

SENSORY ANALYSIS OF LOW FAT STRAWBERRY ICE CREAMS
PREPARED WITH DIFFERENT FLAVOR CHEMICALS AND FAT MIMETICS

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PREPARED WITH DIFFERENT FLAVOR CHEMICALS AND FAT MIMETICS

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SENSORY ANALYSIS OF LOW FAT STRAWBERRY ICE CREAMS PREPARED WITH DIFFERENT FLAVOR CHEMICALS AND FAT MIMETICS

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ABSTRACT

Current demand revealed consumers want healthier ice creams. Fat mimetics are already used in manufacture of low-fat and fat-free ice creams. However, the use of fat mimetics affected flavor and texture characteristics of ice cream, which results in decreased overall acceptability by consumers. The initial objective of this study was to investigate the release behavior of five strawberry flavor compounds in ice creams with Simplese[®], Litesse[®] and Litesse[®]/ Simplese[®] mixes using descriptive analysis. The subsequent objective was to reformulate an artificial strawberry flavor added to lower-fat ice creams with a special fat mimetic and to determine the consumer acceptance of the reformulated low-fat ice creams for developing “better-for-you” ice creams.

A mixed-ANOVA analysis found that fat content, fat mimetics and flavor formulation had a significant influence on the perception of furaneol[™] (cooked sugar flavor), α -ionone (violet flavor) and γ -undecalactone (peach flavor) but there was no interaction between ice cream type and flavor formulation for the three flavors. Furaneol[™] was perceived more strongly in full-fat ice cream, while *cis*-3-hexen-1-ol, α -ionone, γ -undecalactone and ethyl-3-methyl-3-phenylglycidate were perceived more strongly in low-fat ice cream. Ice creams with Simplese[®] and full-fat ice cream had

similar sensory characteristics, while ice creams with Litesse[®] were similar to low-fat ice creams in flavor characteristics, and ice creams with Litesse[®]/ Simplese[®] mixes were closer in flavor profile to low-fat ice cream but had similar texture properties to those of full-fat ice cream. Simplese[®] was found to be a better fat mimetic for duplicating the flavor profiles and mouthfeel of full-fat ice cream.

A number of flavor formulations (36) in ice creams with Simplese[®] were used to reformulate the artificial strawberry flavor to match the flavor profile of full-fat ice cream flavored with the original flavoring. Simplese[®] products had greater sweetness, milky flavor, smoothness, creaminess and mouth coating than full-fat ice cream, and the intensity of sweetness was positively correlated with that of cooked sugar flavor and milky flavor. Cooked sugar flavor, sweetness and their aftertastes were determinants for the degree of taste similarity with full-fat ice cream. Canonical variate analysis (CVA) and principal component analysis (PCA) complementary revealed that the reformulated product, which was the closest in sensory characteristics to full-fat ice cream, was the one in which the concentration of γ -undecalactone was decreased individually by 25%. Cluster analysis found that the product, in which γ -undecalactone and *cis*-hexen-1-ol were decreased by 25%, had the smallest dissimilarity. Perception of furaneolTM could be masked in the presence of γ -undecalactone and α -ionone. The sweetness also decreased with lower intensity of furaneolTM in ice creams with Simplese[®].

A hedonic test was used to evaluate the six ice cream products, including a 10% ice cream (positive control), a 4% ice cream with Simplese[®] (negative control), and four reformulated ice creams, which were the closest in sensory characteristics to the 10% ice cream in previous studies. There were no significant differences between full-fat ice

cream and these reformulated products in which the concentration of γ -undecalactone was decreased individually by 25% or in combination with a 50% decrease of α -ionone. However, there existed significant differences between full-fat ice cream and the two products, in which γ -undecalactone and *cis*-hexen-1-ol were decreased by 25% with or without a 50% decrease of α -ionone spike. The ranking test showed no significant differences among the six ice creams. Texture and sweetness appeared to play a critical role in the overall degree of liking. External preference mapping showed some consumers would like strong milky flavor aftertaste and weak peach flavor, while another group would like more pink color, sweetness, strawberry flavor, milky flavor, violet flavor, violet flavor aftertaste, condensed milk, thickness and mouth coating. A third group was not able to distinguish any differences in taste between these strawberry ice creams. The study was to understand flavor perception in ice creams with or without fat mimetics and was successful in formulating artificial strawberry flavored ice creams using Simplese[®] to match the flavor profile of full-fat ice creams and to meet consumer demand.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Ice creams have been a favorite dessert in the United States since colonial times (Anonymous 2003^a). Today, Western Europe and North America are the two primary regions for ice cream consumption around the world; nevertheless, the United States is the biggest consumption market of ice cream. According to Mintel International's report on "the U.S. ice cream market", ice cream consumption grew nearly 24% between 1998 and 2003 (Anonymous 2003^b). Ice cream and other frozen desserts are consumed by more than 90% of households in the United States, and children are one of primary consumer groups.

Total U.S. sales of ice cream and frozen desserts in 2002 reached \$ 20.5 billion according to the report of International Dairy Food Association (IDFA 2005). Further reports showed that about \$ 8.1 billion was spent on products for "at home" consumption while \$ 12.5 billion was spent on "away from home" frozen dessert purchases (IDFA 2005). Other surveys showed total U.S. production of ice creams and related frozen desserts accounted for more than 1.6 billion gallons per year (Pszczola 2002; Miraglio 2006). Among them, regular ice cream accounts for the largest share of the frozen dessert market (64%) while reduced-fat, low-fat and non-fat ice cream account for 24% of the market (Pszczola 2002). In addition, most of ice cream products in the U.S. are the hard frozen type. In the category of regular ice cream, hard frozen products account for over 87% of all production, whereas for low-fat and non-fat ice creams, soft-serve makes up over 67% of all production (IDFA 2005). America's top five individual flavors in terms

of share of segment on sales of ice cream are: vanilla (33%), chocolate flavors (19%), nut/caramel flavors (7%), neapolitan (a combination of vanilla, chocolate and strawberry, (5%), and strawberry (4%) (IDFA 2005).

Traditionally, a commercial regular ice cream should contain minimum 10% to 16% fat and 18% to 27% sugar. The caloric value of ice cream is about 9.61~11 kJ/g making is a high calorie product (Zhang and Wang 1999). Recent surveys indicated the largest jump in ice cream consumption is in the low-fat and non-fat ice creams categories in the U.S. In 2004, the volume grew almost 16 % to nearly 440 million gallons (Miller 2005). Other surveys also showed that low-fat ice cream is driving the growth while regular and non-fat ice creams are decreasing (Anonymous 2005). This market trend is seen in most developed countries because of consumer concern about the impact of diet on health (Yackel and Cox 1992; Buisoon 2006). In the United States, the demand for calorie reduced foods by consumers is now greater than ever because most adults are overweight. Revisions of dietary fat recommendations have motivated declines in consumption of many high fat content foods, including dairy products, because the amount of fat in the diet, having a high correlation with various illnesses, such as obesity and heart disease, is the top concern for consumers (Buisoon 2006). As a consequence, the dairy industry in the U.S. has developed a variety of low-fat or fat-free ice cream products in order to cater to this tendency. Meanwhile, consumer's perception of low-fat foods depends not only on the nutritional image but also sensory qualities of appearance, texture and flavor (Shamil and Kilcast 1992). Surveys revealed that consumers prefer the taste of high fat products due to better product quality, compared with the similar low-fat or fat-free products (Drewnowski and Greenwood 1983). It is evident that consumers

want healthier ice cream but are not yet satisfied with the taste of the products being offered (Anonymous 1997).

Jiménez-Flores and others (1992) considered the properties of milk fat in ice cream to include imparting a pleasing body and mouthfeel, sensation of richness, pleasing flavor, flavor carrier and contributor to total flavor blend. The perception of flavor in a reduced-fat ice cream changes considerably in part because fat not only plays a key role in the sensory perception of products, such as texture, mouthfeel, appearance and feeling of satiety, but also acts as a flavor precursor, flavor carrier and most importantly as a flavor release modulator (Brauss and others 1999).

The primary difficulties to be overcome in low-fat or fat-free products include improving the mouthfeel and flavor perception to resemble that of full-fat products. To meet this challenge, ice cream manufacturers have been focusing on eliminating the problems resulting from the replacement or removal of milkfat (Marshall 1991; Hatchwell, 1994). Fat mimetics have been used to replace fat in food systems due to their properties and the improvement of texture quality of such foods (Akoh 1998). The emphasis of developing reduced-fat ice creams with carbohydrate- and protein-based fat mimetics began in the 1980s (Alexander 1997). The intense and transient flavor perception of such products has led to continuing research in the area of interactions between aroma volatiles and carbohydrate- and protein-based fat mimetics (Plug and Haring 1993; Druaux and others 1998). Although several model systems have been studied (Guyot and others 1996; Cayot and others 1998; Goubet and others 1998; Rogacheva and others 1999), comparatively less research has been done with actual food products. For ice creams, only few studies also have focus on understanding the effects of

fat replacers on sensory and textural properties of flavored low-fat products, such as chocolate and vanilla (Ohmes and others 1998; Roland and others 1999; Prindiville and others 2000).

1.2 OBJECTIVES

In a series of studies, five compounds, which are typically found in artificial strawberry flavors, were studied in model systems and ice cream. The compounds studied were *cis*-3-hexen-1ol, ethyl-3-methyl-3-phenylglycidate, γ -undecalactone, α -ionone, and furaneolTM (2,5-dimethyl-4-hydroxy-3(2H)-furanone). These compounds, when mixed together in specific concentrations, are perceived as a typical strawberry flavor.

Preliminary studies in our lab were conducted to determine the sensory thresholds and flavor release of the five compounds from 0%, 4% and 10% fat emulsions (Gaddamu 2003), as well as the perception of the five compounds in 4% and 10% ice creams and ice cream mixes using chromatographic methods and descriptive analysis (Loeb, 2004). Clearly, the instrumental methods and model systems to analyze the flavor profiles of the flavoring made with the five flavor chemicals cannot replace or appreciate fully the true flavor perception of ice cream in the mouth.

The initial objective of this study was to investigate the release behavior of the five strawberry flavor compounds in ice cream with protein-based (Simplese[®]) and carbohydrate-based (Litesse[®]) fat mimetics using sensory evaluation. The main endeavor of this study is to collect sensory data for the purpose of reformulating the flavoring compounds so that the flavor profile of lower fat ice creams with fat mimetics becomes indistinguishable from that of full-fat ice creams. Then, the ultimate proposal is to develop high quality and “better-for-you” strawberry ice creams which are acceptable to

U.S. consumers.

Strawberry flavor was chosen for this study because (1) Little information is available on the effect of fat reduction on the flavor profile of strawberry ice cream (Miettinen and others 1999). Nevertheless, (2) Strawberry flavor is one of the most popular ice cream flavors, but, (3) unlike vanilla, it has more than one character impact compound. However, (4) the aroma profile of strawberry has been extensively studied (Larsen and Wattkins 1995; Zabetakis and Holden 1997; Ibáñez and others 1998; Gomes da Silva and Chaves das Neves 1999), which (5) make strawberry flavor easy to prepare. In addition, (6) there is strong indication that strawberry flavor can be affected by fat content since its character impact compounds are diverse in regard to their hydrophobicity or hydrophilicity (Schieberle and Hofmann, 1997; Miettinen and others 1999).

Specific objectives of this study are to:

- (1) Use descriptive sensory tests to evaluate the sensory profile of ice creams with fat mimetics and to evaluate the artificial strawberry flavor profiles using multivariate statistical analysis.
- (2) To reformulate the artificial strawberry flavoring added to lower-fat ice cream with a suitable fat mimetics to match the flavor profile of full-fat ice cream flavored with the original flavoring.
- (3) To test the consumer acceptance for the reformulated lower-fat ice creams.

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CHAPTER 2

LITERATURE REVIEW

2.1 ICE CREAM

2.1.1 Definition & Classification

According to U.S. Federal Regulations (21CFR135.110), ice cream is a frozen food made from a mixture of dairy ingredients, containing at least 10% milk fat before the addition of bulk ingredients, such as flavorings and sweeteners (Marshall and others 2003^a). A gallon of ice cream must weigh a minimum of 4.5 pounds and contain at least 1.6 pounds of food solids (Martinez Martín and others 2001). In addition, the minimum weight of 540g/L limits the amount of air that can be incorporated, called the overrun, which is the percentage of increase in volume over the volume of mix frozen per unit total volume, to approximately the same volume over the volume of mix (Thomas 1981).

Alexander (1997) demonstrated that typical ice creams contain about 10%-12% fat, while some premium products contain 16%-18% fat. Another composition standard for ice cream proposed by the International Ice cream Association (ICA) was described as following: non-fat products <0.5 % fat, low-fat 0.5-2 % fat, reduced fat 2-7% fat and full-fat 10% (Farooq 1997). That is also to say that reduced-fat ice cream is a product of at least 25% total fat than typical ice creams; light ice cream is defined as a product of at least 50% total fat or 33% fewer calories than the referenced products; low-fat ice cream contains a maximum of 3 grams of total fat per serving (1/2 cup), and non-fat ice cream is a product of less than 0.5 grams of total fat per serving (Klahorst 1997; Pszczola 2002; Miraglio 2006). Examples of the composition of some typical ice creams are shown in Table 2-1 (Klahorst 1997).

From a marketing standpoint, ice creams can be classified by several terms, including super-premium, premium, regular and economy ice cream (Pszczola 2002). For example, Haagen-Dazs is one of several famous brands of super-premium ice creams, meaning the ice cream tends to possess very low overrun (25-50%) and high fat content (at least 12% milk fat and more) and to contain the best-quality ingredients. The marketing term of “premium ice cream” is described as low overrun (60-90%) and higher fat content (12-15%) compared with typical ice cream (Pszczola 2002).

The traditional ice cream standards are facing a lot of challenges due to modern food processes and nutritional demands for new products that do not fall into the old categories. One example is that ice cream manufacturers petitioned to remove the limitation on the use of whey in ice cream recipes because the addition of whey could prevent the formation of ice crystals and maintain the creamy character or taste of ice cream as well as aid in freezing and whipping the ingredients together (Skrzycki 2005).

From a flavoring point of view, strawberry ice cream, strawberry flavored ice cream and artificially flavored ice cream also have different definitions. Strawberry ice cream means the product does not contain artificial strawberry flavors. Strawberry flavored ice cream means the product contains both natural and artificial flavors, but the natural flavor predominates in quality. As for artificially flavored strawberry ice cream, those are products flavored exclusively with artificial flavors or with a combination of natural and artificial flavors in which the artificial flavor components predominate (Federal Register Online 2005).

Table 2-1. The composition of some typical ice creams

Product \ Ingredients	Milkfat (%)	NFMS (%)	Sweeteners (%)	Stabilizers (%)	Total Solids (%)
Nonfat ice cream (hard)	<0.8	12-14	18-22	1.0	35-37
Low-fat ice cream (hard)	2-4	12-14	18-21	0.8	35-38
Light ice cream (hard)	5-6	11-12	18-20	0.5	35-38
Reduced-fat ice cream	7-9	10-11	18-19	0.4	36-39
Economy ice cream	10-12	10-11	15	0.3	35-37
Premium ice cream	18-20	6-7.5	16-17	0-0.2	42-45
Super-premium ice cream	20	5-6	14-17	0.25	46
Soft-serve ice cream	3-4	12-14	13-16	0.4	29-31

(Modified by Klahorst 1997)

2.1.2 Composition & Quality Factor

The ingredients of ice creams usually consist of cream, the source of fat, concentrated nonfat milk solids, sugar, stabilizer and emulsifier, and flavoring materials (Mehu 1993). Most of these ingredients in ice cream are multifunctional, contributing to different aspects of ice cream manufacture, product quality and stability.

2.1.2.1 Nonfat Milk Solids

The nonfat portion of milk, called nonfat milk solids (NMS), is composed of approximately 55% lactose, 37% protein, 8% minerals and others, such as vitamins, acids and enzymes (Arbuckle 1986). The amount of NMS in ice cream mixes ranges from 9-12% and usually varies inversely with the fat content. NMS are critical for texture and body of ice cream (Hegenbart 1996). According to U.S. standards of ice

cream, most milk and non-fermented milk products are permitted in ice cream, but there are some specific limits in some ingredients. For example, amounts of whey solids or modified whey solids are limited to 25% of the NMS content (Marshall and others 2003^b). There are several reasons for the limitations, including: (1) the higher lactose content in whey solids increases the potential of crystallization of the sugar (2) the high concentrations of lactose and minerals result in lowered freezing point (3) protein content is decreased in ice cream (Marshall and Goff 2003; Marshall and others 2003^b).

NMS can come from several sources, such as skimmed milk, condensed whole milk and buttermilk. Buttermilk solids can be a superior substitute for NMS, especially in mixes made with butter, butter oil or anhydrous milkfat as the source of fat. Buttermilk contains a higher concentration of fat globule membrane phospholipids than does skim milk (Marshall and Goff 2003; Marshall and others 2003^b).

The added amount of NMS to an ice cream mix is a primary factor for improving the quality of ice cream (Campbell and Marshall 1975). Overall, NMS can lower the freezing point, slow the rate of melting and increase the amount of unfrozen material by adding dissolved serum solids (Mangino 1984; Goff and others 1989). Stampanoni Koferli and others (1996) also indicated NMS can cause a decrease in coldness, ice crystal and melting rate perception and an increase in creaminess and mouth coating. In addition, it also can increase overrun attainable without producing poor textures and strengthen resistance to heat shock and shrinkage (Goff and others 1989; Goff 1995). Lactose in NMS causes a lower freezing point, and milk protein provides a slight flavor, water holding and also affects the formation of size of air cells in ice cream (Campbell and Marshall 1975; Dahlberg 1931). Nevertheless, high

concentrations of NMS could cause some side effects in the quality of ice cream, such as cooked or condensed flavors and sandiness. Sandiness is particularly produced by high amounts of lactose which crystallizes in ice cream. The crystals dissolve slowly during eating and give a gritty mouthfeel (Campbell and Marshall 1975; Goff 1995).

2.1.2.2 Milk Fat

Milk fat, a complex arrangement of triglycerides, is a primary determinant of the texture or body of ice cream, which forms the structured network. Milk fat, containing at least 10% and no more than 20%, is an ingredient of major importance in ice cream because its correct use is vital not only to balance properly the mix but also to satisfy legal standards (Marshall 1991; Goff 1995). The effect of milk fat in ice cream is dependent on several factors including the type and level of fat, the amount of non-fat milk solids and sugar, as well as variety of flavor compounds used in ice cream (Marshall and Arbuckle 1996).

Milk fat comes from milk and cream, the best source, and provides the desirable flavors and aids in good melting properties and in decreasing the size of ice crystals (Hyde 2001). Furthermore, milk fat also affects textural attributes such as viscosity, tenderness, elasticity, emulsification, ice crystallization and other desirable attributes such as richness, smoothness (Marshall and Arbuckle 1996; Yackinous and Guinard 2000; Hyde 2001). The possible mechanism of milk fat contributing necessary structure and texture of ice cream is due to trapped water, creating an oil-in-water emulsion with the interaction of stabilizers and emulsifier during whipping (Hyde 2001).

During the freezing process, milk fat globules concentrate toward the surface of air cells to support the air cell structure as air is incorporated into the mix and are

surrounded by casein subunits absorbed at the fat-water interface (Goff 1995; Koxholt and others 2001; Marshall and Goff 2003). Milk fat coalesces partially during freezing to form and stabilize the ice cream structure and to give body to the ice cream (Goff 1995).

Stampanoni Koeferli and others (1996) showed that, within the 3% to 12% range, fat increased primarily buttery, creamy, and mouth coating characteristics of ice cream and lowered its melting rate, coldness and ice crystal perception, whereas sugar increased sweetness, caramel and vanillin notes and lowered milky flavor. Excessive milk fat decreases whipping ability and results in excessive richness as well as high caloric value (Goff 1995).

2.1.2.3 Sweeteners

Sweetness control in ice cream is very important in order to achieve maximum consumer acceptance and minimum production cost (Wilson-Walker 1982). Many kinds of sweeteners, such as cane and beet sugars, many types of corn sweeteners, maple syrup, honey, inverted sugar, fructose and malt syrup, have been used in ice cream mixes (Stogo 2001; Salama 2004). Ice cream is formulated normally with a sweetness equivalent to 13%-15% sucrose content, with 25% or more of the sweetness provided by corn-based sweeteners (Schaller-Povolny and Smith 1999). Sucrose, corn syrup and high fructose corn syrup are principal sweeteners used in ice cream (Bodyfelt and others 1988; Salama, 2004).

The amount of sweeteners added to ice cream is very important. Besides creating desirable flavor properties, sweeteners also are the major ingredients to lower the freezing point, which is one of the influential factors for quality of the ice cream mixes (Baer and Baldwin 1984). When sweetener content is about 16% or higher, ice cream

tends to become too soft or too dense and chewy, depending on the type of sweeteners used in excess, due to lowering the freezing point. In other words, hardness of ice cream is dependent upon the sugars and other materials (Baer and Baldwin 1984; Grotta 1994). If a mix with a lower freezing point causes less water to be frozen as the ice cream exits the freezer, the storage life of ice cream is shortened due to being more susceptible to increases in ice crystal size during temperature fluctuations (Schaller-Povolny and Smith 1999). Furthermore, as sweetener concentration is increased, viscosity of the mix and firmness of the ice cream increase.

Monosaccharides, such as fructose and glucose, equally lower the freezing point of the mix, although they do it to a greater degree than disaccharides. High molecular weight sugars, such as corn syrup, do not depress the freezing point as much as disaccharides on a weight to weight basis (Bodyfelt and others 1988).

Sweeteners and various flavorings are added to dairy products to improve flavor balance (Haschke and others 1988) and to partially mask acetaldehyde flavor (Kagan 1985). In general, approximately 45% of the sucrose can be replaced with corn syrup for economic, handling or storage reasons (Clark 2000). However, corn syrup with low to medium dextrose equivalents (DE) may impart off-flavors and should constitute no more than about one-third of the total sweetener solids. In fact, low DE sweeteners, made by hydrolysis of starches, do not contribute much sweetness, but they provide great water binding properties (Goff 1995).

The percentage of the sweetening agents obtained from different sources added to the ice cream mix is influenced mainly by the desired (1) concentration of sugar in the mix (2) total solids content of the mix (3) effect on the properties of the mix (4)

concentration of sweeteners other than sugar and (5) relative inherent sweetening power of the sweeteners other than sucrose (Marshall and others 2003^b).

2.1.2.4 Emulsifiers

Mono-, diacylglycerides and sorbitan esters, especially polysorbate 80, are usually used in ice cream as the emulsifiers (Marshall and Goff 2003), and they are supplied to manufacturers as blends with stabilizers. The normal requirements in ice cream ingredients for emulsifiers are between 0.1%- 0.5 % (Clark 2000; Marshall and Goff 2003). Emulsifiers added to ice cream have several important functions, including that they (1) lower the fat and water interfacial tension in the ice cream mix so that they cause protein displacement from the fat globule surface, which in turn reduces the stability of the fat globule causing it to partially coalesce during the whipping and freezing process (Goff and others 1989); (2) promote nucleation of fat during aging of mixes, thus reducing the time needed to age mixes before freezing (Goff 1995); (3) decrease tendencies for shrinkage and lower the rate of melting (Bodyfelt and others 1988); (4) cause a high amount of agglomeration of the fat during freezing. Therefore, the surfaces of the fat globules must have a relatively high concentration of emulsifier (Goff 1995).

In sum, emulsifiers contribute greatly to texture and meltdown properties. They aid in developing the appropriate fat structure and air distribution in the ice cream and provide smoothness and a stiffer body, enabling production of smaller and more evenly distributed air cells, increasing resistance to melting and shrinkage, and improving dryness (Goff and others 1989; Baer and others 1999; Clark 2000).

