had too thick of a consistency. As a result, water was added to the marshmallow fluff to reduce its viscosity.

A container holding the liquid mixture was placed in a plastic bag along with five cups of ice and one cup of salt. This served to freeze the ice cream while simultaneously incorporating air into the ice cream [13]. Salt was included to decrease the melting point of the ice. Kosher salt was specifically used in order to increase the surface area to volume ratio of the crystal, thereby increasing the rate at which it was dissolved.

The plastic bag was shaken with a uniform up and down motion. The ice cream mixture was removed and stirred at five minute intervals. Types 1, 2, and 3 ice cream required different amounts of shaking in order to freeze; therefore, the shaking varied from a total of 15 minutes to a total of 20 minutes. The mixture was then removed from the plastic bag. Twenty-eight grams of chocolate graham crackers and twenty grams of marshmallow fluff were then added to the ice cream base. The final mixture was placed into the freezer to harden until sensory evaluation.

A sensory evaluation was then conducted, in the form of a blind survey. The evaluation consisted of ten categories: crunchiness of graham cracker, color of ice cream, color of chocolate covered graham crackers, color of fluff, chocolate to graham cracker ratio, texture of graham cracker, smoothness of fluff swirl, smoothness of ice cream, sweetness of ice cream, and richness of ice cream. Each category was rated on a scale from 0 to 10 by the evaluator during the assessment. Ideal values were predetermined by group discussion for the optimal ice cream characteristics: a score of 7 for the crunchiness of graham cracker, a score of 4 for the color of ice cream, a score of 9 for the color of graham cracker, a score of 7 for the chocolate to graham cracker ratio, a score of 5 for texture of the graham cracker, a score of 7 for the smoothness of ice cream, a score of 6 for the sweetness of ice cream, and a score of 10 for the richness of ice cream.

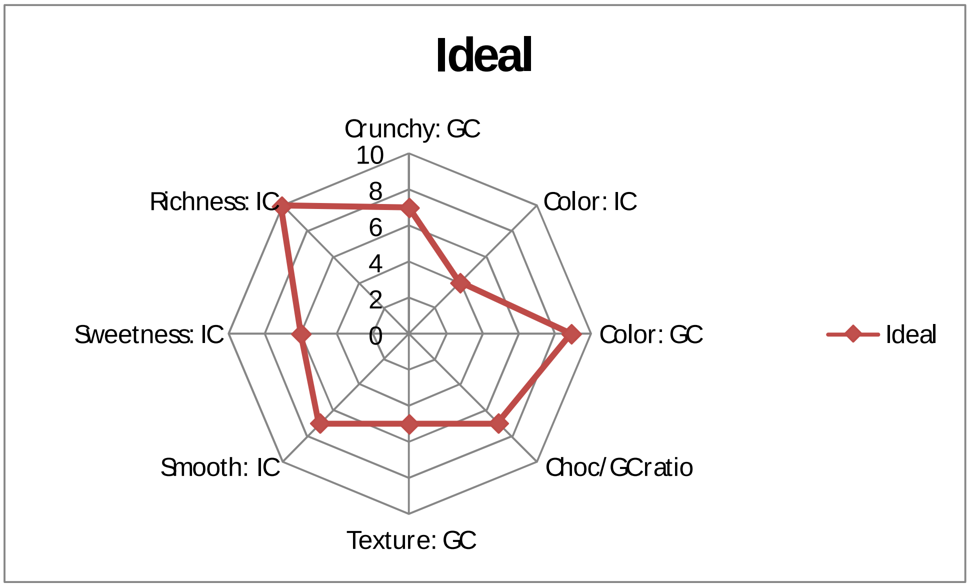

Figure 5. Spider Plot of the Ideal Characteristics

Ten subject were used to analyze the ice cream samples. The ratings for each category were then averaged for each trial, and plotted on a spider plot. The graph consisted of eight axes radiating from a central origin. The axes were labeled with the aforementioned categories. The average ratings were plotted, and then connected from axis to axis. The data was analyzed by comparing actual results to projected results. The trials were compared to the ideal values mentioned previously.