2.1.2.5 Stabilizer

The stabilizer usually is a kind of polysaccharides such as gelatins, gums, egg

yolk solids and seaweed (Bodyfelt and others 1988; Klahorst 1997). The amount used in regular ice creams may range from 0-0.5% (Clark 2000). The stabilizer contributes several functions in ice cream: (1) It can increase the viscosity of products decreasing water migration, maintain homogeneity and control ice crystal growth during the freezing process (Hagiwara and Hartel 1996; Flores and Goff 1999). (2) Stabilizers in ice cream cause a slight increase in melting rate (Arbuckle 1986). (3) During storage, stabilizers play a role in resisting structural changes during “heat shock”, which is the inevitable temperature-cycling during storage that creates ice crystal growth and other types of deterioration due to structural changes (Goff 1995). (4) During consumption, stabilizers provide uniform meltdown, mouthfeel and texture. (5) Stabilizer can contribute to a smoother more resistant body and texture (Arbuckle 1986). However, too much stabilizer can make the mix too viscose, making the ice cream heavy and soggy. In short, stabilizer added to ice cream is to control ice crystal growth during hardening and storage, especially during temperature fluctuations, to give body and stiffness during freezing for air incorporation and to impart smoothness in body and texture (Arbukle 1986; Marshall and others 2003^b). The sensory quality and overall acceptability of ice cream with various stabilizers has been reported (Minhas and others 1997, Minhas and others 2002).

2.1.2.6 Flavorings

Flavor is the most important positive attribute of ice cream. Vanilla, chocolate and strawberry flavor are among the most preferred ice cream products (Marshall and Goff 1993). The type and intensity of flavor in ice cream are the two important flavor characteristics. Flavors should only be intense enough to be recognized easily and to present a delicate pleasing taste. Too much or too little flavoring, unnatural or atypical

flavoring, and too much or too little sweetness could cause important defects in ice cream (Li and others 1997; Marshall and others 2003^b).

Some factors, including mix composition, ingredient quality, process variables, freezing and storage conditions, age of product, temperature of consumption, pH, fat content, sweetness level, stabilizers, incorporation of air and flavorings added, affect the overall flavoring of ice cream (Marshall and others 2003^a; Marshall and Goff 1993). For example, the higher the content of NFS in ice cream, the more flavoring will be added (Hyde 2001). In addition, temperature, hydration, surface area, enzyme saliva and binding phase inversion also affect flavor release during eating (Marshall and Arbuckle 1996).

The procedure for adding flavorings to ice cream usually depends on the type of flavoring used, such as liquid, syrup, semisolid, and solid forms, and the type of freezer. Other than liquid forms, flavorings are added to the batch freezer prior to completion of the freezing process in most situations (Marshall and Goff 1993). Liquid flavorings are added to ice cream mixes prior to freezing. In addition, the performance and type of the freezer also is a critical factor in the use of the mix composition and flavor. For example, ice cream mixes with added chocolate flavor, whip more slowly than mixes of most other flavors (Marshall and Goff 1993). The amount of flavoring added to ice creams needs to be high enough to ensure good impact at the low temperatures of consumption and also to be balanced with sweetness (Marshall and others 2003^b). The typical consumption temperature of ice cream is between -20°C and -5°C. The lower the temperature, the lower the flavor impact perceived.

2.1.2.7 Defects

Ice cream defects can be classified into several categories including flavor defects, body and texture defects, melting quality characteristics, color defects and shrinkage defects (Goff 1995; Clark 2000).

Flavor defects can be classified into four different ways, including flavoring system, sweetening system, processing-related system, and the dairy ingredient flavor. Flavoring system defects include the lack of flavoring, or having too much flavor, or having an unnatural flavor (Goff 1996; Lee and others 2005). The sweetener system is considered to be defect if the product is too sweet or lacks sweetness. However, the most commonly encountered defect in the flavor assessment of ice cream is the dairy ingredient defect.

Body and texture defect primarily includes coarse, icy texture (Goff 1996). Lower stabilizer or emulsifier, lower total solids or coarse air cells could cause a flaky, snowy quality or a crumbly body in ice cream (Lee and others 2005). However, the incorporation of large amounts of air as large air cells with low total solids or low stabilizer could produce a fluffy or spongy defect in ice cream (Lee and others 2005). A sandy texture is the easiest to detect and is caused by lactose crystals (Goff 1995).

Shrinkage is a very serious defect in ice cream. The defect shows up in hardened ice cream and manifests itself in reduced volumes of ice cream, usually pulling away from the top or sides of the container. Structurally, it is caused by a loss of air bubbles and formation of continuous air channels. Some factors including (1) freezing and hardening at low temperature (2) type of container (3) emulsifiers (4) methods of handling in the grocery store and (5) low and high storage temperatures are believed to be

associated with the defect (Goff 1995).

2.1.3 Manufacturing

The basic steps in the manufacturing of ice cream generally consist of two distinct stages: mix manufacture and freezing operations. Mix manufacture consists of combining and blending of ingredients, batch and continuous pasteurization, homogenization and mix aging. Freezing operations usually include a two-step process: under high shear and under quiescent conditions (Caldwell and others 1992; Marshall and Goff 2003).

2.1.3.1 Pasteurization

The main purpose of pasteurization, the biological control point, in ice cream is to destroy the pathogenic bacteria. In addition, it also helps hydrate proteins and stabilizers of the ice cream mix. Both batch pasteurization and the continuous high temperature short time (HTST) method are generally used in the manufacture of ice cream (Goff 1995). Batch pasteurization may be accomplished by heating either to 65.5 °C for not less than 30 minutes or to 71.1 C for not less than 10 minutes, which is the legal minimum for ice cream in a batch pasteurization system (Hyde 2001). The batch method is more suited to the smaller manufacturers, who will mix their ice cream and pasteurize it in the same vessel. One advantage of batch pasteurization is that it produces a better mouthfeel of the ice cream, due to more of the whey proteins being denatured. HTST is more fitting for larger manufacturers who use a plate heat exchanger, which heat-treats a continuous stream of product. The pasteurization temperature for ice cream is higher than that for milk because the sugar added to ice creams coats the bacterial cells and helps to protect them (Goff 1995; Marshall and Goff 2003; Beattie 2004).

2.1.3.2 Homogenization

Homogenization causes ice creams to have a stable, uniform, smooth texture and be whipped more easily during the freezing process, although not all ice cream manufacturers use a homogenizer in the production process line (Goff 1995; Marshall and others 2003).

Homogenization of ice cream mixes causes the formation of a fat emulsion by breaking down or reducing the size of the fat globules found in milk or cream to less than 1 μm (Berger 1990). It provides some functions in ice cream manufacture, including (1) size reduction of fat globules (2) increasing surface area (3) membrane formation to make a smoother ice cream (4) creating greater apparent richness and palatability (5) better whipping ability (6) decreasing the danger of churning the fat (7) enabling the use of butter, frozen cream, etc., and (8) increasing resistance to melting (Goff 1995; Marshall and others 2003). The mix should be homogenized in a two-step homogenizer with the pressure of the first stage between 2000-2500 pounds and between 500-1000 pounds for the second stage (Goff 1995). The higher the fat and total solids in the mix, the lower should be the pressure of the homogenizer. By doing a two-step homogenization, clumping or clustering of the fat is reduced, which produces a thinner more rapidly whipped mix, and melt-down is also improved (Beattie 2004).

2.1.3.3 Aging

The aging process of ice cream mix is performed overnight in insulated and refrigerated storage tanks at a temperature maintained as low as possible without freezing (Hyde 2001). In the process, the fat cools down and crystallizes, and the proteins and polysaccharides (stabilizers) fully hydrate in the ice cream mix. Aging provides some essential functions including that it (1) improves whipping qualities of the mix (2)

improves the body and texture of the ice cream (3) causes the reduction in stabilization of the fat globule (4) causes fat crystallization and (5) increases viscosity (Goff 1995; Marshall and others 2003; Beattie 2004).

2.1.3.4 Freezing and Hardening

The flavor and color usually is added to the aged ice cream mix before operating the freezing process because off-flavors do not occur once the ice cream mix has been aged. Freezing ice cream mix is a dynamic process that freezes a portion of the water and whips air into the frozen mix by the operation of a freezer pump, resulting in an ice cream that has a consistency close to that of soft-serve ice cream (Goff 1995).

If a soft-serve ice cream is made, a horizontal batch freezer specifically designed to dispense the ice cream is used, because the ice cream has a higher solids content (Beattie, 2004). The longer dwell time and lower overrun results in a product with a higher proportion of unfrozen water and consequently there is a greater risk of larger ice crystals to occur (Goff 1995; Beattie 2004)

If the product is going to be sold in liter containers, small tubs or being destined for scooping, one of two types of freezers, batch freezers and continuous freezers may be used. Continuous freezers are more efficient with a shorter dwell time, higher level of air incorporation is possible and a lower proportion of unfrozen water in the product is achieved (Beattie 2004)

Ice cream contains a considerable quantity of air, up to half of its volume. This air is referred to as overrun. This gives the product its characteristic lightness. Without air, ice cream would be similar to a frozen ice cube. The batch type of freezer produces ice creams with a low overrun and is better with recipes, which contain about 30-32% total

solids (Beattie 2004).

After the ice cream has been partially frozen, inclusions, such as nuts, candy or fruit, are added, and the freezing process is continued by subsequent hardening. The ice cream usually is packaged and is placed into a blast freezer at -30°C to -40°C where most of the remainder of the water is frozen.

Some of the important factors affecting hardening rate are size and shape of package, air temperature, air circulation, positioning within the freezer room, drawing temperature from the freezer, composition of the mix and percentage of air incorporated. Quickly freezing the ice cream avoids the formation of large ice crystals. Below about -25°C , ice cream is stable for indefinite periods without danger of ice crystal growth; however, above this temperature, ice crystal growth is possible, and the rate of crystal growth is dependent upon the temperature of storage. This limits the shelf life of the ice cream (Goff 1995; Marshall and others 2003; Beattie 2004).

2.1.3.5 Shelf Life

The shelf life of ice cream is mainly dependent on the storage conditions. Ice cream can last as long as one year, or as little as two weeks. The finished product will have a shelf life of about 12-18 months if kept at around -20°C to -25°C . In order to maintain shelf life, some factors must be taken into consideration, including (1) proper formulation of the ice cream, such as the addition of stabilizer and sugar (2) freezing the ice cream quickly (3) hardening the ice cream rapidly and (4) avoiding temperature fluctuations during storage and distribution (Goff 1995; Marshall and others 2003; Lee and others 2005).

2.2 STRAWBERRY FLAVOR

2.2.1 Introduction

Strawberry flavor is one of the most complex fruit flavors because its formation is closely correlated with metabolic changes occurring during strawberry maturation (Ito and others 1990). More than 360 chemical compounds, including acids, aldehydes, ketones, alcohols, esters, lactones, furans, and other contributing groups, such as sulfur compounds, acetals, phenols, epoxides, and hydrocarbons have been identified in the aroma profile of strawberry (Tressl and others 1969; Yamashita and others 1976; Schieberle and Hofmann 1997; Zabetakis and Holden 1997).

FuraneolTM (4-hydroxy-2,5-dimethyl-3(2H)-furanone), methyl butanoate, ethyl butanoate, *cis*-3-hexenal, ethyl-2-methyl propanoate, and ethyl hexanoate are considered to be the character impact compounds of strawberry flavor (Hirvi 1983; Manning 1993; Schieberle and Hofmann 1997; Zabetakis and Holden 1997; Golaszewski and others 1998; Pérez and others 1999). Among them, 4-hydroxy-2,5-dimethyl-3(2H)-furanone and its methyl ether (mesifuran) are two of the most important aroma compounds and are considered to be glycosidically bound in strawberry (Hirvi 1983; Roscher and others 1997). Some sulfur-containing compounds, such as methylthiol acetate, dimethyl disulfide and methylthiol butyrate, also play an important role in the character impact of strawberry flavor (Dirinck and others 1981). The character impact compounds contributing to the typical strawberry flavors are well known and are used for the production of artificial and natural strawberry-WONF (With Other Natural Flavors) flavors (Schieberle and Hofmann 1997).

2.2.2 Artificial Strawberry Flavor

Strawberry aroma is the result of the combined perception of many aromatic notes, such as caramel, jam, floral, fruity, buttery, sour and grassy (Pérez and others 1993; Schieberle and Hofmann 1997; Gomes da Silva and Chaves das Neves 1999). A typical artificial strawberry flavor is a cocktail of more than 50 chemicals (Lindsay 1984). Artificial strawberry flavoring is a substance that does not come from strawberries, and which has a distinctly different chemical composition from that which gives strawberries their flavor. Nevertheless, the artificial strawberry flavoring is clearly recognized as strawberry by consumers (Keeley 1997). Additionally, the food has to be labeled “artificially flavored” if a flavor representation is made by naming the characterizing flavor provided by an artificial flavor (Lindsay 1984).

Five artificial flavor compounds were used in this study, including *cis*-3-hexen-1-ol, γ -undecalactone, α -ionone, ethyl-3-methyl-3-phenylglycidate and furaneolTM. These compounds mixed together in specific concentrations are perceived as a typical strawberry flavor.

2.2.2.1 *cis*-3-Hexen-1-ol

cis-Hexen-1-ol (C₆H₁₂O, MW: 100.16), also known as ‘leaf alcohol’, is one of the most important flavor and fragrance material used in a majority of fruit and vegetable compositions, and its chemical structure is shown in Figure 2-1. *cis*-Hexen-1-ol, produced by the lipoxygenase breakdown of fatty acids, is associated typically with a “fresh” or “green” note (Galliard and others 1977; Buttery and others 1990). Lipoxygenase acts on linolenic acid to form 13- and 9-hydroperoxides, which are cleaved by hydroperoxide lyase to form hexanal and *cis*-3-hexenal, which is then converted to

cis-3-hexen-1-ol (Pérez and others 1999). Its synonyms are (*Z*)-3-hexen-1-ol, *cis*-3-hexen-1-yl alcohol, leaf alcohol, strawberry leaf extract, 3-hexen-1-ol and β - γ -hexen-1-ol. It is a colorless to pale yellow liquid owning a powerful fresh and intensely green grassy odor with pungent depths. It is soluble in water (Bauer and others 2001) and has been found in many flowers, fruits, and vegetables, for instance, apple, apricot, cherry, grape, kiwi, lemon, melon, mint, orange, plum, strawberry, corn, pumpkin, tomato, tea, etc (Buttery and others 1990; Sakho and others 1997; Pino and others 2001; Leffingwell 2003). In fact, *cis*-3-hexen-1-ol is found in almost all plants with green foliage in at least trace amounts (Chittattu and John 1998).

DeRoos and Wolswinkel (1994) showed *cis*-3-hexen-1-ol has similar correction factors for flavor perception by sniff or by mouth in water and milk, indicating less influence of fat on its release and perception. However, Miettinen and others (2002) observed that an increase in dairy fat levels from 0% to 9% or 18% in strawberry ice cream significantly increased the concentration of *cis*-3-hexen-1-ol in the headspace of samples. The result demonstrated there is an effect of fat on the headspace concentration of *cis*-3-hexen-1-ol.

Gaddamu (2003) found higher threshold concentrations of *cis*-3-hexen-1-ol in the 4% fat mix than in the 10% fat mix, and the threshold value were 0.5 ppm in the 4% fat mix and 0.19 ppm in the 10% fat mix. Some studies have reported the threshold value of *cis*-3-hexen-1-ol in water, including 70 ppb by Fazzalari (1978), 39 ppb to 500 ppb by Rychlik and others (1998) and 0.1-1 mg/kg by Larsen and Poll (1990). In addition, Rychlik and others (1998) demonstrated the threshold value of *cis*-3-hexen-1-ol in oil were 1.1 ppm. The threshold values reported in these literatures vary greatly because the

different methodologies and laboratory conditions were used (Rychlik and others 1998).

2.2.2.2 γ -Undecalactone

γ -Undecalactone ($C_{11}H_{20}O_2$, MW: 184.31), which has a distinct peach odor, is a member of 4-alkyl-substituted γ -lactones and is colloquially called “peach aldehyde”. Its molecular structure is shown in Figure 2-1. It is used in peach flavor formulations, although it is rarely reported in natural extracts (Mosandl and Gunther 1989; Crouzet and others 1990; Material Safety Data Sheet 2004^a). In a non-acidic environment γ -undecalactone imparts a milky, creamy and butter-like flavor at 1 ppm, but at concentrations greater than 3 ppm, it contributes to a coconut-like flavor. Only in an acidic environment does γ -undecalactone impart a peach-like flavor (Guyot and others 1996; Fischetti 2002). 5-Heptyldihydro-2-(3H)-furanone is the IUPAC name for γ -undecalactone and structurally it is a heptyl butyrolactone. Commonly used synonyms include undeca-1,4-lactone, 4-hydroxyundecanoic acid lactone, γ -heptylbutyrolactone, 4-heptylbutan-4-olide, peach aldehyde, peach lactone, persicol and aldehyde C14 peach (FDA 2001). It is a colorless to straw yellow viscous liquid having a strong fruity odor of peach or apricot particularly upon dilution. It is slightly only soluble in water (Bauer and others 2001; Baldwin 2004), as lactones generally are very lipophilic compounds.

Guth and others (2001) suggested that γ -undecalactone is highly lipophilic according to their determination of the partition coefficients in octanol/ water and cyclohexane/water systems. It has been found in butter, peach, apricot, passion fruit and hydrolyzed soy protein. Some reports indicated γ -undecalactone is being used in bakery goods, frozen dairy, chewing gums, meat products, soft and hard candy, alcoholic and

non-alcoholic beverages (Mosandl and others 1990; Salles and others 1991; Burdock 1994).

Hatchwell (1996) indicated the lactone group is known to contribute to fatty sensory properties such as buttery, creamy and rich attribute. Acree and others (1985) indicated that the stereoisomeric compound of γ -undecalactone not only differs in its odor quality but also exhibits tremendous differences in its odor thresholds. The (4R)-configured antipodes are responsible for the pleasant, natural fruity, aroma note. For examples, in a 1% propylene glycol solution, R-(+)-4-heptylbutan-4-olide exhibits a strong fruity-sweet smell, reminiscent of peach, with some bloomy aspects, and tastes sweet with either a caramel (1 ppm concentrates) or a lactone character (10 ppm) when placed into a solution of 10% invert sugar and 0.015% citric acid. However, (S)-(+)-4-heptylbutan-4-olide exhibits fatty-sweet, aldehydic notes in a 1% propylene glycol solution.

The chirality of the γ -lactone and the size of the alkyl side chain in the 4-position both play a key role in determining the sensory properties. Siek and others (1970) indicated that with the alkyl side chain being the same, the taste thresholds of γ - and δ -lactones were higher in deodorized butteroil than those in water. Gaddamu (2003) indicated a higher threshold concentration of γ -undecalactone in the 10% fat mix (13.1 ppm) compared to the 4% fat mix (7.2 ppm). Siek and others (1970) found the threshold levels for γ -undecalactone in water and oil were 0.025 ppm and 0.93 ppm respectively. Keith and Powers (1968) reported the taste threshold of γ -undecalactone in water were 0.15 ppm.

2.2.2.3 α -Ionone

α -Ionone ($C_{13}H_{20}O$, MW: 192) is a member of the aliphatic ketone (C_{13} -cyclic terpenoid ketones) group (Schoch and others 1991). Its synonyms include ionone, 4-(2,2,6-trimethyl-2-cyclohexen-1-yl)-3-buten-2-one, α -cyclocitrylidene acetone and α -irisone, which is the IUPAC name; its molecular structure is shown in Figure 2-1 (Material Safety Data Sheet 2001). It is a pale yellow oily liquid with an odor of violets. In fact, it is the most floral and violet odors of all the ionones and has a fairly powerful woody (R- α -ionone) or fruity (S- α -ionone) character in dilution. It is insoluble in water and soluble in alcohol and oil. Both optical isomers of α -ionone are found in nature (Bauer and others 2001). In general, ionones have a *trans*-configuration, which can be converted into the *cis* isomer by exposure to ultraviolet light. α -Ionone has been used in perfumes, flavorings, and in vitamin A (retinol) production for cosmetics and toiletries as well as in food flavors, such as berry, punch, citrus, raspberry, almond, tobacco and tea flavors (Bauer and others 2001; Material Safety Data Sheet 2001; Material Safety Data Sheet 2005).

De Roos (1997) demonstrated that α -ionone is a lipophilic flavor and its release rate was greatly influenced by the presence of as low as 1% fat. 98% of α -ionone was retained in an oil-in-water emulsion containing of 1% oil but only 45% of the flavor was retained in pure water. It naturally occurs in black currant, carrot, blackberry, burley tobacco, grape brandy, raspberry, roasted almond, rum, whiskey, wine and some plants such as *Acacia Farnesiana* and *Sphaeranthus Indicus L* (Baslas 1959; Takeoka and others 1990; Schoch and others 1991).

α -Ionone has two stereoisomeric compounds: (R)-(+)-(E)- α -ionone and (S)-(-)-(E)- α -ionone. (R)-(+)-(E)- α -ionone has a strong aspects of violet-like, fruity, raspberry-like, flowery characteristics, and (S)-(-)-(E)- α -ionone has woody, cedar wood like, raspberry or β -ionone like properties (Werkhoff and others 1990). Werkhoff and others (1990) reported a threshold of 0.5-5 ppb for (R)-(+)- α -ionone whereas a threshold of 20-40 ppb was reported for its enantiomer (Fehr and Guntem 1992). However, Elisabetta and others (2002) were not able to confirm such strong deviations in the odor profiles or thresholds of α -ionone enantiomers. Rychlik and others (1998) reported the threshold of α -ionone in water ranged from 0.4 to 5 ppb and was reported to be between 0.001-0.01 mg/kg by Larsen and Poll (1990). Fazzalari (1978) indicated the orthonasal thresholds of α -ionone ranged from 50 ppb to 93.8 ppb. Gaddamu (2003) showed that α -ionone had a higher threshold in the 4% fat mix compared to the 10% fat mix and the thresholds were reported to be 0.63 ppm in the 4% fat mix and 0.6 ppm in the 10% fat mix. The result showed fat had little effect on the release of α -ionone at these specific concentrations.

2.2.2.4 Ethyl-3-Methyl-3-Phenylglycidate

Ethyl-3-methyl-3-phenylglycidate (C₁₂H₁₄O₃, MW: 206.24), shown in Figure 2-1, is an unconjugated aromatic ester and a member of the lactone group. Synonyms include strawberry aldehyde, aldehyde C-16, strawberry pure, EMPG, 3-methyl-3-phenylglycidic acid ethyl ester, ethyl-2,3-epoxy-3-methyl-3-phenylpropionate, fraeseol, and 3-methyl-3-phenyloxiranecarboxylic acid ethyl ester (Mosandl 1977; Rowe and others 1999; Bauer and others 2001; Material Safety Data Sheet 2004^b). Its organoleptic

characteristics in dilution are a strong fruity odor, and its slightly acidic taste is suggestive of strawberry. It is not found in nature and not soluble in water. In addition, it gives characteristic, pleasant flavors that have been described as red rather than strawberry or raspberry (Mosandl 1977; Rowe and others 1999). It has been used in bakery goods, frozen dairy, condiment, relish, chewing gums, gelatin, pudding, soft and hard candy, alcoholic and non-alcoholic beverages (Burdock 1994).

Two stereoisomeric flavor compounds are available and the proportion of the *cis*- and *trans*-isomers in a flavor mixture range from 80/20 to 60/40 respectively, depending on the reaction condition. Mosandl (1977) showed the *cis*-isomer had more intense and finer flavor compared to the *cis/trans*-mixture. Gaddamu (2003) reported that the threshold value of the mixture in the 4% fat mix was 0.36 ppm and 0.46 ppm in the 10% fat mix.

2.2.2.5 Furaneol™

Furaneol™ ($C_6H_8O_3$, MW: 128) also known as "Strawberry furanone" or "Pineapple furanone" was originally reported in strawberries by Willhalm and others (1965) and at the same time Rodin and others (1965) reported it in pineapple. Furaneol™, produced mostly through Maillard reactions, is a colorless or pale yellow powder and soluble in water (Pickenhagen and others 1981; Buttery and others 1994). Its synonyms include 2,5-dimethyl-4-hydroxy-3(2H)-furanone, which is its IUPAC name (Figure 2-1), alleton, DHF, DMHF, pineapple ketone and strawberry furanone (Material Safety Data Sheet 2004^c). Its olfactory properties are a caramel burnt sugar flavor at high levels and a fruity flavor at low levels (Pickenhagen and others 1981; Pérez and others 1996; Bauer and others 2001). Furaneol™ plays a key role in the flavor of various fruits such as guava,

pineapple, strawberry (Pickenhagen and others 1981), raspberry (Pabst and others 1991), tomato (Krammer and others 1994), arctic bramble, as well as in roasted products such as coffee, cooked beef (Tonsbeek and others 1968) and popcorn. Glycosidically bound aroma compounds, such as the β -glucoside of furaneolTM, which are important flavor precursors can be isolated and identified from strawberries or strawberry juice (Mayerl and others 1989; Williams and others 1989; Roscher and others 1996). Additionally, furaneolTM is also found in processed foods and beverages such as pineapple and apple juices (Pisarnitskii and others 1992), beef broth (Tonsbeek and others 1968) and roasted almonds (Tei and Yamanishi 1974). It is assumed that furaneolTM is formed in heat-processed foods containing hexoses (Schieberle 1992).

FuraneolTM is not stable and degrades thermally under normal GC conditions, so that it has to be treated in a way to avoid the risk of thermal oxidative decomposition. It already has proved difficult to isolate by organic solvent extraction due to its water-soluble nature (Flath and Forry 1970; Shu and others 1985). Hirvi and others (1980) found that furaneolTM was unstable in aqueous buffer solutions with pH values less than 3 and greater than 5. Another more recent study concluded furaneolTM was unstable at all pH values in aqueous buffer solutions (Roscher and others 1997). Due to the instability of furaneolTM under GC temperature conditions, HPLC methods have been applied to analyze furaneolTM. Sen and others (1991) successfully developed a stable isotopic dilution assay to quantify furaneolTM and its methyl ester in fresh fruits like strawberry, pineapple and related processed products. Sanz and others (1994) used a reverse phase C18 column to analyze furaneolTM and its derivatives, such as glucoside derivatives and mesifurane, in strawberry fruits. It is important for the accuracy of the quantitative data

for a calibration curve to be established and the recovery factor of the extraction to be determined for each analyte individually.

A reverse-phase HPLC method, following a solid phase extractions, was developed for rapid analysis of furaneolTM by Lee and Nagy (1997). Rouseff and others (1998) confirmed that higher values of furaneolTM were obtained by HPLC compared to GC and GC/MS values reported in the literature. The primary reason is the incomplete resolution and non-thermal degradation products in the HPLC method.

Many articles have reported odor threshold values ranging from 0.4-1700 ppb. Pittet and others (1970) indicated the odor and taste thresholds of furaneolTM in water are 0.2 mg/L and 30 µg/L, respectively. Buttery (1995) showed that the odor threshold value is pH dependent in water, including 60 ppb at pH 7, 31 ppb at pH 4.5 and 21 ppb at pH 3.0. Schieberle and Hofmann (1997) found that the threshold of furaneolTM in water is 10 µg/L. FuraneolTM showed higher threshold concentrations in the 10% fat mix (10 ppm) compared with the 4% fat mix (2.9 ppm) (Gaddamu 2003). Rychlik and others (1998) showed the orthonasal threshold value of furaneolTM in water ranged from 0.6 to 60 ppb. Buettner and Schieberle (2000) showed a significant increase in the odor threshold of furaneolTM in the presence of butane-2,3-dione or (Z)-hex-3-enal in water. The result indicated that furaneolTM could be masked in the presence of other compounds. Additionally, the orthonasal and the retronasal threshold value of furaneolTM in oil were 25 ppb and 4 ppb, respectively. The result means the mouth environment increased the release of furaneolTM from the oil to the odor receptors (Rychlik and others 1998). The methyl ether of furaneolTM has a higher threshold level and is described as having a more sherry-like aroma (Pickenhagen and others 1981).

2.2.3 Effect of Strawberry Compounds on Different Fat Systems

Several studies have confirmed the impact of levels and types of fat on release of strawberry aromas or flavors in ice creams or model systems. Miettinen and others (2002) made ice cream with 0, 9, 18% milkfat or vegetable fat and added 8 volatiles, including ethyl acetate, ethyl butanoate, methyl-2-methylbutanoate, ethyl-2-methylbutanoate, isopentyl acetate, ethyl hexanoate, 3-*cis*-hexenyl acetate and 3-*cis*-hexen-1-ol. They demonstrated the headspace concentration of hydrophobic compounds was significantly greater in the nonfat ice cream, while hydrophilic compounds were detected in higher concentration in the headspace of high fat ice creams. Gaddamu's studies (2003) found that the instrumental response for the five flavor compounds also used in this study, including ethyl-3-methyl-3-phenylglycidate, furaneolTM, *cis*-3-hexen-1-ol, α -ionone and γ -undecalatone, increased with the increase of the compounds' concentration in 4% and 10% fat mixes, and the headspace concentration of α -ionone, γ -undecalactone and ethyl-3-methyl-3-phenylglycidate decreased with the increase of fat content in the sample matrix, while *cis*-3-hexen-1-ol had a higher release from the 4% fat mixes than the 10% fat mixes and furaneolTM was not significantly affected by fat content. In a similar study, done by Loeb (2004), 4% and 10% ice creams and mixes were analyzed, instead of plain emulsions, using instrumental analysis and sensory test. The studies found the flavor compounds, with exception of ethyl-3-methyl-3-phenylglycidate and furaneolTM, were perceived more strongly in 4% ice cream and mix than in 10% ice cream and mix. In addition, the instrumental responses were directly related to all sensory attributes with the exception of ethyl-3-methyl-3-phenylglycidate. Sensory analysis of strawberry juice showed that furaneolTM was positively related to fresh flavor and negatively related to

off-flavor, while α -terpineol was inversely related to fresh flavor (Golaszewski and others 1998).

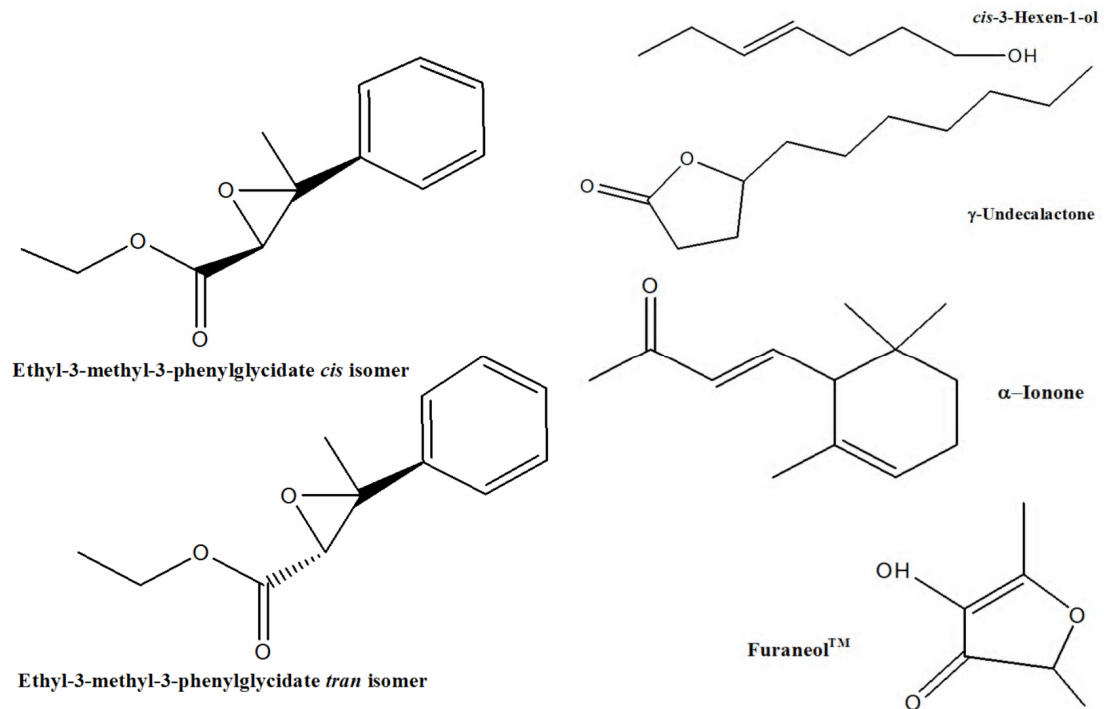


Figure 2-1. Molecular structure of five flavor compounds.

2.3 FAT REPLACERS

2.3.1 Introduction

The term "fat replacer", which can be divided into two categories: fat substitutes and fat mimetics, is defined as a carbohydrate-, protein- or fat-based compound that replaces one or more of the functions of fat in order to reduce calories in foods (Schmidt and others 1993; Drake and others 1996; Hatchwell 1996; Akoh 1998). According to their chemical functional properties, fat replacers are classified into ten general categories, including synthetic fat substitutes, emulsifiers or surface active agent, starch derivatives,

maltodextrins, hemicellulose, β -glucans, soluble bulking agents, microparticulates, composites and functional blends (Gilksman 1991; Clark 1994; Jones 1996^b).

Fat substitutes usually are fat-based derivatives manufactured either by chemical reactions between sugars and fatty acids or by modification of triglycerides, such as Olestra[®], a sucrose fatty acid polyesters, and Salatrim[®], a short and long acyl triglyceride, which are two famous fat substitutes (Giese 1996). Theoretically, fat substitutes replace the fat in foods on a one-to-one, gram-for-gram basis. Most fat substitutes are stable at cooking and frying temperatures (Clark 1994; Giese 1996; Jones 1996^b).

Fat mimetics are carbohydrate-based or protein-based compounds that are physically or chemically processed to mimic the functional properties of fats in food systems (Akoh 1998). The caloric value of fat mimetics ranges from 0 kcal/g to 4 kcal/g. Fat mimetics are better suitable for baking instead of frying because they usually adsorb a substantial amount of water from food. In addition, fat mimetics are generally less flavorful than fats and they usually carry more water-soluble flavor compounds than lipid-soluble flavor compounds. Therefore, emulsifiers may be required for formulating lipophilic flavors with fat mimetics in foods (Akoh 1998; Jones 1996^b).

Fat provides flavor, mouthfeel, texture, structure, process performance, shelf life and appearance so fat mimetics also should provide those characteristics in low fat or fat-free products (Clark 1994; Kuntz 1996; Akoh 1998). However, many studies found that the use of fat mimetics is difficult for mimicking the rheological effects of fats in some product categories (Jones 1996^a). In other words, none of the fat mimetics would fit all applications, and blends of ingredients may be required to fulfill all of the requirements of any one application (Kailasapathy and Songvanish 1998).

Fats and oils cannot simply be taken out of a food product and replaced with fat mimetics and water. Hence, reformulation of low fat foods is required to achieve all the taste and mouthfeel characteristics which consumers want and expect (Anonymous 1992). Many products, such as baked goods, dressings, meat products, sauces, gravies and frozen desserts, have been successfully reformulated with fat mimetics (Yackel and Cox 1992). Low-fat ice cream, in which a certain amount of fat has been replaced with fat mimetics, should taste creamy and not develop ice crystals upon heat shock and possess proper hardness when taken from the freezer (LaBarge 1988; Yackel and Cox 1992; Giese 1996).

Matching a low-fat prototype to a full-fat product can be a difficult task in many instances because added fat mimetics change many sensory attributes, such as flavor release, sweetness, saltiness, aftertaste, mouthfeel and melting properties, physical properties, such as viscosity, texture and appearance, and the microbiological stability, in these products (Yackel and Cox 1992). Screening and evaluating the appropriate fat mimetics in the development of low-fat food products have become a significant goal for food developers and ultimately to business (Yackel and Cox 1992). Fat mimetics, such as polydextrose and maltodextrin, as bodying agents in the fat-free ice creams significantly increase flavor release, fattiness, creaminess, and melting rate of the ice cream (Hyvönen and others 2003). Incorporation of fat mimetics may be more helpful in increasing the viscous properties than the elastic properties in a dairy-based system (Adapa and others 2000). For example, microparticulated protein may provide a dispersed phase, which uniformly distributes bound water throughout the product matrix. Gums or modified starches provide viscosity and control free water and emulsifiers keep the remaining fat

compatible with the large amounts of water present (Clark 1994).

2.3.2 Category of Fat Mimetics

2.3.2.1 Carbohydrate-based Fat Mimetics

Carbohydrate-based fat mimetics, which contain both digestible and indigestible complex carbohydrates, are derived from cereals, grains, and plants, such as gums, starches, pectin, cellulose and other ingredients (Glicksman 1991). They usually function as bulking agents or water holding matrices, which give moistness to the food as well as provide texture, mouthfeel and opacity (Giese 1996). For example, many fat-free and reduced-fat cookies have used corn syrups, syrup solids, and high-fructose corn syrups as fat mimetics to control water activity (Akoh 1998). Polyols such as sorbitol and maltitol as well as fructooligosaccharides may also be used to control water activity (Akoh 1998).

Several carbohydrates are promoted and used for partial or total fat replacement, including (1) gums or hydrocolloids (2) polydextrose or Litesse[®] (Pfizer Chemical Division, NY) (Pfizer, Inc. 1991) (3) cornstarch maltodextrin or *Maltrin*[®] M040 (Grain Processing Corporation, IA) (4) tapioca dextrins (N-Oil[®]) or tapioca maltodextrin (N-Oil[®] II) (National Starch and Chemical Corporation) (5) potato starch maltodextrin, *passelli* SA2 (Avebe America Inc. NJ) (6) modified potato starch, *Staslim*[®] (Duxbury 1991).

Polydextrose, as a bulking agent, can also be considered as a fat-mimetic in low-fat dairy products. However, it is most commonly used to replace sugars in various desserts. Polydextrose has a relatively high viscosity in solution so that it can contribute to the mouthfeel and creaminess of fat-reduced formulations (Mitchell 1996; Roland and others 1999). However, the use of carbohydrate-based fat mimetics in reduced-fat ice

creams caused mixes to have higher viscosities, which can prevent air incorporation and results in limited whipping ability (Marshall and Arbuckle 1996; Adapa and others 2000). Studies showed that ice cream mixes with carbohydrate-based fat mimetics incorporated less air than control mixes and mixes with protein-based fat mimetics (Schmidt and others 1993).

Functionally, carbohydrate-based fat mimetics cause stabilization and emulsification of food products (Alexander 1997). Most of them usually interact with flavors by polar, hydrogen bonds or dipole-dipole interactions. However, since most flavor compounds are more hydrophobic, their application as flavor carriers is greatly limited (Plug and Haring 1993). A specific exception, cyclodextrins, has been shown to complex with lipophilic compounds and has been used in encapsulating flavors (Guichard 2002).

2.3.2.1.1 Litesse[®]

Polydextrose is composed of randomly cross-linked glucose polymers with all types of glucosidic bonds, although 1-6 bonds are predominant (minimum 90%), sorbitol end-groups (maximum 2.0%) and monoester bonds with citric acid (Torres and Thomas 1981). Litesse[®], made by Pfizer, Inc. (New York, NY), is a polydextrose derivative containing minor amounts of bound sorbitol and citric acid (Pfizer, Inc. 1991; Burdock and Flamm 1999; Strugnell 1993). Litesse[®] is a white-to-cream colored powder that has a pH (10% solution) of 2.5-3.5 and forms a melt above 130 °C, which is clear, bright, non-sticky and exhibits no crystallization (Mitchell 2004). It supplies 1 kcal/g because of being only partially metabolized in the intestinal tract (Mitchell 2004). The high viscosity property of Litesse[®] in aqueous solution provides bulk and mouthfeel perception in food

systems (Strugnell 1993; Mitchell 2004). However, the molecular weight has to be less than 22,000 so that it can maintain an acceptable solubility in water. Strict control of its molecular weight governs its solubility and the amount used in foods can be easily placed in solutions. The slow addition of Litesse[®] to water with sufficient mechanical agitation and blending with other dry ingredients can facilitate the preparation of concentrated solutions (Sandrou and Arvanitoyannis 2000).

According to the regulation by the Food and Drug Administration (FDA), Litesse[®] may be used in frozen dairy desserts, baked goods, confections, frostings, salad dressings, gelatins, puddings, fillings, hard and soft candy, and chewing gum (Artz and Hansen 1994; Strugnell 1993). For example, it causes less depression of the freezing point in an ice cream mix than does sucrose. This feature can permit the use of Litesse[®] in fat-free frozen desserts to provide satisfying total solids and desirable mouth and body qualities. Furthermore, it has excellent technological functionality and remains stable over a range of pH and processing conditions (Mitchell 2004).

Litesse[®] is a fat and sugar replacer, bulking agent, flavor carrier, freezing-point depressant and humectant (Murphy 2001; Mitchell 2004). Litesse[®] is approved as a bulking agent, formulation aid, humectant, and texturizer (21 CFR 172.841). Currently, there are four commercial products of Litesse[®], including polydextrose, Litesse[®], Litesse[®] II and Litesse[®] Ultra[™], which are produced from polydextrose using further processing to reduce acidity and bitterness (Mitchell 2004). Litesse[®] and Litesse[®] II are second and third generation polydextroses with a reduced titratable acidity and improved flavor compared to polydextrose. Litesse[®] II, which was specifically developed for use in light foods, provides a higher level of sugar and fat replacement (Mitchell 1996). In

addition, Litesse[®] Ultra[™] contains a maximum of 0.25% reducing sugars so it can be used in the formulation of sugar free foods. The sensory characteristics of Litesse[®] and Litesse[®] II in aqueous solution were similar when judged by trained panelists using Quantitative Descriptive Analysis, and there are no significant differences between the two Litesse[®] products at the same concentration in aqueous solution (Mitchell 1996). Polydextrose usually has a potential laxative effect so it is required for labeling in food products containing more than 15 g polydextrose per serving which must state “Sensitive individuals may experience a laxative effect from excessive consumption of this product.”(Akoh 1998).

Litesse[®] has a similar functionality to sugar, but it is not sweet and can therefore be used in conjunction with artificial sweeteners (Strugnell 1993). However, sweetness was the most intense flavor property and Litesse[®] II was judged sweeter than Litesse[®] at a concentration of 20%. The sweetness of Litesse[®] II was probably enhanced by its lower titratable acidity. Litesse[®] II was also less bitter, astringent, and oily than Litesse[®] (Mitchell 1996).

Some studies have confirmed beneficial effects of Litesse[®] on the intestinal tract, including being tooth friendly, enhancing the fiber content, reducing glycemic index, lowering fecal pH, and reducing the production of some carcinogens such as indole and *p*-cresol in a comparative study (Endo and others 1991; Zhong and others 2000; Murphy 2001; Berry 2005). Litesse[®] is a slowly fermentable prebiotic and provides a sustained release of energy throughout the colon so that it causes a shift in the microbial community in the gut and enhances the growth of microbes with a positive effect, including *Bifidobacteria*, which allows the further fermentation of lactic acid. Using a

4-stage colon simulation technique, the production of butyrate from Litesse[®] by gut microbes, is dose dependent and continues into the distal colon. Butyrate, a short-chain fatty acid, is produced from Litesse[®] and is one of the important microbial metabolites, which contribute to normal colon function and decrease gut pH, reducing numbers of bacteroides. In addition, it is used as the main energy source by colonocytes and gut immune cells and protects against intestinal cancer by stimulating the programmed death of cancer cells. Litesse[®] is well tolerated at levels as high as 90 g/day, and its prebiotic effects have been reported at levels as low as 4 g/day (Mitchell 2004).

2.3.2.2 Protein-Based Fat Mimetics

Protein-based fat mimetics are derived from a variety of protein sources, including egg, milk, whey, soy, gelatin, and wheat gluten, and they are digestible and metabolizable (4 kcal/g) (Artz and Hansen 1994).

Protein-based fat mimetics could form a matrix that holds water as well as provide hydrophobic binding sites for binding flavor compounds (Marshall and Arbuckle 1996), although it is generally accepted that proteins are less effective water-binders than starches or carbohydrates (Clark 1994). Reversible adsorption of flavors by van der Waals interaction and irreversible binding by covalent or electrostatic linkages usually occur between protein and flavor compounds (Fischer and Widder 1997; Li and others 2000). Flavors have to be reversibly bound to the protein matrix in order to allow flavor release and to be perceived. Some studies demonstrated whey protein concentrates, whey powder, dry sweet whey and many different types of whey products have been successfully used in ice cream and other related dairy products for substitution of non-fat milk solids (NMS) (Young and others 1980; Jelen 1983; Adesso and Kleyn 1986).

However, the proportion of whey solids, including modified whey products, cannot be more than 25% of NMS due to flavor characteristics and textural defects (Marshall and Arbuckle 1996). Protein-based fat mimetics have generally been used in frozen and refrigerated products, dairy products, salad dressings and margarines (Strugnell 1993) but they are not suitable for frying foods. Some can be used in soup, pasteurized and baked products but only when processing temperatures are not too high (Strugnell 1993).

2.3.2.2.1 Simplese®

Simplese®, a product of the NutraSweet Company (Deerfield, IL), is a product made from milk whey protein or egg white and skimmed milk protein in an internationally patented process called “microparticulation” (Dziezak 1989; Strugnell 1993). It is a whey protein microparticulate ranging from 0.1µm to 3.0µm and provides 4 kcal/g on a dry basis as compared with the 9 kcal/g provide by fat (Bruce 1994). Specially, formulations with hydrated gels can provide calorie values as low as 1 kcal/g for a 25% gel (Akoh 1998). In general, microparticulated fat mimetics form microscopic coagulated round deformable particles that mimic the mouthfeel and texture of fat (Akoh 1998).

In February, 1990, FDA approved Simplese® to be used to partially or fully replace fat in food products and affirmed it as GRAS (21 CFR 184.1498) in 1990 for use in frozen dessert products, and in 1994 for use in yogurt, cheese spreads, frozen desserts, cream cheese, and sour cream (Strugnell 1993; Artz and Hansen 1994; Bruce 1994; Akoh 1998). For example, Simplese® replaces butterfat and can undergo standard manufacturing procedures for making ice cream. Frozen dessert made with Simplese® has less than 1% fat content and about 50% of the energy of a super premium ice cream

(16% fat), and yet has a similar taste and mouthfeel (Singer and Dunn 1990).

The basic manufacturing process of Simplese[®] is as cooking and blending of whey protein into very small and fine round spheres so that Simplese[®] particles will roll over each other to create a sensory property of creaminess or smoothness associated with fat, especially in high moisture applications (Duxbury 1991; Strugnell 1993; Bruce 1994). Simplese[®] also improves the ability to interact at air interfaces in ice cream and causes a stable emulsion (Mitchell 1993).