EXPERIMENTAL RESULTS

Type 1 Ice Cream: Low Fat

For our low fat ice cream, the different trials did not vary greatly (Figure 6). Differences in ratings were insubstantial and were not noted. All trials equally failed in duplicating the ideal values.

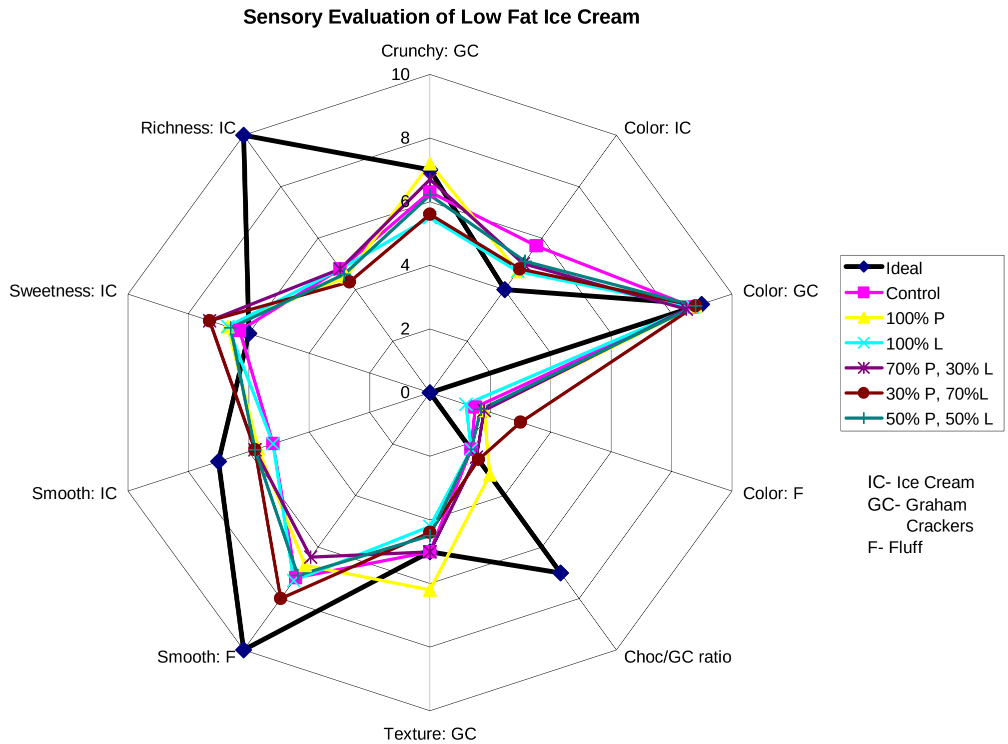

Figure 6. Spider Plot of the Low Fat Ice Cream

<u>Type 2 Ice Cream: Light</u>

For the Type 2 ice cream, it was determined that Trial 4 most closely matched the desired characteristics chosen at the start of the experiment. Trial 4 had the least deviation from the ideal ice cream mixture (Figure 7). In particular, it became extremely close to meeting the criteria for the categories of smoothness and overall texture of the ice cream, the crunchiness of the graham cracker bits, as well as the color of the chocolate coating on the graham cracker pieces.

In contrast, the results of the sensory evaluation established that Trial 3 deviated the most from the ideal ice cream characteristics, especially in the categories of the chocolate to graham cracker ratio, smoothness, sweetness, and richness of the ice cream. The overall consensus of the testing panel was that Trial 3 was the least appealing for consumption out of all six samples.

Although Trials 1, 2, 5, and 6 reached the desired criteria for several categories, the overall results were not as optimal as Trial 4.