Simplese[®] cannot be heated and frying and baking temperatures cause it to congeal and lose the creamy consistency (Bruce 1994). It is claimed to give an acceptable taste in fat-free frozen desserts and has been used to make low-fat ice creams or frozen dessert. Schirle-Keller and others (1994) suggested that Simplese[®] behaved more like fat in terms of flavor interactions than did carbohydrate-based fat mimetics. In addition, some studies have reported that protein-based fat mimetics used in reduced-fat ice cream exhibited distinctive flavor notes, including whey, syrupy, milk powder and cooked milk (Ohmes and others 1998; Roland and others 1999). Hansen and Heinis (1991) indicated that the increase of whey protein concentrations from 0.125 to 0.5 % caused decreases in vanillin flavor from moderately less than the vanillin reference to much less than the vanillin reference. Simplese[®] also retains the biological value of the protein used and any antigenic/allergenic properties of the protein (Gershoff 1995).

Simplese[®] D-100 was more similar to fat in its functionality to reduce the vapor pressure of many flavor compounds, especially aldehydes, and its effects on flavor and fat interactions, than other kinds of fat mimetics, in a system containing 0.5% Tween 80 and fat ranging from 0-20% (Schirle-Keller and others 1994). In addition, Schirle-Keller

and others (1994) also found Simplese[®] D-100 and Simplese[®] D-300 interacted with long chain aldehydes and unsaturated aldehydes, but not with ketones. The authors indicated that the aroma profile of unsaturated aldehydes in food systems containing either of the two fat mimetics would likely be indistinguishable from that of comparable fat-containing systems.

The study of Kailasapathy and Songvanish (1998) found that ice creams with Simplese[®] had the lowest iciness compared with several other carbohydrate-based fat mimetics. The reason may be related to the higher total solids content for Simplese[®] based ice cream. Arbuckle (1986) indicated that increased total solids in an ice cream causes mechanical obstruction to ice crystal growth and has a smoother texture. In addition, Simplese[®] based ice cream provided a high elastic product, which contained the strongest internal bonds, and required less force to pull the plunger away from ice cream due to its strong water binding properties, protein hydration and swelling (Kailasapathy and Songvanish 1998).

Schirle-Keller and others (1994) concluded that foods formulated with protein-based fat mimetics should have characteristics closer to those of fat-containing products in terms of flavor profile than would be the case of those containing other fat mimetics; nonetheless, the need for reformulation would remain.

2.4 LOW-FAT ICE CREAM

Consumption of low-fat or non-fat dairy products has increased in recent years due to potential health benefits and nutritional advantages (Yackel and Cox 1992). The low-fat market extension has forced dairy food manufacturers to devise products in order

to satisfy demands of consumers. However, the retention of organoleptic characteristics in low-fat products is difficult, and they faced a lot of challenges in maintaining quality of low-fat products (Duxbury 1991; Farooq 1997).

2.4.1 Challenge

Flavor is one of the most important factors in the choices of consumers whether these flavors are occurring naturally in food or are added to formulations (Curtis 2006). Flavor can be defined as the joint perception of taste, smell and mouthfeel. So, flavor represents a complex mix of perceptions that are interpreted from chemical, physiological and psychological elements into the likes and dislikes of the foods while consumers are eating (Anonymous 1993).

The primary difficulties to be overcome in low-fat or fat-free products are to maintain the quality of texture and flavor intensity. To meet this challenge, the dairy industry has endeavored to conduct a lot of research and development (Marshall 1991; Hatchwell 1994). Texture quality has been addressed with some achievements using fat mimetics but flavor is not so easily solved (Hatchwell 1994). Marshall (1991) demonstrated major challenges for manufacturing reduced-fat, low-fat and non-fat ice creams, which are related to providing creaminess and body, minimizing ice crystal formation, and finding good flavoring formulas.

2.4.2 Formulating Reduced-Fat Ice Cream

When formulating ice cream, the issues of fat, sugar and cholesterol reduction should be treated successfully to produce a high quality product. Fat can be replaced with the proper combinations of fat mimetics. Sugar alternatives can be used, while cholesterol can be removed from butter and egg yolk by several techniques, such as supercritical

fluid extraction or chelation with β -cyclodextrin (Sandrou and Arvanitoyannis 2000).

There are too many things that fat does in foods so it is not totally realistic to expect to find any one thing to replace it (Kuntz 1996). Texture and flavor are primary issues in developing low- or non-fat products, so it is an important objective to apply basic theory of flavor and fat reduction to formulate a great-tasting, reduced-fat product such as ice creams (Kuntz 1996). The problems of unbalanced flavor release and off-flavor of low-fat ice cream can be solved by adding specific flavors in combination with a small amount of fat (Sandrou and Arvanitoyannis 2000). From experience with many products, specific problematic characteristics of reduced-fat products have been identified, such as the poor masking of off-flavors in a reduced fat system.

Hatchwell (1996) discussed several important areas of consideration to match the objective of reformulating low-fat foods. First, the quality of raw material is really important because any defects in raw materials become more apparent in a reduced-fat product than in a full-fat product. In general, the specific flavors inherent to the raw material used in the formulation are “uncovered”, so that unexpected flavors in the final products become more distinct. The quality of the base is another important factor. The base with no flavor in itself is undesirable as an ice cream, but at least it must have some dairy characters on which to build (Hatchwell 1996). In addition, the balance of sweetness and saltiness is critical because there is more water in reduced-fat systems. When the sweetness and saltiness are adjusted, the increased salt and sugar could affect the flavor balance. Thus, flavor systems should be developed after reformulation of the base is complete. A balanced flavor profile could be achieved by modifying the flavor formula. A small amount fat can significantly improve the flavor quality and temporal

profile, so effective use of fat in reduced-fat products is important (Hatchwell 1996; Sandrou and Arvanitoyannis 2000; Marshall and Goff 2003; Delwiche 2004).

Some the specific flavors have to be considered in low-fat ice creams to improve flavor perception, such as mouthfeel flavors, fat flavors, dairy flavors and flavor modifiers (Kuntz 1996; Pszczola 2004). Mouthfeel flavor is a combination of aroma chemicals providing a feeling of fullness and flavor delivery. It can help delay and prolong flavor impacts but too high of an intensity of mouthfeel is unpleasant (Kuntz 1996). When mouthfeel flavor is added during processing instead of prior to or after processing, it provides a better effect and blends better with the whole system.

In order to resolve flavor challenges of reduced-fat foods, the temporal sensory profile of full-fat products needs to be considered. One example is vanilla ice cream. As consumers taste reduced-fat vanilla ice creams, there are immediate impacts of smoky, beany, woody, medicinal, alcoholic and something described as “foreign”. Then these flavor characteristics are gone quickly, leaving little aftertaste or no aftertaste at all. The experience is different from tasting full-fat vanilla ice cream. Specific WONF Vanillas have been developed for low- or non-fat products to blend and balance well. They are formulated to minimize unpleasant characters. When they are used in combination with mouthfeel flavors added prior to processing, a similar flavor profile compared to the flavor profile of full-fat systems can be achieved (Hatchwell 1994; Marshall and Goff 2003).

Chocolate flavor is another example. Poor creamy taste, dark, woody, fudgy with notes reminiscent of a dirty and wet ashtray were perceived in low-fat chocolate ice creams (Hatchwell 1994). The addition of coca powder can be used to manipulate flavor

profiles. Vanillin also is used in chocolate flavor to sweeten the chocolate profile and to give it a “lift”. Mouthfeel or cream flavors added prior to processing contribute to the chocolate profile as well (Hatchwell 1994; Kobs 1998).

2.4.3 Relationship Between Flavor Release and Fat Content in Ice Cream

Ice cream is one of few foods that change their state from a semisolid to a liquid during eating. As mentioned, fats in ice cream influence a variety of properties, including flavor, appearance, texture and mouthfeel (Hatchwell 1994; Hatchwell 1996; Roland and others 1999). Their multimodal properties include acting as a flavor precursor, carrier and modifier as it can react with flavor components (Hatchwell 1994; Hatchwell 1996). Lipids act as a solvent for flavors because most flavor chemicals are hydrophobic and dissolve easily in fat. They may influence the temporal profile of flavor, flavor intensity, flavor properties, flavor masking and flavor development (Hatchwell 1996; Li and others 1997; Hyvönen and others 2003; Chung and others 2003). On the other hand, fats also contribute to texture and mouthfeel characteristics of foods during eating (Li and others 1997; Roland and others 1999; Chung and others 2003).

Fats acting as precursors also play an important role in the processing of foods and in storage stability by reacting with proteins and other components when heated (Hatchwell 1994; Marshall and Arbuckle 1996). Studies have known the impact of fat concentration on the appearance and texture of foods (Philips and others 1995; Gelin and others 1996; Phillips and Barbano 1997). However, while its effect on flavor release and perception has been investigated, no final conclusion can be drawn. Beal (1998) indicated that the amount and the type of fat could affect the perceived aroma of ice cream. Higher fat ice creams had better flavor and texture ratings. The addition of fat increased buttery

and creamy notes as well as mouth coating, and sensory quality improved and overall preference increased in vanilla ice creams (Stampanoni Koeflerli and others 1996; Li and others 1997). In addition, Guinard and others (1997) presented that increased fat (10%-18%) in vanilla ice cream caused higher buttery, custard and sweet flavor. High fat contents can depress the perceived intensity of sweetness and flavors. Smooth mouthfeel can also decrease the perception of flavor as the fat deposits on the tongue.

Hyvönen and others (2003) indicated that the release rate of flavor is controlled by its affinity to fat when fat is present in the food system. When fat is removed or reduced in food systems, the intensity and release rate of flavor is in general increased (Overbosch and others 1991; Shamil and Kilcast 1992; Bennett 1992). Similarly, a higher fat content in foods caused a slower flavor release within the mouth (Hatchwell 1996). More recently, Frøst and others (2001) showed faster increases and decreases in dynamic flavor perception with lower fat levels. In other words, many studies had difficulties to prove a specific effect of fat on the temporal release of flavor. For example, Mialon and Ebeler (1997) found an effect of fat on the temporal release of vanillin, which is rather polar, but failed to find a similar result for the non-polar limonene. Shamil and others (1992) found that lower fat content of cheeses and salad dressings resulted in the increase of the declaration time and rate of flavor release. However, Guinard and others (2002) did not observe any effect of fat on the release garlic, but did in the case of pepper, in salad dressings upon fat reduction (0%, 6.75% and 13.5% fat levels).

Hyvönen and others (2003) indicated that fat content of strawberry ice cream slightly affected the perceived rate of flavor release and flavor intensity using time-intensity analysis. Ingham and others (1995) indicated that the volatiles released

from strawberry, which persisted the longest in the nosespace, were the smaller esters, methyl acetate and ethyl acetate. The reason may be due to differences in polarity between these compounds and other less polar esters. Ingham and others (1995) demonstrated that the maximum concentration of aroma volatiles released from strawberries occurred at the point of swallowing during the eating process. Prior to this, only 40%-60% of the maximum level of volatile concentrations was observed. It is likely that the effect is associated with swallowing the juice and saliva present in the mouth at this time, causing transfer of volatiles to the nasal cavity.

2.4.4 Relationship Between Full-Fat Ice Cream and Low-Fat Ice Cream

Lowering fat content in ice cream is achieved by using less of the original fat level or substituting fat with fat mimetics. In low-fat and fat-free ice creams, milk fat is replaced by fat mimetics, which cause changes in texture and affect perceptibility parameters (Marshall 1991; Brauss and others 1999).

Many studies indicated that ice cream containing higher amounts of milk fat was perceived to be low in iciness and hardness, high in thickness, smoothness, gumminess and mouth coating (Prindiville and others 1998; Ohmes and others 1998). Regular ice creams had higher intensity than low-fat and fat-free ice creams in milk flavor and aftertaste and sweet aftertaste, but were lower in stale flavor. In fact, studies indicated that milk fat itself has a sweet, buttery, creamy flavor due to fatty acids, fatty acid esters, lactones and carbonyl compounds (Hatchwell 1994). Milk fat also functions as a precursor that interacts with other food components during hydrolysis, oxidation, and processing to create new flavors, such as caramellic and cultured flavors (Prinvidille 1998). Milk fat also masks a lot of off-flavors due to their fat-solubility and being present

at below threshold levels in ice cream (Hatchwell 1994).

Kruel (2004) showed significant differences in sensory properties for strawberry ice creams with different fat levels, and significant effects of fat level on fat mimetics. Her studies found faster increases or decreases in flavor release, creaminess and thickness with lower fat levels of ice cream.

Low-fat ice creams containing a higher level of NFSM generally had a significant influence on flavor perception, and it also offered a slightly salty taste in some cases (Guichard 2002). Low-fat ice cream usually tends to have a lower flavor impact because fat is not available to promote the flavor and both stabilizers and fat mimetics used could bind elements of the flavorings making them unavailable to the palate. In other words, ice cream technologists may need to increase sweeteners and flavor levels to overcome the problem in many low-fat systems (Kuntz 1996; Guichard 2002).

Only very few ice creams have successfully managed to combine low-fat and low-carbohydrate contents to achieve a low-calorie frozen dessert that is similar in taste, flavor and mouthfeel characters to a high-fat equivalent (Hatchwell 1994).

2.4.5 Relationship Between Fat Mimetics and Low-Fat Ice Cream

The amount of fat mimetics in ice creams cause changes in sensory properties. Therefore, in order to replace fat with fat mimetics in the food matrix, a good understanding of the functions of fat in that specific system prior to selecting the type of fat mimetics is necessary (Kruel 2004). However, the amount of fat being replaced and the degree of substitution also need to be considered in the choice of fat mimetics. Ice cream manufacturers have attempted to simulate texture and flavor of low-fat or reduced-fat ice creams by adding bulking agents, such as carbohydrate-based fat

mimetics or concentrated milk components as protein-based fat mimetics to fat-free formulations (Roland and others 1999). The primary purpose of fat mimetics is to offer sufficient total solids and to achieve the desired texture, body and flavor in a low-fat or fat-free product. If a fat mimetic successfully replaces fat in a food product, the overall aroma profile of the products should be similar. Therefore, flavor formulations must be modified to reflect the differences between the interactions of the flavor with fat and with fat mimetics (Schirle-Keller and others 1992).

An appropriate combination of two or more fat mimetics in frozen desserts would be better than a single fat mimetic (Glickman 1991). For example, the mixtures of soluble bulking agents, microparticulated protein and starch derivatives can produce desired reduced-fat or low-fat products due to their specific characteristics (Glickman 1991). Some studies also suggested a combination of protein, starches and hydrocolloids creates synergistic effects for lowering fat and retaining textural characteristics of the products (Ordonez and others 2001; Ruthing and others 2001).

Kruel (2004) used several fat mimetics in low-fat or fat-free strawberry-flavored ice cream to determine the effect of fat and fat mimetics. Her studies concluded ice creams with Tara Gum fat mimetics at 0%, 4% and 7% were found to be significantly different from one another in all sensory attributes. In addition, the 4% and 7% strawberry ice cream with the MAG-nifique Mouthfeel fat mimetic were not significantly different in key texture attributes, while the 4% and 7% strawberry ice creams with Litesse® were not significantly different in the aroma/flavor and texture attributes (Kruel 2004).

Ohmes and others (1998) showed that ice creams made with Simplesse® were not

significantly different in flavor and texture from a nonfat control. Schmidt and others (1993) concluded that ice cream made with Simplese[®] D-100 was more similar to full-fat ice cream in terms of rheological properties than was ice cream made with maltodextrin-based fat mimetics. Chung and others (2004) also came to similar conclusions for cherry-flavored ice cream with Simplese[®], but found there are distinctive condensed milk flavor and stickiness that distinguished them from the full-fat reference. In addition, Simplese[®] was a more effective fat mimetic compared to Litesse[®] in the suppression of the overall intensity and the rate of flavor release during eating of cherry-flavored ice cream when they were added to the 0% fat ice cream to represent a 6% fat level. Chung and others (2004) also demonstrated ice creams, including regular products and fat mimetic containing products, were separated more by texture than by flavor attributes using canonical variate analysis (CVA).

Kailasapathy and Songvanish (1998) used several fat mimetics, such as Slendid[®] and Simplese[®], in ice creams and evaluated their effects. Their studies found that Simplese[®] ice cream showed the least iciness compared with the full-fat ice cream. The Slendid[®], a carbohydrate-based fat mimetic, ice cream, had the highest mix viscosity and foaming properties and melting characteristics, which were similar to the 13% fat ice cream.

Zhang and Wang (1999) indicated the physical properties of ice creams were not significantly different if they were manufactured by using a proportion of 12%:2% of fructooligosaccharide to sorbitol to replace 14% sugar, 6% Litesse[®] to replace 6% cream and the addition of 0.2% sodium citrate and 0.6% sodium caseinate.

In sum, fat mimetics, such as Tara gum, Litesse[®], Slendid[®] and Simplese[®] have

been used in the development of low-fat ice cream. The type of fat mimetic is more important than the milk fat content in influencing the sensory properties of ice cream (Chung and others 2004). Tara gum is a good choice when substituted in a 7% strawberry-flavored ice cream to resemble a 10% strawberry-flavored ice cream, and Litesse[®] seems to have potential for replacing fat in a 4% strawberry-flavored ice cream to resemble a 10% ice cream (Kruel 2004). However, none of the fat mimetics was able to mimic fully the volatile profile of the full fat ice cream, but Simplese[®] was closer than Litesse[®] in mimicking the flavor release pattern of the full-fat reference sample (Chung and other 2004). Different fat content of ice cream with the same fat mimetic did not significantly affect the sensory characteristics but they were significantly different when different fat mimetics were used (Chung and others 2004; Kruel 2004). In addition, the expression of the differences due to fat mimetics will be amplified as the fat content decreased in ice cream (Chung and others 2004).

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CHAPTER 3

EFFECT OF FAT LEVEL ON THE PERCEPTION OF FIVE FLAVOR CHEMICALS IN ICE CREAM WITH OR WITHOUT FAT MIMETICS BY USING A DESCRIPTIVE TEST

3.1 INTRODUCTION

During the last few decades, numerous ice cream studies have been conducted ranging from improving quality of full-fat ice creams to new low-fat product development using profiling. These studies have shown that some ingredients in ice cream, mainly sugar and fat, have significant effects on the characteristics of flavor and texture (King 1994; Specter and Setser 1994; Stampanoni Koeflerli and others 1996; Guinard and others 1997; Li and others 1997). The primary difficulties to be overcome in low-fat or fat-free products include improving the mouthfeel and flavor perception to resemble that of full-fat products. To meet this challenge, ice cream manufacturers have been focusing on eliminating the problems resulting from the replacement or removal of milk fat (Marshall 1991; Hatchwell 1994).

In recent years, carbohydrate-based fat mimetics, such as Litesse[®], SPLENDID[™], N-Lite[®] and protein-based fat mimetics, such as Simplesse[®], N-Lite[™]D have been used widely in manufacture of ice creams due to prevalence of low-calories foods (Kailasapathy and Songcanich 1998; Yilsay and others 2006). However, the use of fat mimetics in ice cream affected flavor and texture characteristics of ice cream, which resulted in decreased overall acceptability by consumers. Based on these reasons, recent studies on low-fat ice cream with fat replacers concentrated on several topics; including

- (1) Effect of fat replacers on sensory characteristics and physical properties in ice

creams (Specter and Setser 1994; Kailasapathy and Songcanich 1998; Ohmes and others 1998; Roland and others 1999; Adapa and others 2000; Aime and others 2001; Welty and others 2001).

(2) Effect of fat replacers on flavor release in ice cream (Linna 2001; Chung and others 2003)

(3) New product development for ice cream with fat replacers (Prindiville and others 2000; Krueel and others 2004; Yilsay and others 2006).

Flavor is a combination of the perception of mouthfeel, taste and aroma. Release of flavor compounds during eating is a key quality parameter of foods. Mechanistic models that were developed of flavor release from foods in the mouth have been applied rapidly in flavor detection (De Roos and Wolswinkel 1994; Hills and Harrison 1995). However, these methods are still not representative of the real flavor release during consumption.

Descriptive analysis is a powerful tool in the measurement of flavor and texture because it can characterize how changes in product formulation affect sensory properties based on the combined judgments of a group of at least ten trained panelists, who function as a human analytical tool to give precise and consistent sensory judgments (Einstein 1991; Heymann and others 1993). From the product development viewpoint, the technique aims to further establish the cause-and-effect relationships connecting identification of functional ingredients and process variables with consumer preferences (Stone and Sidel 1993). The method also can facilitate the understanding of the important chemical and physical product differences that relate to the sensorial aspect (Lawless and Heymann 1998; Chung and others 2003,). A variety of sensory descriptive methods is

available and may be used in different situations, including Flavor Profile[®], Texture Profile (Brandt and others 1963), Quantitative Descriptive Analysis[®] (Stone and Sidel 1993), Spectrum Descriptive Analysis (Rutledge and Hudson, 1990), Free Choice Profiling and Time-intensity method (Lawless and Heymann 1998).

In studying interactions between flavor compounds and fat replacers in ice creams, most studies have tried to understand the effect of overall flavor perception such as chocolate (Prindiville and others 2000) vanilla (Mehu 1993; Roland and others 1997; Yilsay and others 2006) and strawberry (Kruel 2004) in low-fat or fat-free ice cream with fat mimetics. Relatively little research has focused on exploring the perception or release of flavor compounds, such as aldehyde, ketone and alcohol, in ice cream manufactured with fat mimetics. Welty and others (2001) used GC-MS and headspace solid-phase microextraction (SPME) technique to detect selected volatile compounds of chocolate ice creams in different fat ice creams with or without one of three fat mimetics (Simplese[®], Dairy Lo, or Oatrim). Chung (2002) studied the release of artificial cheery flavor in ice cream with or with fat replacers using descriptive analysis.

Strawberry flavor was chosen for this study because (1) Little information is available on the effect of fat reduction on the flavor profile of strawberry ice cream (Miettinen and others 1999). Nerveless, (2) Strawberry flavor is one of the most popular ice cream flavors, but, (3) unlike vanilla, it has more than one character impact compound. However, (4) the aroma profile of strawberry has been extensively studied (Larsen and Wattkins 1995; Zabetakis and Holden 1997; Ibáñez and others 1998; Gomes da Silva and Chaves das Neves 1999), which (5) make strawberry flavor easy to prepare. In addition, (6) there is strong indication that strawberry flavor can be affected by fat

content since its character impact compounds are diverse in regard to their hydrophobicity or hydrophilicity (Schieberle and Hofmann, 1997; Miettinen and others 1999).

Only few studies have investigated the release of flavor compounds of strawberry flavored ice creams. Miettinen and others (2002) used electronic and human nose to detect aroma differences among ice creams along with fat content, including ethyl-acetate, methyl-2-methylbutanoate, ethyl-butanoate, ethyl-2-methylbutanoate, isopentyl-acetate, ethyl-hexanoate, *cis*-3-hexen-1-ol, and *cis*-3-hexenyl-acetate. Hyvönen and others (2003) indicated that fat content of strawberry ice cream slightly altered the perceived rate of flavor release and flavor intensity using time-intensity analysis. Previous studies in our lab were conducted to determine the sensory thresholds and flavor release of the five compounds, including *cis*-3-hexen-1-ol, ethyl-3-methyl-3-phenylglycidate, furaneolTM, γ -undecalactone, and α -ionone from 0%, 4% and 10% fat emulsions (Gaddamu 2003), as well as the perceptions of the five compounds in 4% and 10% ice creams and ice cream mixes using chromatographic methods and descriptive analysis (Loeb 2004).

The objective of this study is to investigate the release behavior of five strawberry flavor compounds in ice cream with protein- and carbohydrate-based fat mimetics. The five flavoring compounds were spiked separately at two hundred percent of base concentration using five ice cream formulations (10%, 4% without fat mimetics, 4% with Simplese[®], 4% with Litesse[®] and 4% with both fat mimetics Litesse[®]/ Simplese[®] (L/S mixes) using descriptive analysis to evaluate the sensory profile. Thus, the initial studies focused principally on understanding the impact of the five compounds on sensory properties of 10% ice cream (control) and 4% ice creams with or without fat mimetics in

order to provide the information for reformulating the flavoring compounds for lower-fat ice creams with fat mimetics.

3.2 MATERIALS AND METHODS

3.2.1 Materials

Two different fat mimetics: Litesse[®], an improved polydextrose powder (Danisco, St. Louis, MO, USA) and Simplese[®]100, microparticulated whey protein concentrate 53 (CP Kelco, San Diego, CA, USA) were used in the study. The five flavor compounds were food grade, and included *cis*-3-hexen-1-ol, ethyl-3-methyl-3-phenylglycidate, furaneol[™], γ -undecalactone and α -ionone. They were procured from the Flavor and Fragrance division of Sigma Aldrich (St. Louis, MO, USA). Skim milk and heavy whipping cream were purchased from Prairie Farms Inc. (Carlinville, Illinois, USA). Nonfat dry milk (spray process grade A) made from pasteurized milk came from Dairy America (Fresno, CA, USA). Pure cane sugar was purchased from United States Sugar Co. (Clewiston, FL, USA) or from Wal-Mart (Bentonville, AR, USA). Nonfat ice cream stabilizer #19 was purchased from Opta Food Ingredient Inc. (Bedford, MA, USA), clear sweet 36/48 corn syrup was purchased from Cargill Inc. (Minneapolis, MN, USA) and strawberry red liquid color, composed of water, citric acid, sodium benzoate, red 40 and blue 1, was procured from Sensient flavors Inc. (Fenton, MO).

In this study, five different ice cream bases containing 4%, 10% ice cream, 4% ice cream with the addition of fat mimetics (Litesse[®], Simplese[®] or both) were used to make ice creams. Their composition based on weight percentage is shown in Table 3-1. The six kinds of flavor formulations containing all five artificial flavors that were used in the ice creams for this study are shown in Table 3-2 and propylene glycol was used as the base

for all the flavor formulations. Two hundred percent of the control level of the five flavors individually was spiked each in one of the experimental formulation. Thus, five kinds of ice creams contained six different flavor levels so a total of thirty strawberry ice cream samples were produced.

3.2.2 Methods

3.2.2.1 Ice Cream Manufacture

All ice creams were prepared in the Dairy Pilot Plant of the Food Science department at the University of Missouri-Columbia. Table 3-1 lists the basic formulations for both 4% and 10% fat ice cream mixes. A ten gallon batch was prepared for each of the ice cream formulations.

All dry ingredients, which were weighed in advance, were mixed thoroughly with the weighed liquid ingredients (skim milk and cream) in a mixing vat and then agitation and heating were started. The 36/48 DE corn syrup was added slowly to the mix. The mixes were pasteurized using high temperature short time (HTST) at 81.5 °C for 25 s (Processing Machinery and Supply Co., Philadelphia, PA). Then, the pasteurized mixtures were homogenized in a two-stage homogenizer (APV-Gaulin GmbH, Philadelphia, PA) at 20.70 MPa for the first stage and 3.45 MPa at the second stage, respectively. The pasteurized ice cream mixes were cooled at the ambient temperature for a while and then aged overnight at 4 °C.

Each of the aged ice cream mixes was poured individually into a one gallon bucket for the addition of flavor and color. Table 3-2 lists the six flavoring formulations. Each bucket was flavored with one of the flavor formulations (0.1%, v/v). Strawberry red liquid color was added to each bucket at the rate of 0.4 ml/L and mixed fully before

freezing. A Taylor[®] freezer (Rockton, IL) was used to freeze the mixes to soft ice creams. Aliquot of the frozen ice creams were packed in 4oz Styrofoam containers with semi-transparent lids for sensory test and the residues were packed in half-gallon containers or one-gallon zipper seal storage bags for backup. Lastly, the soft ice creams were stored at -40°C for hardening. Ice cream samples were made in triplicate according to Appendix A.

3.2.2.2 Sensory Evaluation of Ice Cream

3.2.2.2.1 Descriptive Panel and Training of Panelists

Thirty ice cream samples, shown as Appendix A, were evaluated by twelve trained panelists. The panelists, who were all graduate students at the University of Missouri Columbia, were recruited and chosen based on their availability and willingness to participate in the project, and all signed a consent form for their participation (Appendix H). The twelve panelists were ballot-trained for three-2 hour training sessions on three consecutive days. In this study, the sensory attributes and related references were initially decided upon by the panel leader, according to previous studies (Loeb 2004), instead of the panelists. During the training period, the entire descriptive panel received instructions regarding the attributes, the references and the test procedures from the panel leader. Test samples, containing all five kinds of ice creams and all six flavor formulation of 4% and 10% ice creams, were chosen for training by the panel leader. Panelists were instructed to understand that the perceived intensities of each reference provided were to be considered as being equal to 12 (i.e. 12 cm), and were asked to make a vertical line at the perceived intensities of the attributes for sampled ice cream across the 15 cm unstructured line scales anchored at the two ends with low intensity = 0 and high

intensity =15 using a paper ballot (Appendix I). To reduce carry-over effect, panelists were instructed to cleanse their palates by chewing a small piece of unsalted crackers and by rinsing with water between samples.

These attributes and references for the ice creams were slightly modified based in panelist feedback after panelists had participated in the first training session. Finally, a total of twenty six attributes containing appearance, rate of melt, flavor, texture and aftertaste, and fifteen references were used in the test. The attributes are listed in Table 3-3 together with their definitions and reference materials, where they were supplied.

Before the actual testing, an informal pretest was performed by the Compusense five 4.6 program to evaluate if all panelists had thoroughly understood these attributes and was able to communicate their perceptions correctly. The other purpose of this informal pretest was for the panelists to gain experience with a computerized test before performing the actual testing. The descriptive panel evaluated three randomly selected ice creams in duplicate in the pretest. After the pretest, the informal data were analyzed immediately by some statistical methods to evaluate significant differences for attributes. A personal training sessions focusing on inconsistent panelists were performed according to the results of the pretest.

3.2.2.2.2 Computerized Descriptive Test

Once the actual descriptive analysis was conducted, samples were evaluated in individual booths under normal light. A complete randomized block design was used for all tests. Each ice cream was made and evaluated in three replications; and for each study, the panelists evaluated each replication in three sub-replications. The order of presenting the thirty samples was determined by the Compusense five 4.6 program. Then the thirty

samples were divided into five sessions. Two sessions were held per day, and six samples were given in each session. Each sample was evaluated in triplicate, and all tests for the three replications were finished with a two week time period (See Appendix B). To avoid positional biases, the Compusense five 4.6 program was employed to create three-digit random numbers for each sample and to perform randomized product presentation arrangements across each session. Prior to analysis, the ice cream samples were stored at least 24 hours at -13°C to -15°C and served between -11°C to -15°C. A series of six samples were served nomadically per session. The perceived intensity of each attribute for each product was evaluated on the computer monitor controlled by the Compusense five 4.6 systems (Guelph, Ontario, Canada).

3.2.2.3. Color Measurement

A Konica Minolta chromameter (Model CR-410, Konica Minolta, Inc., Mahwah, NJ) was used to measure ice cream color. Each of the ice creams was measured three times in different positions and measurements were made in triplicate. Hunter L (whiteness), a (+a redness; -a, greenness), and b (+b yellowness; -b blueness) were used to calculate the color index based on illuminant A, an incandescent lamp. The following equation was used for the calculation of the color index (E) (Lu and others 2002)

$$\text{Color Index (E)} = (L^2 + a^2 + b^2)^{1/2}$$

3.3 DATA ANALYSIS

In this study, we were interested in determining the flavor profile in ice creams in order to get information for reformulating the flavoring for use with lower-fat ice cream. Mixed models of analysis of variance (ANOVA) were applied for the analysis of sensory

data to determine significant differences among the products at $P < 0.05$. Because each single replicate was finished before the next one was started, the replicate effect has a time interpretation. In addition, the full product factor is equal to the set of two main factors, one being ice cream type with five levels and the second being flavor formulation with six levels, and one two-factor interaction (leading altogether to thirty products). The main effects of ice cream type and flavor formulation and their interaction (product) were designated as fixed effects and assessor, replicate, assessor-product interaction, assessor-replicate interaction and product-replicate interaction were considered random (Brockhoff 2001). LSMEANS with a pdiff procedure (a pairwise t -test) and a macro for converting mean score to letter groupings in Proc Mixed developed by Saxton (1998) were used to determine if there were significant differences between products based on a p -value of 0.05 level of significance. Multivariate analysis of variance (MANOVA) using the Wilk's lambda statistic was used to determine if there was an overall significant difference among products when comparison was based on using all the dependent variables.

A principal component analysis (PCA) was performed on the covariance matrix of the mean values of thirty ice creams ($n=30$) for all sensory attributes. Pearson's correlation coefficient with the average ratings of the original attributes ($n=30$) also was calculated to aid interpretation of the individual PCs in terms of the original attributes. Stepwise selection with discriminant analysis of the mean data ($n=30$) was used to determine the critical attributes for variations among products. Canonical variate analysis (CVA) of the raw data ($n=30 \times 3 \times 12$) was conducted to analyze the descriptive data and used to map treatments and attributes in a data space.

Descriptive data were analyzed using the SAS statistical software 8.2 version (SAS Institute, Cary, NC, USA) and the graphs were drawn using Microsoft EXCEL 2003 (Microsoft Inc., WA, USA). All SAS programs used are shown in Appendix G. Data from the instrumental analysis was analyzed by the GLM procedure in SAS with the LSD mean separation option to determine if there were significant differences at $P < 0.05$.

Table 3-1. Ice cream formulation per 100g basis for 10% and 4% ice cream with or without fat mimetics

Product Ingredient	10%	4%			
	Regular	Regular	Litesse [®] (L) ^g	Simplese [®] (S) ^h	Litesse [®] / Simplese [®]
Nonfat Dry milk (0% fat; 97%NFMS) ^a	6	6.4	6.4	6.4	6.4
Skim milk (0% fat; 8.25% NFMS) ^b	44.9	55.6	55.6	55.6	55.6
Cream (35% fat; 5.5% NFMS) ^c	28.6	11.5	11.5	11.5	11.5
Cane Sugar (100% Total Solids) ^d	12.0	12.0	12.0	12.0	12.0
Corn Syrup (80% Total Solids) ^e	8.0	8.0	8.0	8.0	8.0
Stabilizer ^f	0.5	0.5	0.5	0.5	0.5
Water	0	6	0	0	0
Fat replacer	---	---	6	6	3/3
Total Milk Fat	10.01	4.025	4.025	4.025	4.025
Total Non-fat Milk Solids (NFMS)	11.1	11.1	11.1	11.1	11.1
Total Solids	40.05	34.05	40.05	40.05	40.05

^a Nonfat dry milk (Dairy America, Inc., CA): Spray process grade A nonfat dry milk made by pasteurized milk

^b Skim milk (Prairie Farms Dairy, Prairie Farms Inc., IL)

^c Cream (Prairie Farms Dairy, Inc., IL) Heavy whipping cream

^d Cane sugar (United States Sugar Corporation, DL) Pure cane sugar

^e Corn Syrup (Cargill Incorporated, MO) Clear sweet 36/48 corn syrup

^f Stabilizer (Opta Food Ingredient Inc., MA) Nonfat ice cream stabilizer #19

The composition of Stabilizer /emulsifier 19 is whey protein, microcrystalline cellulose, sodium carboxyl-methyl cellulose, mono-, di-glycerides, carrageenan maltodextrin and polysorbate 80.

^g Litesse[®] (Danisco Cultor, America) Improved polydextrose powder.

^h Simplese[®] (CP Kelco, San Diego, CA) Microparticulated whey protein concentrate 53 (53 grams retained on the sieve while Simplese[®] was heat treated).

Table 3-2. Flavor formulation for 10% and 4% ice creams with or without fat mimetics

Flavoring Formulation	Compound (g/100g)				
	<i>cis</i> 3-Hexeno-1-ol (CH)	Ethyl-3-methyl-3-phenylglycidate (EMP)	Furaneol™ (FUR)	γ-Undecalactone (GU)	α-Ionone (AI)
All flavor (100% Control)	0.375	3.750	1.875	0.500	0.375
<i>cis</i> 3-Hexeno-1-ol (200% Spike - CH2)	0.750	3.750	1.875	0.500	0.375
Ethyl-3-methyl-3-phenylglycidate (200% Spike - EMP2)	0.375	7.500	1.875	0.500	0.375
Furaneol™ (200% Spike - FUR2)	0.375	3.750	3.750	0.500	0.375
γ-Undecalactone (200% Spike - GU2)	0.375	3.750	1.875	1.000	0.375
α-Ionone (200% Spike - AI2)	0.375	3.750	1.875	0.500	0.750

Propylene glycol was added to all flavor formulations to a total weight of 100 g/bottle.

■ 200% of the spiked flavor compounds ■ 100% of the spiked flavor compounds

Table 3-3. Attribute reference and definition for descriptive panel

Attribute		Definition / Direction	Reference
	Pink color Dense	Light pink to dark pink under white light. Degree of the sample holding together as being scraped off	0.08 % strawberry red solution of skim milk
	Rate of melt	The seconds to melt a spoonful of ice cream in the mouth while rubbing it gently against the roof of the mouth with the tongue	
Flavor	Sweetness	Taste on the tongue elicited by sugars or other high potency sweeteners	20% (w/v) sugar solution
	Strawberry flavor	The intensity or strength of strawberry flavor during mastication	Strawberry syrup
	Candy flavor	The intensity of candy flavor	0.0014% candy flavored in 10% ice cream
	Cooked sugar flavor	The intensity of cooked sugar flavor	0.0007% furaneol TM in 10% ice cream
	Grassy flavor	The intensity of grassy flavor as reference	0.00014% <i>cis</i> -3-hexan1-ol in 4 % ice cream
	Violet flavor	The intensity of violet flavor as reference	1.86x 10 ⁻⁴ % α -ionone in 4 % ice cream
	Peach flavor	The intensity of peach flavor as reference	0.00014% γ -undecalactone in 4 % ice cream
	Milky flavor Condensed milk	The intensity of whole milk flavor as reference The intensity of condensed milk as reference	Whole milk Carnation [®] Condensed milk
Texture	Coldness	A chilling of the tongue and palate soon after the sample is placed in the mouth	
	Thickness	Degree of thickness of the ice cream after melting in mouth	Heavy whipping cream
	Smoothness	The force necessary to compress sample against the roof of the mouth	Pudding
	Creaminess	Degree of fat-like, full-bodies liquids after melting in mouth	Heavy whipping cream
	Mouth coating	Degree of fatty mouth or coated mouth after swallowing	Philadelphia Double Cream Cheese
Aftertaste	Sweet aftertaste	The intensity of sugar taste residue after swallowing	The same reference with sweetness
	Strawberry aftertaste	The intensity of strawberry flavor residue after swallowing	The same reference with strawberry flavor
	Candy aftertaste	The intensity of candy flavor residue after swallowing	The same reference with candy flavor
	Grassy aftertaste	The intensity of grassy flavor residue after swallowing	The same reference with glassy flavor
	Cooked sugar aftertaste	The intensity of cooked sugar flavor after swallowing	The same reference with cooked sugar flavor
	Violet aftertaste	The intensity of violet flavor residue after swallowing	The same reference with violet flavor
	Peach aftertaste	The intensity of peach flavor residue after swallowing	The same reference with peach flavor
	Milky aftertaste Astringency	The intensity of coating mouth after swallowing The intensity of dry mouth after swallowing	The same reference with milky flavor 1 bag brewed tea in 250 ml hot water

3.4. RESULTS AND DISCUSSION

3.4.1 Analysis of Variance (ANOVA)

Analysis of variance (ANOVA) is commonly used to analyze sensory data. However, many research papers ignored or only briefly mention the model of the analysis of variance that was used (Steinsholt 1998). There are two main models of ANOVA: 1. The fixed model in which assessors are considered a fixed effect and the 2. Mixed model in which assessors are a random effect. Whether subjects are to be regarded as random or fixed effects depends on whether or not the conclusions need to be extended beyond the panelists to the population from which the assessors were drawn (Carlucci and Monteleone 2001)

O'Mahony (1998) indicated that whether subjects are to be regarded as random or fixed effects depends on whether or not conclusions need to be extended beyond the panelists tested to the population from which the assessors were drawn. Because sensory analysis is always concerned with the product's descriptions, the ideal situation about food products must be valid in the sense that the results have to be the same when redoing the experiment with a new panel. Therefore, the judges ought to be considered as random effects and the mixed model should be used. On the other hand, judges are never truly randomly sampled, but they met the criteria of being a sample of a larger population of potential judges and of not being available for subsequent replications. Also, each treatment effect such as ice cream type and flavor included not only the differences among treatments and random error but also the interaction of each judge with the treatment variable (Lawless and Heymann 1998). Treating panelists as random allows for more flexibility. The result can be reproduced statistically because the main effect of products with the interaction is compared (Quinion-Rose 1998).

As stated previously, in this study, we were interested in determining the flavor

profile in ice creams in order to get information for reformulating the flavoring for use with lower-fat ice cream. The ninety batches of ice cream were produced in random order and then twelve trained judges were used for the evaluation of the products. Several sessions were needed to go through all the products, and all sessions necessary for a single replicate were carried out before the next replications was started. Therefore, the replicate effect has a time interpretation. The general analysis of variance model (a mixed model) for a sensory evaluation is suggested as the following equation (Brockhoff 2001)

$$X_{ijk} = \mu + \beta_j + D_i + G_k + (D\beta)_{ij} + (DG)_{ik} + (G\beta)_{jk} + \varepsilon_{ijk}$$

Where $\varepsilon_{ijk} \sim N(0, \sigma^2_E)$ and independent

β_j : the main effect of Products, D_i : Judge effect, G_k : Replicate effect

$D\beta_{ij}$: Judge by Product effect, DG_{ik} : Judge by Replicate effect,

$G\beta_{jk}$ Product by Replicate effect

The random assumption can be expressed as

$$D_i \sim N(0, \sigma^2_J)$$

$$G_k \sim N(0, \sigma^2_R)$$

$$D\beta_{ij} \sim N(0, \sigma^2_{JP})$$

$$DG_{ik} \sim N(0, \sigma^2_{JR})$$

$$G\beta_{jk} \sim N(0, \sigma^2_{PR})$$

$$\varepsilon_{ijk} \sim N(0, \sigma^2_E)$$

The main effect of product is a fixed model and all the remaining effects are considered random. That all these effects are considered as random effects essentially stems from the assumption that the replicate and the assessor effects are considered random.

Ice cream products were composed of ice cream type (I) with five levels and flavor formulation (F) with six levels. Thus, there are three product factors: ice cream type, flavor formulation and their interaction. The mixed model analysis was carried out in SAS as shown in Appendix G.

Results in Table 3-4 show that ice cream type had a significant effect ($P < 0.05$) on pink color, cooked sugar flavor, violet flavor, peach flavor, milky flavor, condensed milk flavor, coldness, smoothness, thickness, creaminess, mouth coating), sweet aftertaste, violet flavor aftertaste, peach flavor aftertaste, cooked sugar flavor aftertaste and milky flavor aftertaste. Flavor formulation showed a significant effect ($P < 0.05$) on cooked sugar flavor, violet flavor, violet flavor aftertaste and peach flavor aftertaste. There were no significant differences for any of the attributes for the interaction of ice cream type with flavor formulation.

Table 3-5 shows the mean intensities of the sensory attributes for ice cream with or without fat mimetics (Litesse[®], Simplesse[®] and Litesse[®] and Simplesse[®] mix (L/S mix). The 10% ice cream and 4% ice cream with Litesse[®] had a lighter pink color than the 4% ice cream and the 4% ice cream with Simplesse[®] or the L/S mix. The 4% ice cream without any fat mimetic had the darkest pink color. The rate of melting for the five ice creams showed no significant differences.

In regard to flavor attributes, ice creams with fat mimetics were slightly sweeter than 4% ice cream or 10% ice cream, although there were no significant differences. In other words, the fat mimetic products had significantly sweeter aftertaste than ice cream without fat mimetics. The reason for this slight increase in sweetness could be due to a positive correlation between sweetness and cooked sugar flavor (Table 3-10). The 10% ice cream and the 4% ice creams with fat mimetics were perceived slightly stronger in strawberry flavor and strawberry aftertaste compared with 4% ice cream, although there

were no significant differences. This is in agreement with the results of Linna (2001).

In milky flavor, 10% ice cream had a significantly higher intensity than 4% ice cream with or without fat mimetics. As for milky aftertaste, 4% ice cream with Simplese[®] was not significantly different from 10% ice cream. Ice cream with Simplese[®] and L/S mix had significantly higher scores in condensed milk flavor than 10% ice cream. The Litesse[®] product had the lowest intensity in condensed milk flavor, although there were no significant differences compared with ice creams without fat mimetics. In addition, among these products, the Simplese[®] products had the strongest astringency, and 4% ice cream and 4% ice cream with Litesse[®] had lower astringency than 10% ice cream, although there were no significant differences among them.

In studying the perception of the five favoring compounds in ice cream products, *cis*-3-hexen-1-ol (grassy flavor) and ethyl-3-methyl-3-phenylglycidate (candy flavor) did not show significant differences between 10% ice cream and 4% ice cream with or without fat mimetics. Furaneol[™] was perceived stronger in 10% ice cream, while α -ionone and γ -undecalactone were perceived strongest in 4% ice cream. For furaneol[™] (cooked sugar), the 4% ice creams with fat mimetics were not significantly different from the 10% ice cream but the Simplese[®] sample had a higher intensity than the Litesse[®] sample or the 10% fat ice cream. However, for cooked sugar aftertaste, the 10% ice cream seems to have stronger cooked sugar intensity compared with the Simplese[®] products. On the other hand, there were significant differences in perception of α -ionone in 4% ice cream with or without fat mimetics compared to that of 10% ice cream, but no significant differences were perceived amongst the low-fat ice creams, although ice cream with Litesse[®] had a higher intensity in α -ionone than the ice cream with Simplese[®]. The perception of γ -undecalactone in 10% ice cream and ice cream with Simplese[®] was significantly lower than that in 4% ice cream with Litesse[®] or L/S

mix.

In regard to texture attributes, 4% ice cream had the highest intensity in coldness, and the full-fat ice cream had the lowest intensity. Ice cream with Litesse[®] was not significantly different from 10% ice cream, while both ice creams containing Simplesse[®] and L/S mix, were not significant different in coldness from the 4% ice cream. Smoothness, creaminess and mouth coating had higher intensities in 10% fat ice cream than in 4% ice creams with or without fat mimetics. In addition, there were no significant differences among ice creams with fat mimetics in the intensity of smoothness, creaminess and mouth coating. Creaminess, a highly desirable attribute in ice cream, is contributed by milk fat. Ice creams with Litesse[®] and L/S mix were not significantly different in creaminess from 10% ice cream and had higher creaminess intensities than ice cream with Simplesse[®]. As for thickness, there were no significant differences between 10% ice cream and 4% ice creams with fat mimetics, but ice cream with Simplesse[®] was clearly thicker than 10% ice cream and 4% ice cream with Litesse[®] and L/S mix.