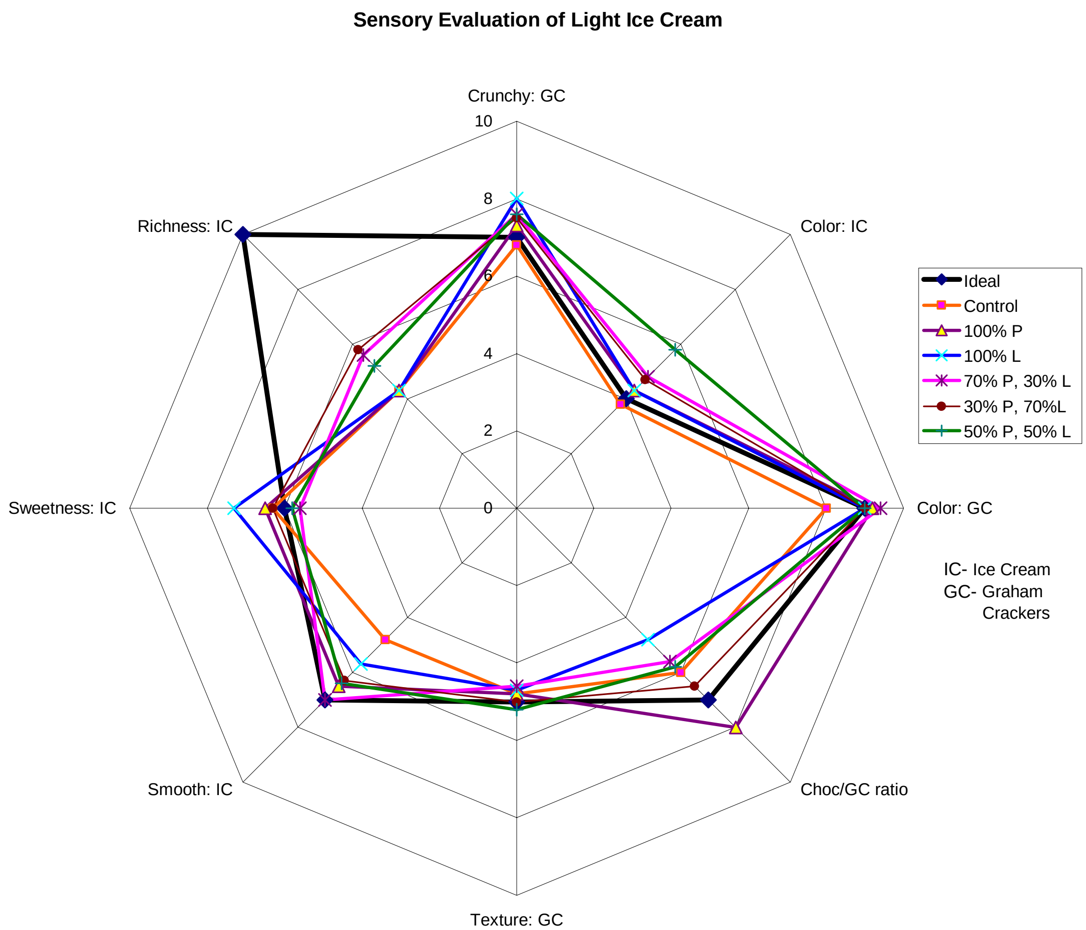

Figure 7. Spider Plot of the Light Ice Cream

<u>Type 3 Ice Cream: Regular</u>

All of the trials with regular ice cream had a better overall texture and richness rating due to its higher fat content. Trial 1 most closely matched the ideal characteristics, followed by Trial 5 (Figure 8). Overall, there was not much deviation among the qualities of the regular ice cream recipe.

The sensory evaluation of the Type 3 ice cream differed slightly from previous evaluations because the graham crackers were removed from the various samples in order to more efficiently evaluate the chocolate base. Therefore, the spider plot does not display the categories involving the graham cracker pieces.