Table 3-6 shows the effect of the six different flavor formulations on the mean values of the attributes. The spiking of furaneolTM showed slightly increased sweetness and its aftertaste, although flavor formulation did not have a significant effect on sweetness and sweet aftertaste. The spiking of furaneolTM significantly increased the intensity of cooked sugar flavor but yielded no significant increase in cooked sugar aftertaste. The spiking of α -ionone and γ -undecalactone significantly increased the intensity of the corresponding attributes, violet, peach flavor and peach flavor aftertaste. Similarly, the attribute candy flavor aftertaste was significantly increased by the ethyl-3-methyl-3-phenylglycidate spike but it was also reflected in candy flavor intensity. The grassy flavor aftertaste was reflective of the *cis*-3-hexen-1-ol spike, but it

was not significantly different from the control formulation. In addition, the spiking of *cis*-3-hexen-1-ol and γ -undecalactone also significantly increased the perception of violet flavor and violet flavor aftertaste compared to control. While there was also an increase in violet flavor and violet flavor aftertaste for the spikes of furaneolTM or ethyl-3-methyl-3-phenylglycidate, they were not significantly different from the control or *cis*-3-hexen-1-ol and γ -undecalactone spikes. Although violet flavor and violet flavor aftertaste were not raised to the level perceived when α -ionone was spiked, it seems that the two flavor attributes, which are derived from the α -ionone in the flavoring formulation, are synergistically enhanced by the spiking of any of the other flavorings, with *cis*-3-hexen-1-ol and γ -undecalactone significantly increasing the perception of these two attributes above that seen for the control (100% spiked for the five flavor compounds).

My results for pink color intensity between 10% ice cream and 4% ice cream with or without fat mimetics are in agreement with the studies of Roland and others (1999). The primary reason for the darker color in lower-fat ice cream without fat mimetics is the reduction of fat content. The white color of the milk fat lightens the color (Phillips and others 1995). However, Kailasapathy and Songvanish (1998) evaluated the characteristics of ice cream with fat mimetics and indicated that samples with Simplese[®] had a significantly lower score (10= very yellow and 1= very white) which means they were lighter in color than the full-fat ice cream. These results do not match the results in this study for ice creams made with Simplese[®].

Ohmes and others (1998) also reported that ice cream with Simplese[®] was not different in rate of melting compared with ice cream made by non fat milk solids and milk fat using sensory test. In addition, Chung (2002) indicated that ice cream with Simplese[®] had a higher melt rate than ice cream with Liteesse[®], which is in agreement

with my results. The high viscosity properties of fat mimetic in ice cream are responsible for the slow rate of melting (Adapa and others 2000; Ohmes and others 1998). In my case, melting rate and viscosity showed significant positive correlation (Pearson coefficient: 0.916 p=0.029). Li and others (1997) showed 10% ice cream melted more slowly than 4% ice cream as determined by a physical method. In theory, high-fat ice cream would be expected to melt more slowly than would low-fat ice cream containing similar amounts of total solids, stabilizer and emulsifier because milk fat slows the rate of heat transfer. Slower perceived melt rate for high-fat ice creams has been confirmed by descriptive analysis, time intensity analysis and physical methods (Stampanoni Koeferli and others 1996; Roland and others 1999; Chung 2000; Frøst and others 2005). Yislay and others (2006) found that regular fat ice cream melted slowly in the mouth but there were no significant differences among low-fat or fat-free ice creams with or without Simplesse[®]. My result showed that there were no significant differences between high-fat (10%) and low-fat (4%) ice cream. Guinard and others (1997) measured the melt rate by a physical method and concluded there was an interaction between sugar and fat on the effect of melting rate, indicating a higher sugar level (18%) with an increase of fat content only caused a minor increase in melting rate. In our experiment, the ice cream contained 12% sucrose and 8% high fructose corn syrup, which increased the viscosity of the melted ice creams influencing the melting rate of low-fat ice cream.

Roland and others (1999) also found that ice cream with Litesse[®] and maltodextrin was sweeter than the 10% ice cream, but the sweetness of ice cream with fat mimetics did not differ significantly. Chung (2002) compared different fat ice creams without or with Litesse[®] or Simplesse[®] and found that the Simplesse[®] sample tended to be sweeter than other ice creams. Yilsay and others (2006) reported no

significant differences between ice cream with Simplese[®] and regular/low fat ice cream. My result also showed ice cream with Simplese[®] was sweeter than other ice creams, although there were no significant differences among them.

Loeb (2004) demonstrated that milky flavor, condensed milk flavor, and milky flavor aftertaste are all perceived significantly higher in 10% ice cream than in 4% ice creams. Chung (2002) also indicated that there was a tendency that the condensed milk attribute is enhanced by an increase in fat level of ice cream. Several studies also concluded that ice cream with Simplese[®] had a significantly stronger intensity in cooked milk flavor and a weaker fresh milk flavor than did ice cream containing milk fat (Ohmes and others 1998; Chung 2002). My results are in agreement with these conclusions.

Ohmes and others (1998) also found that vanillin-flavored ice cream with Simplese[®] had a stronger astringent taste than vanilla ice cream made with milk fat, but Prindiville (2000) indicated that chocolate-flavored 2.5% fat ice cream made with Simplese[®] had lower astringency than 2.5% ice cream without a fat mimetic. By reviewing other studies, Krueel (2004) reported fat-free strawberry flavored ice cream had higher intensity in astringency than low-fat and full-fat ice cream, and the 4% ice cream had a higher astringency than the 10% ice cream, although there were no significant differences between low-fat and full-fat ice creams (Krueel 2004). In addition, the study also reported 4% ice cream with Litesse[®] had a higher astringency than the 10% ice cream, although differences were not significant. Although that tendency disagrees with my research, the differences in flavor composition and other ingredients might be the reason for these differences.

Among the five compounds, both furaneol[™] and *cis*-3-hexen-1-ol, being soluble in water, are highly polar compounds, whereas ethyl-3-methyl-3-phenylglycidate

and α -ionone are nonpolar compounds. These results seem to show a positive correlation of intensity of perception with the polarity of the compounds. In other words, the lipophilic compounds have a strong intensity in lower-fat ice creams because the flavor release is suppressed by fat. Clearly, fat and fat mimetics have significant interactions with furaneolTM, α -ionone and γ -undecalactone. Fat mimetics used in the studies improved the perception of furaneolTM in low-fat ice cream to be similar to that in full-fat ice cream. Simplese[®] had a stronger binding ability with *cis*-3-hexen-1-ol, γ -undecalactone and α -ionone than Litesse[®] in ice cream. In addition, for ice cream with the L/S mix, it is interesting that the grassy flavor and peach flavor were more similar to that of the Litesse[®] sample. The reasons could involve the stereochemistry of the molecule, the solubility with fat and differences in reaction rate of the flavor chemicals with Litesse[®] and Simplese[®].

Previous studies in our lab were conducted to determine the sensory thresholds and flavor release of the five compounds from 0%, 4% and 10% fat emulsions (Gaddamu 2003), as well as the perceptions of the five compounds in 4% and 10% ice creams and ice cream mixes using chromatographic methods and descriptive analysis (Loeb, 2004). In the fat emulsion systems, flavor release of α -ionone, γ -undecalactone, *cis*-3-hexen-1-ol and ethyl-3-methyl-3-phenylglycidate decreased with the increase of fat content in the sample matrix, although it was not significant for α -ionone and γ -undecalactone, while the release of furaneolTM was not affected by fat content (Gaddamu 2003). Loeb's studies (2004), using descriptive analysis, found ethyl-3-methyl-3-phenylglycidate and furaneolTM were perceived stronger in 10% ice cream and α -ionone and γ -undecalactone were perceived strongest in 4% ice cream. However, my study indicated ethyl-3-methyl-3-phenylglycidate had a slightly higher intensity in 4% ice cream than in 10% ice cream, although there were no significant

differences between the two ice creams.

From the viewpoint of molecular polarity, it is logical that ethyl-3-methyl-3-phenylglycidate, a non-polar molecule, has a higher release from a low-fat than a full-fat environment. In addition, ethyl-3-methyl-3-phenylglycidate is an ester compound. Reiners and others (2000) indicated that the increase in the hydrophobic chain length for ester compounds increases the binding constant with protein. A possible interaction of ethyl-3-methyl-3-phenylglycidate with Simplese[®] might explain why there is no difference in release of ethyl-3-methyl-3-phenylglycidate from the 4% ice cream with Simplese[®] compared to the 10% ice cream, even though the polarity of ethyl-3-methyl-3-phenylglycidate would suggest a higher release in all 4% ice creams.

The protein-based fat mimetics, such as Simplese[®] 100, had more interactions with flavor compounds, such as aldehydes and ketones than did carbohydrate-based fat mimetics, due their characteristics of providing binding sites for hydrophobic flavor volatiles (Schirle-Keller and others 1994; Hatchwell 1994; Marshall and Arbuckle 1996). This retention may cause a significant decrease in the odor perception (Guichard and Langourieux 2000). It could explain partially why the Simplese[®] samples had lower intensity in peach flavor and violet flavor than the Litesse[®] sample. In general, hydrophobic compounds may bind into the hydrophobic pocket of the protein by hydrophobic interactions although the structural feature of a molecule might influence the binding (Guichard and Langourieux 2000). In other words, food with protein-based fat mimetics should be more similar to the characteristics of fat-containing products in flavor profile than would those with carbohydrate-based mimetics. My results also showed that the 4% ice cream with Simplese[®] had a more similar flavor profile to that of the 10% ice cream than did the 4% ice cream with Litesse[®]. Schirle-Keller (1992)

indicated that Simplese[®]100 interacts with flavor compounds more like fat does than any other fat replacers. In part that is due to a small percentage of fat (1.72%) contained in Simplese[®]. On the other side, proteins also interact with flavor compounds. For example, derivatives of furaneol[™], such as ethyl furaneol[™], that contain a longer hydrophobic side chain would be more hydrophobic, increasing the binding constants, and this would allow furanone based flavor chemicals to have increased interaction with protein (Reiners and others 2000). In other words, proteins have very weak interactions with furaneol[™] due to the polarity of the furanone ring combined with the few short hydrophobic side chains (Reiners and others 2000).

Miettinen and others (1999) observed that the increase of fat levels from 0% to 9% or 18% in strawberry ice cream significantly increased the concentration of *cis*-3-hexen-1-ol in the headspace of the samples, demonstrating an effect of fat on the headspace concentration of *cis*-3-hexen-1-ol. De Roos and Woiswinkel (1994) reported perception of *cis*-3-hexen-1-ol ortho- and retro-nasally was similar for water and milk solutions, indicating less influence of fat on its release and sensory perception, than on its headspace concentration. In a later study, Miettinen and others (2002) determined the aroma differences among five strawberry ice creams of varying fat content (0%, 9% or 18% dairy or vegetable fat) using static headspace gas chromatography and reported the headspace content of *cis*-3-hexen-1-ol was not significantly different between 9% and 18% dairy fat or 9% and 18% vegetable fat, but there were significant differences between the nonfat sample and the sample containing dairy fat. Fabre and others (2002) indicated that *cis*-3-hexen-1-ol had low affinity to proteins, and there were no significant differences for *cis*-3-hexen-1-ol release in five protein solutions and five different emulsions. In addition, Mei and others (2004) indicated that the aroma release of *cis*-3-hexen-1-ol could be suppressed by sweeteners, with 55DE high-fructose corn

syrup having the greatest effect. The above-mentioned studies could be partial explanations why there were no significant differences in this study for grassy flavor.

De Roos (1997) demonstrated that α -ionone is a lipophilic flavor chemical, and its release rate was greatly influenced by the presence of as low as 1% fat. FuraneolTM is soluble in water, and Buettner and Schieberle (2000) showed a significant increase in the odor threshold of furaneolTM in the presence of butane-2,3-dione or (Z)-hex-3-enal in water, indicating that furaneolTM could be masked in the presence of other compounds. A similar result was shown for the retronasal perception of strawberry aroma after-smell from different matrices by Buettner and Mestres (2005), which can explain why some odor impressions, such as peach and flowery might have covered to some extent the caramel (furaneolTM) sensory impressions. Additionally, the orthonasal and the retronasal threshold values of furaneolTM in oil were 25 ppb and 4 ppb, respectively, which means the mouth's environment increases the release of furaneolTM from the oil to the odor receptors (Rychlik and others 1998).

Roland and others (1999) indicated that icy mouthfeel (coldness) is greater in low-fat ice creams, and Aime and others (2001) stated that perception of coldness is expected to be lower in the higher fat ice cream. The increased water content in the low-fat ice cream, which is available to form larger ice particles, has been cited as the possible mechanism (Bodyfelt and others 1988). Ice cream with Litesse[®] exhibited low coldness intensity partly because carbohydrate-based fat mimetics have a high capacity of holding water in ice cream. However, the water holding capacity of carbohydrate-based fat mimetics could have been lost when Litesse[®] and Simplese[®] were mixed in the ice cream. Kailasapathy and Songvanich (1998) showed that a reduced fat ice cream with Simplese[®], which contained the highest total solids, had a lower score in iciness than the full-fat (13%) ice cream. Marshall and Arbuckle (1996)

stated a high total solids content inhibits ice crystal growth and results in a smoother texture for ice creams. In this study, the ice creams with fat mimetics and full-fat ice cream had the same percent total solids. Thus, Litesse[®] clearly was better able to mimic the fat for inhibiting icy crystal growth.

Conforti (1994) indicated that replacing 50% of the sucrose in vanilla ice cream with high fructose corn syrup resulted in a smooth texture along with increased fat level. In this study, the formulation of the five ice creams contained 12% sucrose and 8% high fructose corn syrup. In other words, high fruit corn syrup, fat content and fat mimetics have an influence on the perception of smoothness. It is interesting that the L/S mix products had higher intensities for the three attributes than the Litesse[®] or Simplese[®] products. Clearly, there was a synergistic effect of the two different fat mimetics to improve smoothness, creaminess and mouth coating when mixed together. Ohmes and others (1998) reported ice cream made with Simplese[®] was scored lower in smoothness, mouth coating than ice cream containing milk fat, but there were no significant differences. My results are in agreement with Ohmes' conclusion. The fat content in ice cream was strongly correlated to smoothness, creaminess and mouth coating due to interaction between milk fat and other ingredients (Yilsay and others 2006). In addition, non-fat milk solids also caused an increase in creaminess and mouth coating (Stampanoni Koeferli and others 1996). Protein-based and carbohydrate-based fat mimetics displayed a high degree of mouth coating in ice cream due to highly viscous properties (Ohmes and others 1998; Adapa and others 2000). In addition, Aime and others (2001) indicated that the type of mouth coating between regular fat and reduced fat ice cream is likely to be different.

The particle size of fat mimetics is an important determinant of texture and mouthfeel of foods (Ohmes and others 1998). For example, Simplese[®] is a

microparticulated protein producing particles ranging from 0.1-3 μm in diameter. Bringe and Clark (1993) reported that particle sizes from 0.1 to 2 μm impart a creamy sensation but particles larger than 3 μm cause powdery or gritty mouthfeel.

Chung (2002) indicated that low-fat ice cream made with Simplese[®] performed better than low-fat ice cream with Litesee[®] in improving stickiness and thickness of ice cream due to its microparticulated properties. Yilsay and others (2006) found no significant differences between regular ice creams and ice cream with Simplese[®].

In summary, Simplese[®] is a better choice for reformulating the flavoring of ice cream than Litesee[®] or L/S mixes because it yields properties more similar to those of 10% ice creams.

Table 3-4. Summary of mixed-ANOVA of ice cream and flavor formulation effects for each attribute measure

Attribute		SV ^a	Num DF	Den DF	F-Ratio ^b	Attribute		SV	Num DF	Den DF	F-Ratio
Appearance	Pink color	F	5	68.2	2.27	Texture	Coldness	F	5	118	0.86
		I	4	68.2	8.63***			I	4	118	4.91**
		FxI	20	68.2	1.15			FxI	20	118	0.73
	Dense	F	5	319	0.82		Smoothness	F	5	65	1.62
		I	4	319	1.83			I	4	65	9.16***
		FxI	20	319	0.92			FxI	20	65	1.09
Rate of Melt		F	5	52.8	0.14		Thickness	F	5	69.3	0.08
		I	4	52.8	1.29			I	4	69.3	4.93**
		FxI	20	52.8	0.99			FxI	20	69.3	1.11
Flavor	Sweet	F	5	83.8	1.22		Creaminess	F	5	75.8	0.7
		I	4	83.8	1.85			I	4	75.8	15.49***
		FxI	20	83.8	1.03			FxI	20	75.8	0.82
	Strawberry	F	5	319	1.05	Mouth coating	F	5	78.5	0.38	
		I	4	319	0.59		I	4	78.5	11.27***	
		FxI	20	319	0.61		FxI	20	78.5	0.48	
	Candy	F	5	63.2	1.38	Aftertaste	Sweet aftertaste	F	5	319	1
		I	4	63.2	0.37			I	4	319	5.8**
		FxI	20	63.2	1.31			FxI	20	319	0.92
	Cooked sugar	F	5	58.3	2.82*		Strawberry aftertaste	F	5	60.8	0.47
		I	4	58.3	6.1**			I	4	60.8	0.89
		FxI	20	58.3	1.34			FxI	20	60.8	0.9
	Grassy	F	5	59.1	1.23		Candy aftertaste	F	5	58	1.69
		I	4	59.1	1.29			I	4	58	0.83
		FxI	20	59.1	0.58			FxI	20	58	0.58
	Violet	F	5	67.2	4.52**		Grassy aftertaste	F	5	63.6	1.15
		I	4	67.2	3.93**			I	4	63.6	0.6
		FxI	20	67.2	0.6			FxI	20	63.6	0.79
	Peach	F	5	81	1.76	Violet aftertaste	F	5	66.3	4.29**	
		I	4	81	4.79**		I	4	66.3	4.38**	
		FxI	20	81	0.58		FxI	20	66.3	1.11	
	Milky	F	5	319	0.53	Peach aftertaste	F	5	85.5	3.26**	
		I	4	319	5.15**		I	4	85.5	3.82**	
		FxI	20	319	0.64		FxI	20	85.5	0.84	
Condensed milk	F	5	67.9	0.03	Cooked sugar aftertaste	F	5	58	0.61		
	I	4	67.9	8.47***		I	4	58	5.73**		
	FxI	20	67.9	0.65		FxI	20	58	1.02		
^a SV: Source of Variation F: Flavor formulation I: Ice cream ^b * ** *** Significant at P<0.05, 0.01, and 0.001, respectively						Astringency	F	5	54.1	0.13	
							I	4	54.1	1.97	
							FxI	20	54.1	1.1	
						Milky aftertaste	F	5	1015	1.05	
							I	4	1015	10.54***	
							FxI	20	1015	0.96	

Table 3-5. The mean values of attributes for the ice cream with or without fat mimetics

Ice cream		10% ice cream	4% ice cream			
			Original	Original	Litesse®	Simplese®
Attribute						
	Pink color	6.18±2.92 ^c	7.44±3.01 ^a	5.99±2.72 ^c	7.09±2.78 ^{ab}	6.81±3.03 ^b
	Dense	7.89±3.38 ^a	7.46±3.39 ^b	7.78±3.44 ^{ab}	7.90±3.46 ^a	7.85±3.52 ^a
Rate of Melting		14.25±7.05 ^{ab}	14.15±6.89 ^{ab}	14.10±6.52 ^b	14.77±6.66 ^a	14.36±6.61 ^{ab}
Flavor	Sweetness	7.51±3.06 ^{ab}	7.50±2.99 ^b	7.69±2.86 ^{ab}	7.92±2.92 ^a	7.89±2.99 ^{ab}
	Strawberry	5.30±2.64 ^a	5.08±2.52 ^a	5.29±2.42 ^a	5.26±2.62 ^a	5.23±2.61 ^a
	Candy	4.78±2.92 ^a	4.98±2.89 ^a	4.98±2.92 ^a	4.95±2.90 ^a	4.99±3.05 ^a
	Grassy	2.71±2.74 ^a	2.75±2.63 ^a	3.05±2.86 ^a	2.74±2.63 ^a	3.06±2.96 ^a
	Cooked sugar	4.85±2.93 ^{ab}	4.16±2.94 ^c	4.60±2.92 ^b	5.06±3.10 ^a	4.86±3.05 ^{ab}
	Violet	3.40±3.02 ^b	3.92±3.00 ^a	4.20±3.16 ^a	3.86±3.11 ^a	4.01±3.19 ^a
	Peach	3.68±2.91 ^c	4.43±3.07 ^{ab}	4.40±3.01 ^{ab}	3.97±3.19 ^{bc}	4.54±2.95 ^a
	Milky	5.73±2.70 ^a	5.07±2.80 ^b	5.11±2.75 ^b	5.21±2.64 ^b	5.09±2.73 ^b
	Condensed milk	3.30±2.66 ^{bc}	3.15±2.62 ^c	3.08±2.54 ^c	3.99±2.94 ^a	3.58±2.75 ^{ab}
Texture	Coldness	8.76±2.60 ^b	9.67±2.13 ^a	8.85±2.50 ^b	9.39±2.18 ^a	9.39±2.10 ^a
	Thickness	6.51±2.47 ^{ab}	5.91±2.45 ^c	6.23±2.52 ^{bc}	6.71±2.54 ^a	6.47±2.60 ^{ab}
	Smoothness	7.05±2.73 ^a	5.85±2.86 ^b	6.71±2.81 ^a	6.71±2.77 ^a	6.89±2.75 ^a
	Creaminess	7.06±2.62 ^a	5.73±2.94 ^c	6.72±2.78 ^{ab}	6.61±2.81 ^b	6.87±2.83 ^{ab}
	Mouth coating	5.38±2.56 ^a	4.11±2.32 ^c	4.86±2.40 ^b	5.09±2.57 ^{ab}	5.11±2.65 ^{ab}
Aftertaste	Sweet aftertaste	4.17±2.58 ^b	4.23±2.59 ^b	4.54±2.78 ^a	4.75±2.87 ^a	4.71±2.73 ^a
	Straw. aftertaste	4.03±2.66 ^a	4.10±2.59 ^a	4.02±2.57 ^a	4.18±2.72 ^a	4.25±2.66 ^a
	Candy aftertaste	3.46±2.85 ^a	3.69±2.82 ^a	3.66±2.79 ^a	3.64±2.79 ^a	3.78±2.89 ^a
	Grassy aftertaste	2.29±2.73 ^a	2.22±2.64 ^a	2.45±2.64 ^a	2.36±2.65 ^a	2.41±2.75 ^a
	Cooked sugar	3.82±2.83 ^a	3.13±2.60 ^c	3.46±2.85 ^b	3.70±2.83 ^{ab}	3.74±2.86 ^{ab}
	Violet aftertaste	2.41±2.65 ^b	2.94±2.76 ^a	3.03±2.94 ^a	3.09±3.07 ^a	3.02±3.00 ^a
	Peach aftertaste	2.75±2.65 ^b	3.39±3.00 ^a	3.16±2.73 ^b	3.04±2.88 ^{ab}	3.35±2.86 ^a
	Milky aftertaste	5.05±2.92 ^a	4.23±2.93 ^b	4.48±2.84 ^b	4.95±2.90 ^a	4.48±2.78 ^b
	Astringency	3.18±2.55 ^{ab}	2.90±2.29 ^b	2.94±2.45 ^b	3.39±2.72 ^a	3.16±2.53 ^{ab}

There are no significant differences at $p < 0.05$ among the samples with the same superscript letter.

Table 3-6. The mean values of attributes for ice cream at six different flavor formulations

Attribute \ Flavor		Flavor Compound					
		AI2	CH2	CO	EMP2	FUR2	GU2
	Pink Color	6.77±2.94 ^a	6.98±2.85 ^a	6.79±2.94 ^a	6.08±2.87 ^b	6.57±2.96 ^{ab}	7.01±3.01 ^a
	Dense	7.94±3.42 ^a	7.65±3.32 ^a	7.80±3.53 ^a	7.58±3.47 ^a	7.84±3.41 ^a	7.85±3.50 ^a
Rate of Melt		14.51±7.03 ^a	14.35±6.35 ^a	14.24±6.89 ^a	14.26±6.78 ^a	14.30±6.68 ^a	14.30±6.78 ^a
Flavor	Sweetness	7.62±2.99 ^{ab}	7.67±2.81 ^{ab}	7.74±3.00 ^{ab}	7.76±3.01 ^{ab}	7.99±3.00 ^a	7.44±2.99 ^b
	Strawberry	5.13±2.53 ^a	5.17±2.50 ^a	5.13±2.68 ^a	5.38±2.54 ^a	5.33±2.54 ^a	5.14±2.60 ^a
	Candy	4.97±2.88 ^{ab}	4.72±2.84 ^b	4.94±3.04 ^{ab}	5.21±2.96 ^a	4.73±2.89 ^b	5.04±3.00 ^{ab}
	Grassy	2.97±2.89 ^a	3.09±2.83 ^a	2.65±2.70 ^a	2.72±2.64 ^a	2.71±2.73 ^a	3.03±2.81 ^a
	Cooked Sugar	4.53±3.06 ^b	4.84±2.97 ^{ab}	4.72±2.96 ^b	4.46±2.91 ^b	5.15±3.07 ^a	4.55±3.00 ^b
	Violet	4.37±3.05 ^a	4.05±3.18 ^{ab}	3.36±2.88 ^c	3.76±3.02 ^{bc}	3.69±3.07 ^{bc}	4.05±3.33 ^{ab}
	Peach	4.21±3.09 ^{ab}	3.92±2.84 ^b	3.98±3.12 ^b	4.27±2.96 ^{ab}	4.28±2.97 ^{ab}	4.59±3.22 ^a
	Milky	5.28±2.74 ^a	5.19±2.82 ^a	5.20±2.77 ^a	5.27±2.73 ^a	5.40±2.78 ^a	5.11±2.59 ^a
	Condensed milk	3.46±2.70 ^a	3.41±2.80 ^a	3.44±2.74 ^a	3.42±2.83 ^a	3.40±2.60 ^a	3.39±2.69 ^a
Texture	Coldness	9.31±2.46 ^a	9.04±2.30 ^a	9.18±2.38 ^a	9.03±2.43 ^a	9.21±2.30 ^a	9.50±2.11 ^a
	Smoothness	6.39±2.86 ^b	6.66±2.77 ^{ab}	7.00±2.84 ^a	6.68±2.81 ^{ab}	6.46±2.78 ^b	6.65±2.81 ^{ab}
	Thickness	6.34±2.51 ^a	6.29±2.39 ^a	6.38±2.60 ^a	6.39±2.46 ^a	6.42±2.67 ^a	6.38±2.56 ^a
	Creaminess	6.41±2.83 ^a	6.69±2.72 ^a	6.73±2.85 ^a	6.49±2.96 ^a	6.64±2.82 ^a	6.63±2.83 ^a
	Mouth coating	4.91±2.64 ^a	4.90±2.46 ^a	4.75±2.43 ^a	4.91±2.58 ^a	5.06±2.58 ^a	4.91±2.55 ^a
Aftertaste	Sweet	4.54±2.78 ^{ab}	4.47±2.69 ^b	4.34±2.62 ^b	4.47±2.62 ^{ab}	4.68±2.87 ^a	4.38±2.73 ^{ab}
	Straw.	4.15±2.56 ^a	4.01±2.65 ^a	4.10±2.69 ^a	4.16±2.56 ^a	4.05±2.65 ^a	4.22±2.74 ^a
	Candy	3.61±2.74 ^{ab}	3.43±2.77 ^b	3.52±2.69 ^b	3.96±2.93 ^a	3.69±2.87 ^{ab}	3.67±2.94 ^{ab}
	Grassy	2.53±2.94 ^a	2.38±2.71 ^{ab}	2.10±2.57 ^b	2.35±2.59 ^{ab}	2.32±2.63 ^{ab}	2.40±2.62 ^{ab}
	Peach	3.12±2.82 ^{bc}	2.77±2.64 ^c	3.01±2.72 ^{bc}	3.30±2.73 ^{ab}	3.09±2.88 ^{bc}	3.54±2.93 ^a
	Violet	3.39±2.97 ^a	2.98±3.03 ^{ab}	2.49±2.67 ^c	2.75±2.88 ^{bc}	2.79±2.96 ^{bc}	2.99±2.93 ^{ab}
	Cooked Sugar	3.55±2.80 ^a	3.55±2.87 ^a	3.55±2.81 ^a	3.53±2.75 ^a	3.76±2.92 ^a	3.47±2.76 ^a
	Astringency	3.05±2.48 ^a	3.09±2.62 ^a	3.17±2.55 ^a	3.18±2.56 ^a	3.12±2.46 ^a	3.07±2.46 ^a
	Milky	4.52±2.85 ^{ab}	4.49±2.92 ^b	4.64±2.83 ^{ab}	4.70±2.95 ^{ab}	4.81±2.88 ^a	4.67±2.90 ^{ab}

There are no significant differences at $p < 0.05$ among the samples with the same superscript letter.

3.4.2. Color Analysis

Color differences among ice creams with or without fat mimetics (control samples) also were determined by instrumental analysis as shown in Table 3-7. The 4% ice creams with or without fat mimetics had a significantly lower L value than the full-fat ice cream, indicating low-fat ice creams were less white in comparison to that of the full-fat ice cream. The Litesse[®] product was whiter than the other low-fat ice creams and the Simplese[®] product was the darkest. The L/S mix products had the greatest redness (a score), although the products were not significantly different from each other. No significant differences ($P=0.0635$) were observed in the b value among samples either, although the L/S mix product had the highest score, and the 4% ice cream had the lowest value in yellowness. In comparison with the sensory results (Table 3-8), whiteness had a negative but non-significant correlation (Pearson coefficient -0.738) while yellowness and redness did not have any relationship with the pink color. In other words, whiteness plays an important role in determining the pink color intensity in ice creams. On the other hand, for example, the Simplese[®] and L/S mix products had a lower score in pink color than the 4% ice cream in the sensory analysis but they were less white and less yellow than 4% ice cream in the instrumental analysis. Interestingly, the yellowness and redness have a positive correlation (Pearson coefficient 0.686) and it could explain partially the intensity of pink color in ice cream with Simplese[®] and L/S mix. Lu and others (2002) used a color index to evaluate the color of taro ice products. In this study, the index was used and the results indicated that 10% ice cream had the highest color index and 4% ice cream with Litesse[®] had the lowest color index. The color index and the instrumental analysis may not correspond well with the sensory intensity scores for color. Roland and others (1999) also reported ice cream

products with fat mimetics and 10% ice cream had higher scores in yellowness than 0.1% ice cream.

Table 3-7. Color values (L,a,b) of ice cream without or with fat mimetics (control samples) reported as L,a,b

Sample		Value	L*	a*	b*	E
10%	Original		68.25 ^a	22.68 ^a	8.91 ^{ab}	^A 72.50
	Original		63.23 ^c	22.61 ^a	7.79 ^b	^{BC} 67.61
4% ice cream	Litesse [®]		65.54 ^b	21.07 ^a	8.07 ^b	^C 65.14
	Simplese [®]		60.87 ^d	21.41 ^a	8.91 ^{ab}	^{BC} 67.40
	L/S mix		61.97 ^{cd}	24.47 ^a	9.99 ^a	^B 69.32

L = black (0) to white (100), a= green(-) to red (+), b= blue (-) to yellow (+)

Color Index (E)=(L²+a²+b²)^{1/2}

There are no significant differences at p<0.05 among the samples (n=3) with the same superscript letter.

Table 3-8. Pearson coefficients of instrumental parameters (L a b value) with the pink color attribute (n=5)

Variables	PCL	L	a	b
PCL	1			
L	-0.738	1		
a	0.244	-0.134	1	
b	-0.053	-0.260	0.686	1

Values in bold are significantly different from 0 with a significance level alpha=0.05

3.4.3 Multivariate Analysis of Variance (MANOVA)

Twenty-six attributes, including two appearance attributes, nine flavor attributes, five texture attributes, nine aftertaste attributes and rate of melting, were used to describe the differences in the sensory properties of the thirty ice cream samples containing six formulations with five ice creams.

Before each attribute was examined individually, a mixed model multivariate analysis of variance (MANOVA) was performed to evaluate whether significant differences existed among flavor formulation, ice cream type and their interaction (Appendix G). The test hypothesis is as follows:

Ho: There are no significant differences among the effects.

Ha: There are significant differences among the effects.

Set $\alpha = 0.05$, if p-value < 0.05, then reject Ho.

The P-value of Wilk's lambda F Statistic test for two effects, flavor formulation (P=0.0022) and ice cream type (fat mimetics and fat, P<0.0001) and their interaction (P<0.0001) is less than 0.05 which showed they were significant (Table 3-9). In other words, flavoring and fat significantly affected the sensory attributes in the ice cream and all ice creams were significantly different in their overall sensory properties as measured by the twenty-six sensory attributes.

Table 3-9. Statistics and significance of various effects on all attribute measures

Effect	MANOVA Summary		
	Wilk's Lambda	F-value	Pr >P
Ice cream	0.00191713	2.88	<.0001
Flavor	0.01405387	1.62	0.0022
Ice cream X Flavor	0.04778577	1.29	<.0001

3.4.3 Principal Component Analysis (PCA)

Covariance matrix was used in principal component analysis (PCA) to analyze the mean value data of sensory attributes because they were evaluated by using the same measurement units and their variance did not differ widely. The eigenvalues of the covariance matrix showed that the first 3 PCs accounted for 59.81% of the total variance in the data set. PC I explained 31.04% of the variance in the data set and PC II and PC III explained an additional 16.01% and 12.76%, respectively, of the variance in the data set (Figure 3-1 to Figure 3-3). They were identified to be crucial in explaining the variance of the ice cream samples with the 26 sensory attributes. The first axis was dominated primarily by creaminess, smoothness, mouth coating, coldness, pink color, milky aftertaste, peach flavor and peach flavor aftertaste. By contrast, the second axis controlled sketchily rate of melt, coldness, strawberry flavor aftertaste, cooked sugar flavor, cooked sugar aftertaste, condensed milk, sweetness and sweetness aftertaste. The third axis contrasted mainly grassy flavor and grassy aftertaste, peach flavor, candy flavor aftertaste and pink color. In other words, PC I and PC II (47.05%) explained principally texture attributes, cooked sugar flavor cooked sugar aftertaste and milky flavor with its aftertaste (Figure 3-1). PC I and PC III primarily illustrated peach flavor, peach flavor aftertaste and grassy aftertaste (Figure 3-2). PC II and PC III clarified sweetness, sweet aftertaste, grassy flavor, grassy flavor aftertaste and rate of melt (Figure 3-3). Other attributes, such as pink color, candy flavor, candy flavor aftertaste, violet flavor, violet flavor aftertaste, strawberry flavor and strawberry flavor aftertaste were distributed by all three PCs.

Smoothness, creaminess and mouth coating are all positively correlated with one another but negatively correlation with coldness. Pearson correlation also showed

significant differences among the four attributes (Table 3-10). The flavor attributes stemming from the five compounds were perceived positively with their corresponding aftertaste attributes. For example, peach with peach aftertaste, cooked sugar with cooked sugar aftertaste, and violet with violet aftertaste had highly positive correlations with each other (Pearson correlation coefficient > 0.77) (Table 3-10). However, strawberry flavor and its aftertaste, or milk flavor and condensed milk displayed less correlation. Strawberry flavor aftertaste had a significant correlation with sweetness.

For flavor attributes, cooked sugar flavor and cooked sugar aftertaste were negatively correlated with peach flavor, candy flavor and their aftertastes and positively correlated with condensed milk, milky aftertaste, mouth coating, creaminess and thickness in PC I. Violet flavor and violet aftertaste were positively correlated with peach flavor and its aftertaste in PC I (Figure 3-1).

Overall, texture attributes are more important factors than flavor attributes in ice creams. Important flavor attributes include peach flavor with its aftertaste, cooked sugar with its aftertaste, milky flavor with its aftertaste, and violet flavor with its aftertaste. Chung and others (2002) found that ice creams, including regular and fat mimetics containing products, were separated more by texture attributes than by flavor attributes. My studies using PCA also showed similar characteristics, which is that texture attributes are more primary drivers in differentiating the products containing fat mimetics than flavor and aftertaste attributes.

Figure 3-4 to Figure 3-6 show the principal component analysis of the 30 ice cream with 26 sensory attributes with PC I vs PC II, PC I vs PC III and PC II vs PC III, respectively. Briefly, the results illustrate that PC I is affected by fat content and PC II is

dominated primarily by fat mimetics. From the PC I vs PC II and PC I vs PC III, it can be seen that the Simplesse[®] products appear to be negatively correlated with the Litesse[®] products, and the properties of the L/S mix products is between Simplesse[®] and Litesse[®]. Also, the third PC was not significantly influenced by texture attributes but greatly affected by flavor attributes and pink color. As a result, the third axis could have a relationship with flavor formulation or flavor concentration. For example, pink color was distributed on PC I, PC II and PC III. Clearly, pink color on PC I was affected mainly by fat content and on PC II by fat mimetics.

Briefly, grassy flavor is affected by fat content and fat mimetics but grassy flavor aftertaste primarily was influenced only by fat content. In other words, the PCA map showed ice cream with the three fat mimetics displayed similar intensities for grassy flavor aftertaste. Different from the result of ANOVA, PCA maps showed fat content and fat mimetic had an influence on candy flavor and its aftertaste. Also, it seems fat content had a greater influence on peach flavor than did fat mimetics.

The PCA results showed 4% ice creams were characterized by pink color, peach flavor, candy flavor, violet flavor and coldness along PC I, which means the 4% ice creams had stronger intensities for pink color, coldness, peach flavor, candy flavor, violet flavor and had less intensities for mouth coating, strawberry flavor, milky flavor thickness, creaminess, and smoothness compared with other ice creams on PC1. The 10% ice cream and 4% ice cream with Simplesse[®] had stronger intensities for the texture attributes of mouth coating, creaminess and smoothness, and cooked sugar flavor was more strongly perceived compared with other ice creams on PC I. However, from PC I and PC II, it seems that the overall 10% ice cream had higher mouth coating, creaminess, smoothness and milky flavor

than the 4% ice cream with Simplese[®], and the Simplese[®] products had higher cooked sugar flavor, cooked sugar aftertaste, condensed milk and thickness than did 10% ice cream.

The PCA map of PC II and PC III only accounts for 28.77% of the total variance in the data set. From PC II and PC III (Figure 3-6), it can be concluded that sweetness, sweet aftertaste, condensed milk, cooked sugar, cooked sugar aftertaste and coldness are perceived to a greater extent in ice cream with Simplese[®] than in ice cream with Litesse[®]. In addition, ice cream with L/S mix had similar properties to ice cream with Simplese[®].

In the 10% ice cream, the spiking of *cis*-3-hexen-1-ol tended to increase the intensity of grassy flavor and of cooked sugar flavor (Figures 3-4 and 3-5). The spiking of γ -undecalactone tended to increase the intensity of peach and cooked sugar flavor (Table 3-5). However, the spiking of furaneol[™] significantly increased cooked sugar flavor, and the spiking of α -ionone and ethyl-3-methyl-3-phenylglycidate significantly increased the intensity of the corresponding attributes, violet flavor and candy flavor.

In the 4% ice cream, the spiking of *cis*-3-hexen-1-ol, γ -undecalactone, α -ionone and ethyl-3-methyl-3-phenylglycidate was inclined to increase the intensity of the corresponding attributes, grassy flavor, peach flavor, violet flavor and candy flavor but the spiking of furaneol[™] was inclined to decrease the intensity of cooked sugar flavor or increase the intensity of other flavor (Table 3-4).

In the 4% ice cream with Simplese[®], the spiking of α -ionone significantly changed the flavor profile compared with the control formulation and the α -ionone spike was significantly reflected by the attribute violet. The spiking of *cis*-3-hexen-1-ol, ethyl-3-methyl-3-phenylglycidate, furaneol[™], and γ -undecalactone tended to increase the intensity of the corresponding attributes, grassy, candy, cooked sugar and peach favor.

In the ice cream with Litesse[®], the corresponding attributes were reflective of each of the flavoring compound spikes. In other words, the change of concentration of α -ionone in Simplese[®] products and that of γ -undecalactone in Litesse[®] products has a great effect on violet flavor and peach flavor, respectively. As for the ice cream with L/S mix, the change of the concentration of ethyl-3-methyl-3-phenylglycidate, α -ionone and γ -undecalactone significantly affects candy, violet and peach flavor, respectively.

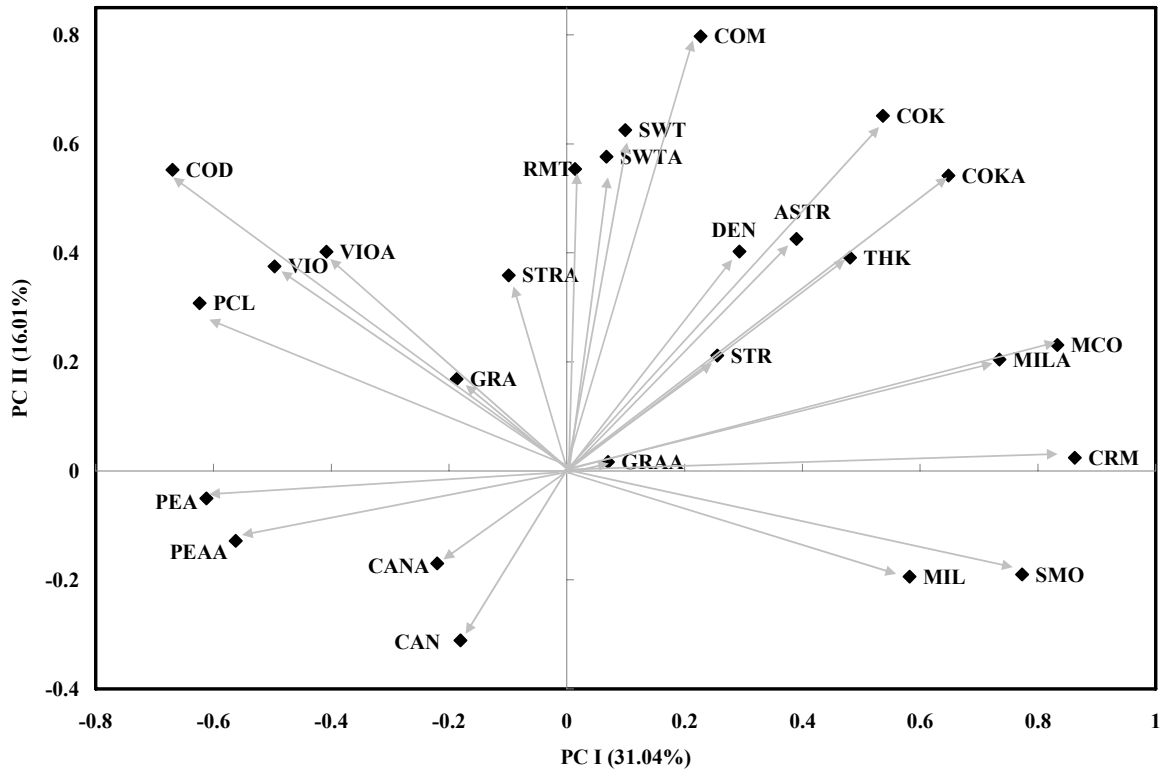


Figure 3-1. Principal component analysis of 26 sensory attributes on PC I vs PC II (Covariance model).

Parenthesis denotes the percent explained by the corresponding PC dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste	RMT	Rate of melt		

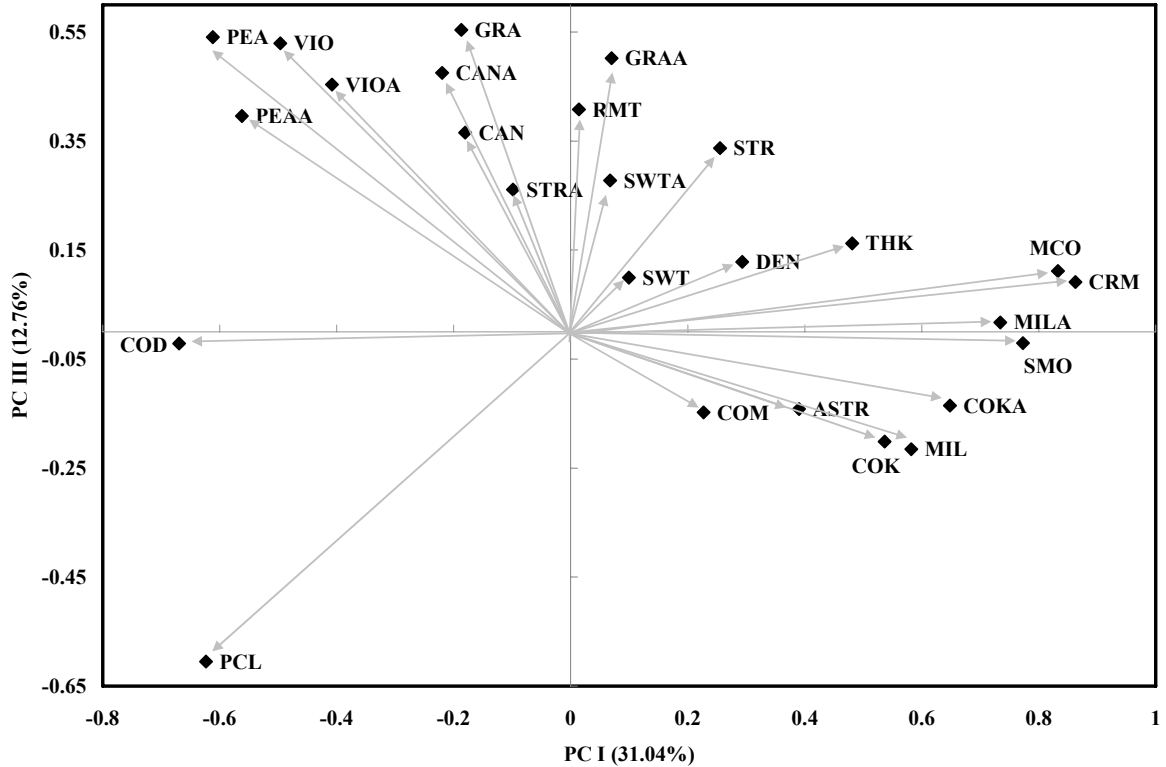


Figure 3-2. Principal component analysis of 26 sensory attributes on PC I vs PC III (Covariance model).