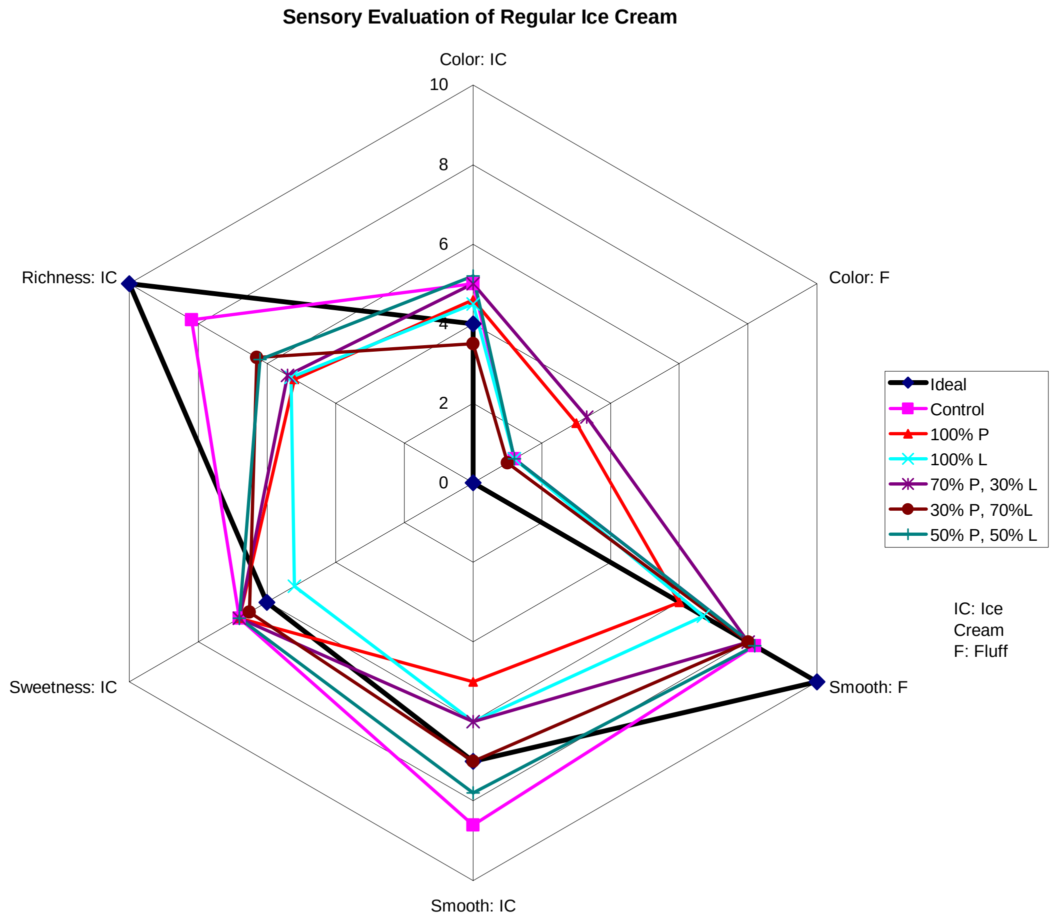

Figure 8. Spider Plot of the Regular Ice Cream

CONCLUSION

Through sensory evaluation and extensive analysis of results, the original hypothesis was established to be correct for the light ice cream recipes. In light ice cream, Trial 4 containing 70% polysorbate-80 and 30% lecithin, was found to most closely reach the expectations of the ideal dessert. When utilized in such a ratio, polysorbate-80 and lecithin produce the ice cream with optimal qualities.

These results concur with many previous experiments conducted on the effects of emulsifiers in frozen desserts. In one study, emulsifiers were found to have a particularly noticeable effect on the consistency of ice creams, in particular low fat and light recipes [8]. Thus, by combining the two emulsifiers together, the ice cream benefited from the properties of both polysorbate-80 and lecithin. It has been proven in past experiments that the individual properties of emulsifiers have more effect on individual properties than the amount used [19].

The properties of polysorbate-80 provided for greater quality in the categories of smoothness and texture in the sensory evaluation. Polysorbate-80 is specifically targeted for dairy fats. In the experiments with the low fat and light ice creams, polysorbate-80 prevented the milk proteins from completely coating the fat globules [19]. Therefore, a smoother and richer texture was achieved, accounting for the observed higher results in all three types of ice cream produced.

The 30% lecithin was also important in achieving the optimal ice cream characteristics. Like polysorbate-80, it provided the ice cream with a creamy texture. By creating micelles, the smoothness and richness of the ice cream were greatly improved [20] as displayed by the results of the sensory evaluation. Lecithin played a crucial role in dissolving the ice crystals of the ice cream, a quality taken into account for the texture analysis in the sensory evaluation. Lecithin's polar phosphate head was able to dissolve in the polar ice crystals [21].

The 70% polysorbate-80 to 30% lecithin ratio was necessary to obtain the desired ice cream qualities in this experiment. Lecithin, in previous studies, has been found to create lower flavor scores [8]. This study concluded that Trial 3, 100% lecithin recipe, resulted in the poorest flavor of ice cream. By utilizing a smaller percentage of lecithin than polysorbate-80, the ice cream retained the desirable effects of lecithin but did not altering the flavor in any significant or detrimental way.

In the low fat ice cream category, Type 1, all trials received approximately equivalent scores in sensory evaluation, regardless of the presence or amount of emulsifier. This can be attributed to the low percentage of fat. As the number of fat molecules is reduced, the effect of the emulsifiers becomes negligible.

In the regular ice cream category, Type 3, the control was found to be the most ideal. Because there was a higher fat content in the Type 3 ice cream, emulsifiers served to amplify the waxy feel already generated by the fat globules. Thus, the ice creams containing emulsifiers left evaluators with a waxy mouthfeel and often an aftertaste. In contrast, such results were not observed in the ice cream recipes of lower fat content because the emulsifiers were more necessary to create a smoother and richer texture, working to combine the low content of fat into a cohesive mixture.

Overall, Trial 3 of 100% lecithin in all ice cream types was rightfully found to diverge most greatly from the ideal ice cream flavor. Similarly, Trial 5 of 70% lecithin and 30% polysorbate-80 received poor scores on the sensory evaluations. These results correlated with previous scientific studies on lecithin, which showed that lecithin caused an undesirable greasy palate [8].

Unfortunately, in this experiment, there was much room for human error. First of all, there were possible errors in measurement of ingredients in the ice cream bases. When combining the ingredients to heat on the stove, it was very difficult to pour the complete amount of polysorbate-80 out of the plastic cup because it was very viscous and often stuck to the sides of the container. Furthermore, the individual pieces of lecithin would remain trapped at the bottom of the cup and not end up in the final base.

Heating to pasteurize the ice cream also allowed for more error since every sample was not heated at the exact same rate. Some were heated on low temperatures in order to reach 75ºC, whereas other batches were heated on higher temperatures. In combination, the thermometers were often held at different positions in the mixture while heating, with it occasionally residing on the bottom of the pan. Such an error would produce an inaccurate temperature reading and may have affected the pasteurization of the ice cream and the activation of the stabilizers.

There was also error in the aging of the ice cream. Ice cream is supposed to be aged in the refrigerator overnight to three days. However, due to special circumstances, the ice cream types were aged for four days.

Another human error evident in this experiment were the conditions under which the ice cream was solidified. Each person shaking the ice cream used different techniques to solidify the ice cream.

The sensory evaluation was a further source of error in this experiment. Only a small sample of the population was tested, rather than a large sample that would have been more representative. Although a blind sensory evaluation was conducted, there was difficulty in gaining unbiased and accurate results because panelists would sample various different types of ice cream in a short period of time. Furthermore, the graham cracker pieces and fluff swirls made it difficult for evaluators to determine the significant differences of the ice cream's texture, flavor, and smoothness.

The overall results of the experiment cannot be disregarded despite the errors evident in this process. The original hypothesis was supported by the light ice cream. The 70% polysorbate-80 and 30% lecithin received the best sensory evaluations. However, as fat content changed, the hypothesis was not supported. According to our data, there is no optimal blend of emulsifiers.

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