Parenthesis denotes the percent explained by the corresponding PC dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste	RMT	Rate of melt		

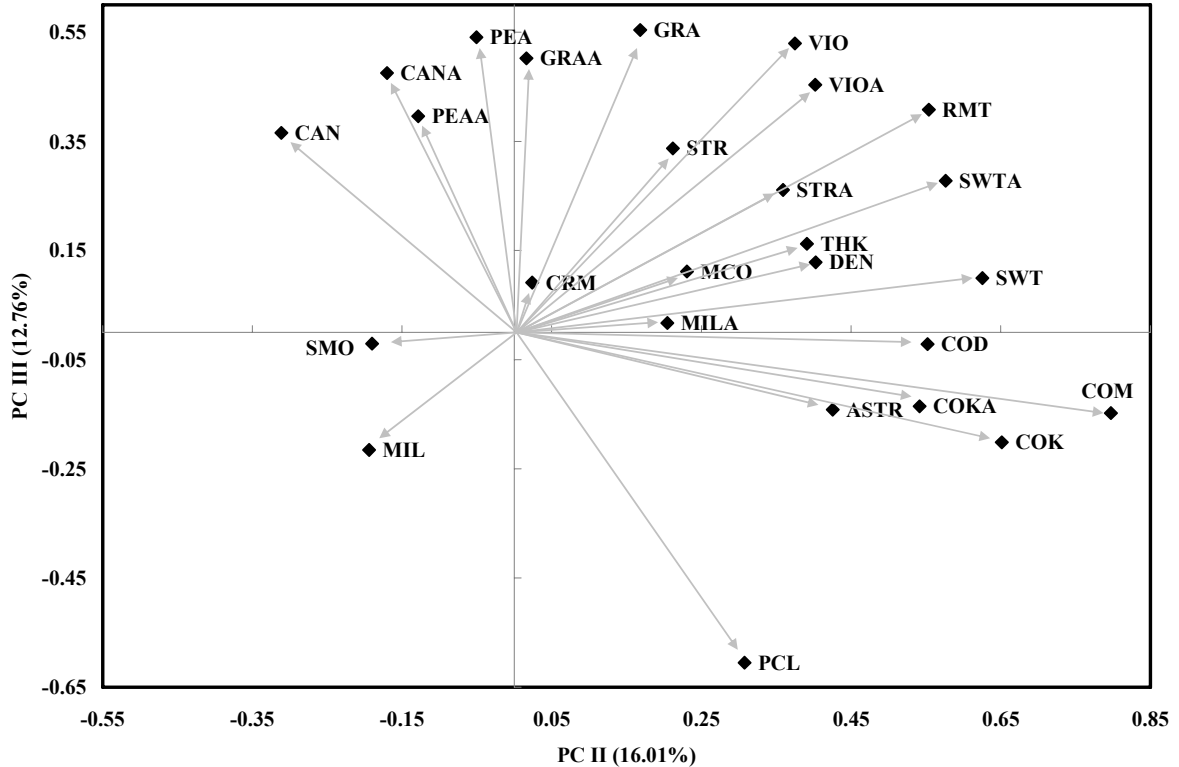


Figure 3-3. Principal component analysis of 26 sensory attributes on PCII vs PC III (Covariance model).

Parenthesis denotes the percent explained by the corresponding PC dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste	RMT	Rate of melt		

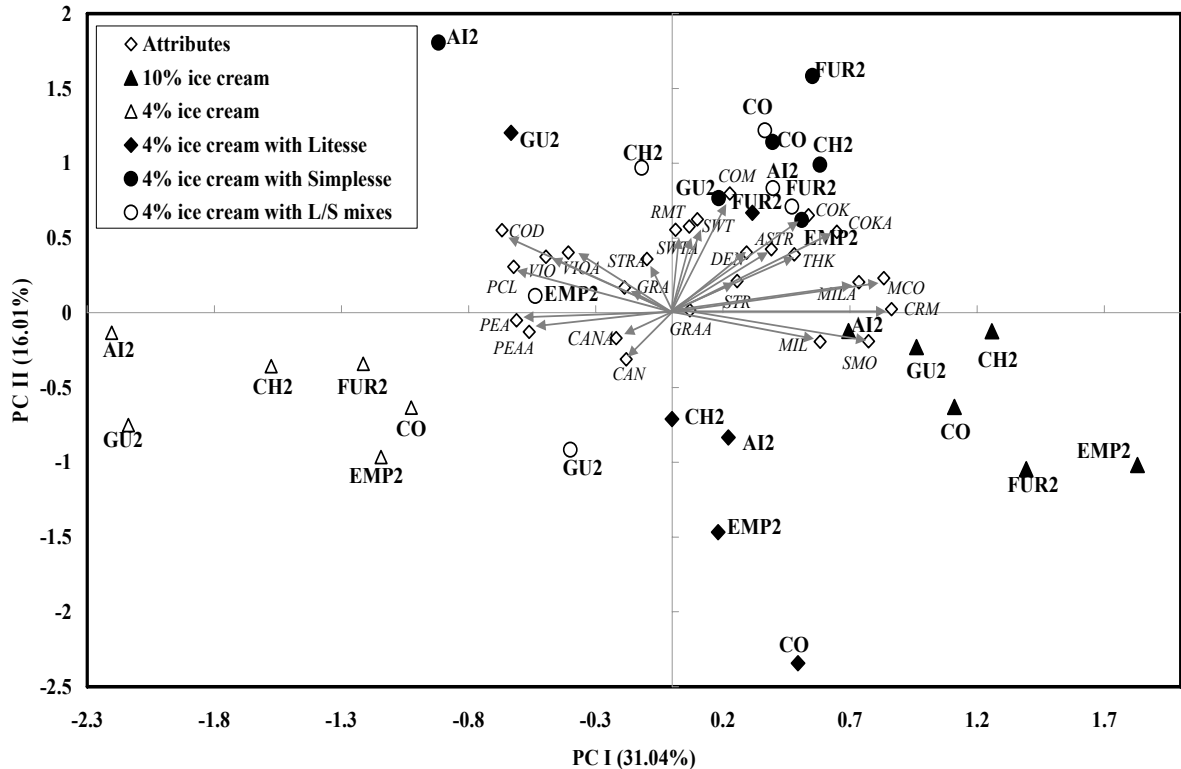


Figure 3-4. Principal component analysis of 30 ice creams with sensory attributes on PC I vs PC II (Covariance model).

Parenthesis denotes the percent explained by the corresponding PC dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste	RMT	Rate of melt		
CO2	Control spike				
CH2	<i>cis</i> -3-Hexen-1-ol spike				
EMP2	Ethyl-3-methyl-3-phenylglycidate spike				
FUR2	Furaneol TM spike				
GU2	γ -Undecalactone spike				
AI2	α -Ionone spike				

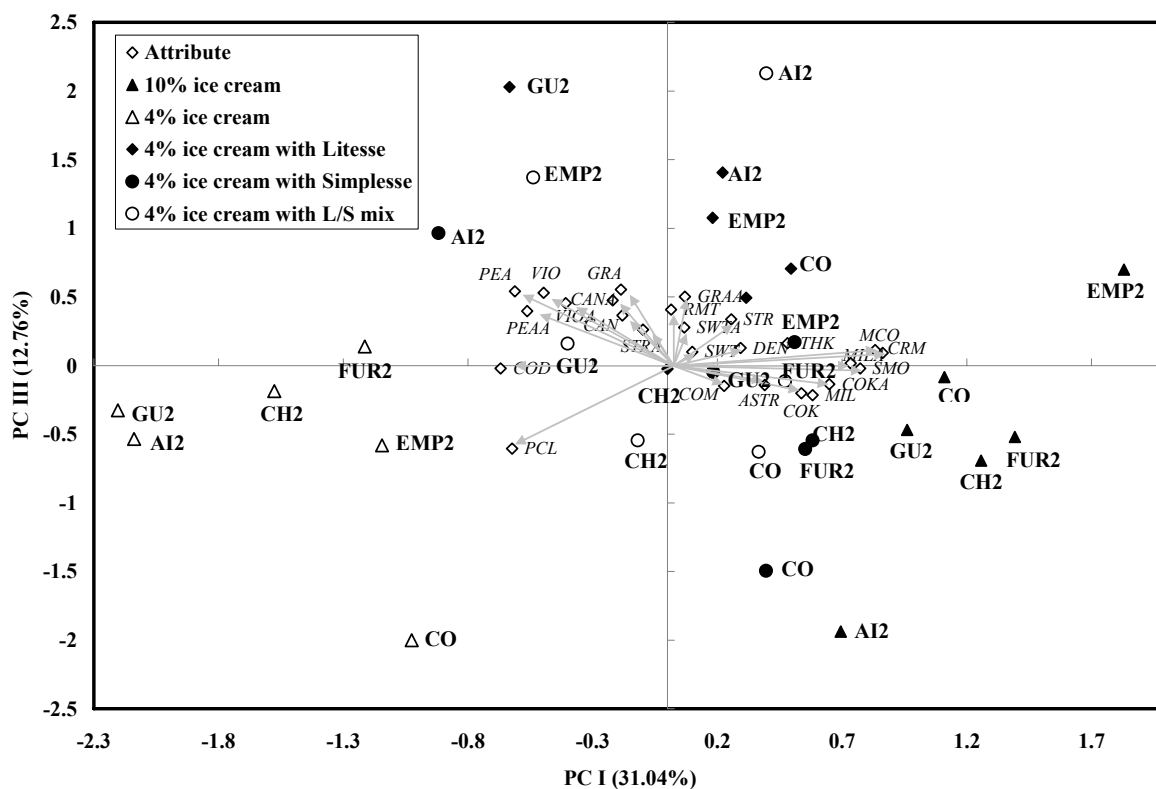


Figure 3-5. Principal component analysis of 30 ice creams with sensory attributes on PC I vs PC III (Covariance model).

Parenthesis denotes the percent explained by the corresponding PC dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste	RMT	Rate of melt		
CO2	Control spike				
CH2	<i>cis</i> -3-Hexen-1-ol spike				
EMP2	Ethyl-3-methyl-3-phenylglycidate spike				
FUR2	Furaneol TM spike				
GU2	γ -Undecalactone spike				
AI2	α -Ionone spike				

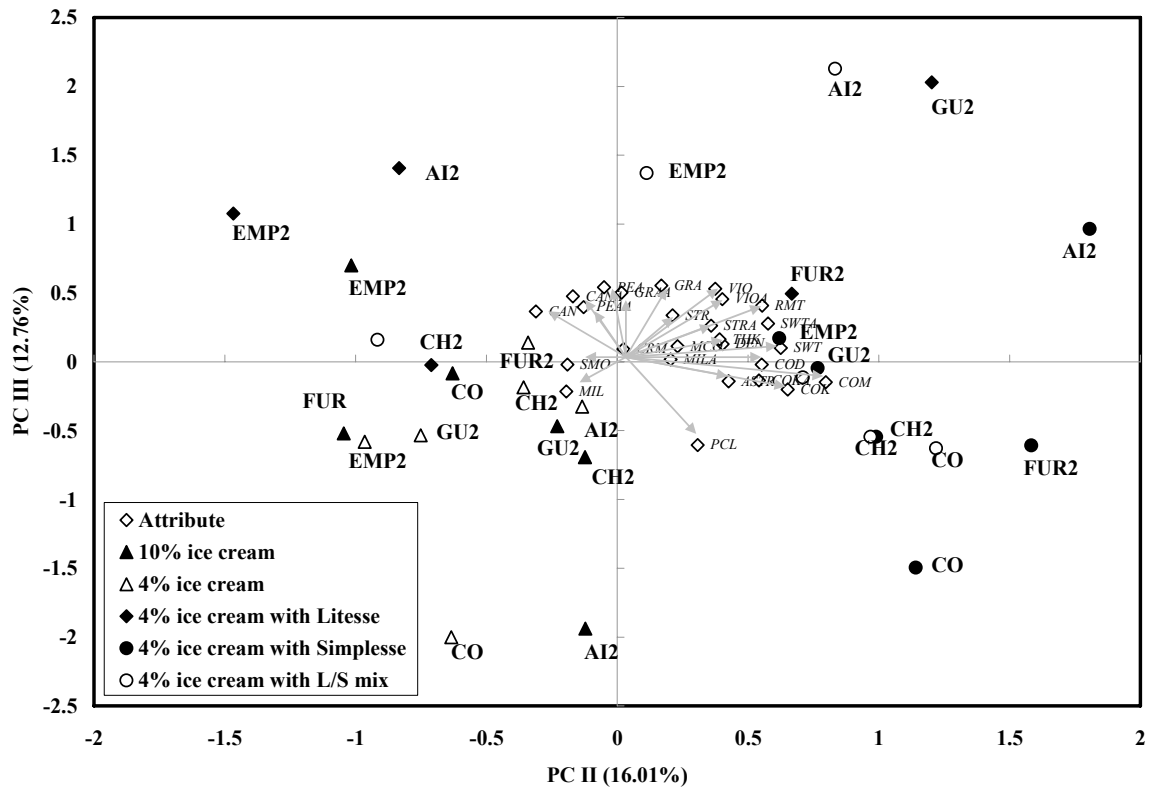


Figure 3-6. Principal component analysis of 30 ice creams with sensory attributes on PC II vs PC III (Covariance model).

Parenthesis denotes the percent explained by the corresponding PC dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste	RMT	Rate of melt		
CO2	Control spike				
CH2	<i>cis</i> -3-Hexen-1-ol spike				
EMP2	Ethyl-3-methyl-3-phenylglycidate spike				
FUR2	Furaneol TM spike				
GU2	γ -Undecalactone spike				
AI2	α -Ionone spike				

Table 3-10. Pearson correlation of ice cream without and with fat mimetics (n=30)

	PCL	DEN	RMT	SWT	STR	CAN	COK	GRA	VIO	PEA	MIL	COM	COD	THK	SMO	CRE	MCO	SWTA	STRA	CANA	GRAA	VIOA	PEAA	COKA	ASTR	MILA
PCL	1																									
DEN	-0.101	1																								
RMT	-0.077	0.228	1																							
SWT	-0.012	0.281	0.166	1																						
STR	-0.375	0.286	0.165	0.404	1																					
CAN	-0.016	-0.058	0.139	-0.255	0.129	1																				
COK	-0.063	0.275	0.250	0.417	0.177	-0.536	1																			
GRA	-0.057	-0.120	0.404	-0.157	-0.070	0.102	0.029	1																		
VIO	0.115	0.136	0.209	0.252	0.014	-0.020	-0.146	0.532	1																	
PEA	0.120	0.023	0.065	0.080	0.096	0.446	-0.432	0.365	0.483	1																
MIL	-0.345	0.147	-0.091	-0.083	-0.033	-0.119	0.188	-0.263	-0.473	-0.453	1															
COM	0.191	0.305	0.416	0.422	0.217	-0.185	0.554	-0.087	0.025	-0.297	0.003	1														
COD	0.549	0.001	0.264	0.250	-0.014	-0.058	-0.030	0.175	0.424	0.400	-0.470	0.357	1													
THK	-0.216	0.397	0.479	0.016	0.238	-0.055	0.515	0.158	-0.181	-0.250	0.080	0.432	-0.057	1												
SMO	-0.374	0.180	-0.198	-0.053	0.007	0.095	0.201	-0.143	-0.449	-0.382	0.303	0.100	-0.615	0.253	1											
CRE	-0.478	0.264	-0.062	0.098	0.111	-0.136	0.418	0.059	-0.293	-0.386	0.361	0.181	-0.561	0.449	0.784	1										
MCO	-0.386	0.403	0.132	0.153	0.323	-0.031	0.527	0.012	-0.197	-0.374	0.411	0.330	-0.437	0.502	0.715	0.795	1									
SWTA	0.010	0.246	0.131	0.687	0.266	0.023	0.366	0.080	0.378	0.226	-0.158	0.453	0.146	0.001	0.083	0.132	0.249	1								
STRA	0.040	0.202	0.220	0.369	0.318	0.193	-0.078	0.069	0.223	0.254	-0.246	0.298	0.359	0.067	-0.135	0.076	0.038	0.316	1							
CANA	-0.147	-0.239	-0.029	0.099	0.205	0.615	-0.341	0.141	0.092	0.596	-0.136	-0.092	0.166	-0.128	-0.037	-0.171	-0.100	0.320	0.210	1						
GRAA	-0.258	-0.182	0.252	-0.233	0.085	0.081	0.027	0.525	0.276	0.076	-0.172	-0.030	-0.148	0.363	0.026	0.165	0.165	0.020	-0.005	0.102	1					
VIOA	0.120	0.094	0.243	0.263	-0.036	-0.046	-0.106	0.343	0.825	0.296	-0.530	0.138	0.339	-0.096	-0.269	-0.262	-0.213	0.435	0.219	-0.022	0.378	1				
PEAA	0.173	-0.191	-0.025	-0.155	-0.118	0.417	-0.456	0.329	0.276	0.776	-0.392	-0.213	0.458	-0.133	-0.218	-0.373	-0.336	0.084	0.197	0.684	0.079	0.210	1			
COKA	-0.183	0.365	0.126	0.491	0.287	-0.383	0.791	-0.101	-0.128	-0.411	0.382	0.531	-0.116	0.266	0.389	0.540	0.696	0.382	0.119	-0.207	-0.138	-0.133	-0.443	1		
ASTR	-0.098	0.298	-0.043	0.509	0.267	-0.154	0.376	-0.309	-0.132	-0.291	0.311	0.566	0.078	0.084	0.266	0.319	0.318	0.548	0.386	0.006	-0.279	-0.033	-0.260	0.536	1	
MILA	-0.391	0.289	0.260	0.155	0.312	0.021	0.426	-0.245	-0.420	-0.442	0.509	0.382	-0.266	0.526	0.464	0.574	0.671	0.081	0.122	-0.015	0.014	-0.344	-0.299	0.540	0.411	1

In bold, significant values (except diagonal) at the level of significance $\alpha=0.050$ (two-tailed test)

PCL: Pink color, DEN: Dense, RMT: Rate of melt. SWT: Sweetness, STR: Strawberry flavor, CAN: Candy flavor, COK: Cooked sugar flavor, GRA: Grassy flavor, VIO: Violet flavor, PEA: Peach flavor, MIL: Milky flavor, COM: Condensed milk flavor, COD: Coldness, THK: Thickness, SMO: Smoothness, CRE: Creaminess, MCO: Mouth coating, SWTA: Sweet aftertaste, STRA: Strawberry aftertaste, CANA: Candy aftertaste, GRAA: Grassy aftertaste, VIOA: Violet aftertaste, PEAA: Peach aftertaste, COKA: Cooked sugar aftertaste, ASTR: Astringency, MILA: Milky aftertaste

3.4.4. Stepwise Discriminant Analysis

Flavor is a combination of mouth feel, taste, and aroma perception. In order to understand the effect of ice cream type and flavor formulation on flavor profile for ice creams, stepwise selection was applied to a select group of twenty three dependent variables, including flavor, texture and aftertaste attributes, for the purpose to discard redundant sensory attributes for separating the ice cream type and flavor formulation. The stepwise procedure was calculated for ninety observations (thirty products with three replications), and eleven of the twenty three related attributes were picked up by the procedure, including creaminess, condensed milk flavor, milky flavor, peach flavor, thickness, sweet aftertaste, milky flavor aftertaste, cooked sugar aftertaste, coldness, violet flavor and smoothness for ice cream type (Figure 3-7 to Figure 3-9). In other words, these attributes were significantly affected by fat content and fat mimetic type. Discriminant analysis of ice cream types showed that the first three functions which accounted for 96.70% of the total variance ratio and the three were significantly different at $P < 0.05$. The function 1 explained 50.71% of the variance ratio and the function 2 and function 3 contained 21.38% and 15.61% of the variances, respectively (Figure 3-7 to Figure 3-9). Clearly, the function 1 separated full-fat ice creams and low-fat ice creams, while function 2 effectively separated ice creams with mimetics from ice creams without mimetics. Thickness, milky flavor and milky aftertaste are influential factors in the first dimension and peach flavor, creaminess and sweet aftertaste were primary drivers of the second dimension. The function 3 was affected by condensed milk, violet, creaminess, coldness and sweet aftertaste.

The 10% ice cream was mostly characterized by the strong intensity of milk

flavor and milky flavor aftertaste. High condensed milk, thickness coldness and sweet aftertaste were the primary properties of ice cream with Simplese[®]. Ice cream with Litesse[®] had high intensities for peach flavor, violet flavor and creaminess, while 4% ice cream with L/S mix had high intensities for peach flavor and smoothness. In addition, from the discriminant analysis for ice cream type it can also be concluded that ice cream with Simplese[®] had similar properties to full-fat ice cream while ice cream with Litesse[®] was similar to low-fat (4%) ice cream.

Figure 3-10 explains the first two functions which accounted for 89.17 % of the total variance ratio. Stepwise analysis for flavor formulation showed that sweetness, violet flavor, cooked sugar flavor and peach flavor aftertaste were significant attributes. Both the formulation with the spiked furaneol[™] and control formulation had strong sweetness intensities. The spiking of furaneol[™] also caused a strong cooked sugar flavor. The spiking of α -ionone and *cis*-3-hexen-1-ol resulted in a high intensity of violet flavor, while the γ -undecalatone formulation was weaker in violet flavor but stronger in peach flavor aftertaste than the α -ionone and *cis*-3-hexen-1-ol spiked samples.

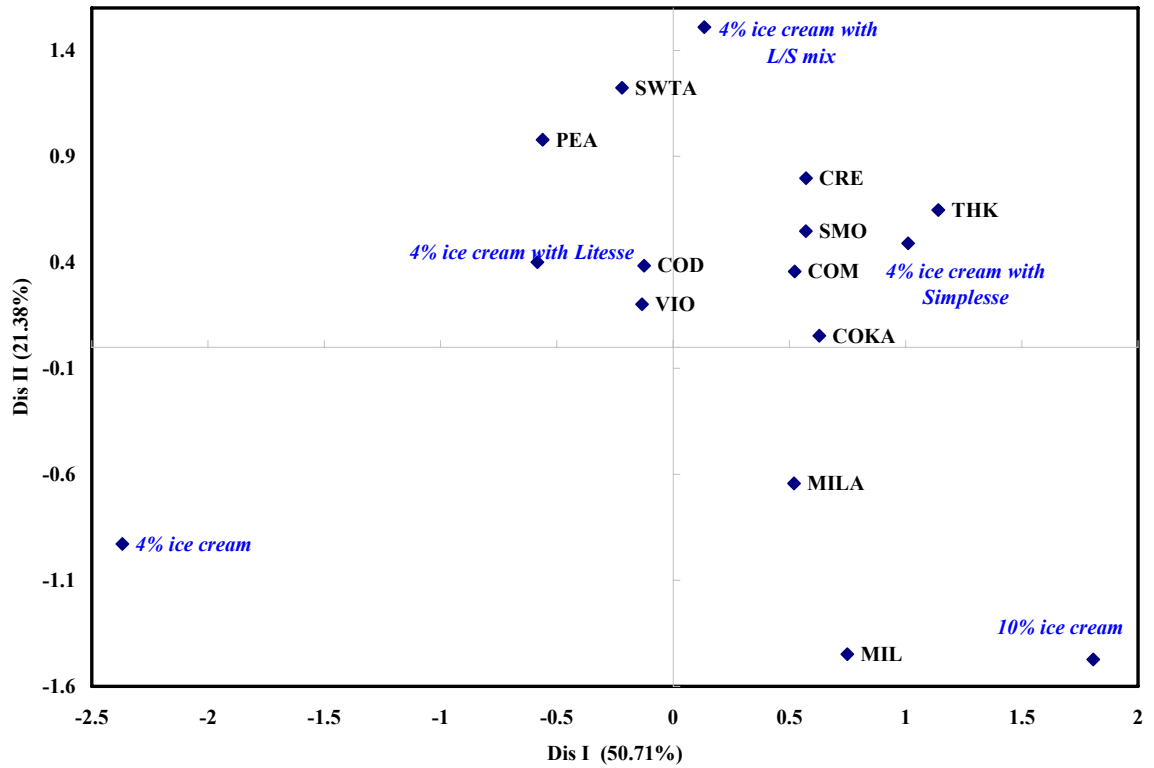


Figure 3-7. Stepwise discriminant analysis of ice cream type with stepwise selection of variables on Disc I and Disc II.

Parenthesis denotes the percent explained by the corresponding DIS dimension.

VIO	Violet flavor	PEA	Peach flavor	MIL	Milky flavor
COM	Condensed milk	COD	Coldness	SMO	Smoothness
THK	Thickness	CRE	Creaminess	COKA	Cooked sugar aftertaste
MILA	Milky aftertaste	SWTA	Sweet aftertaste		

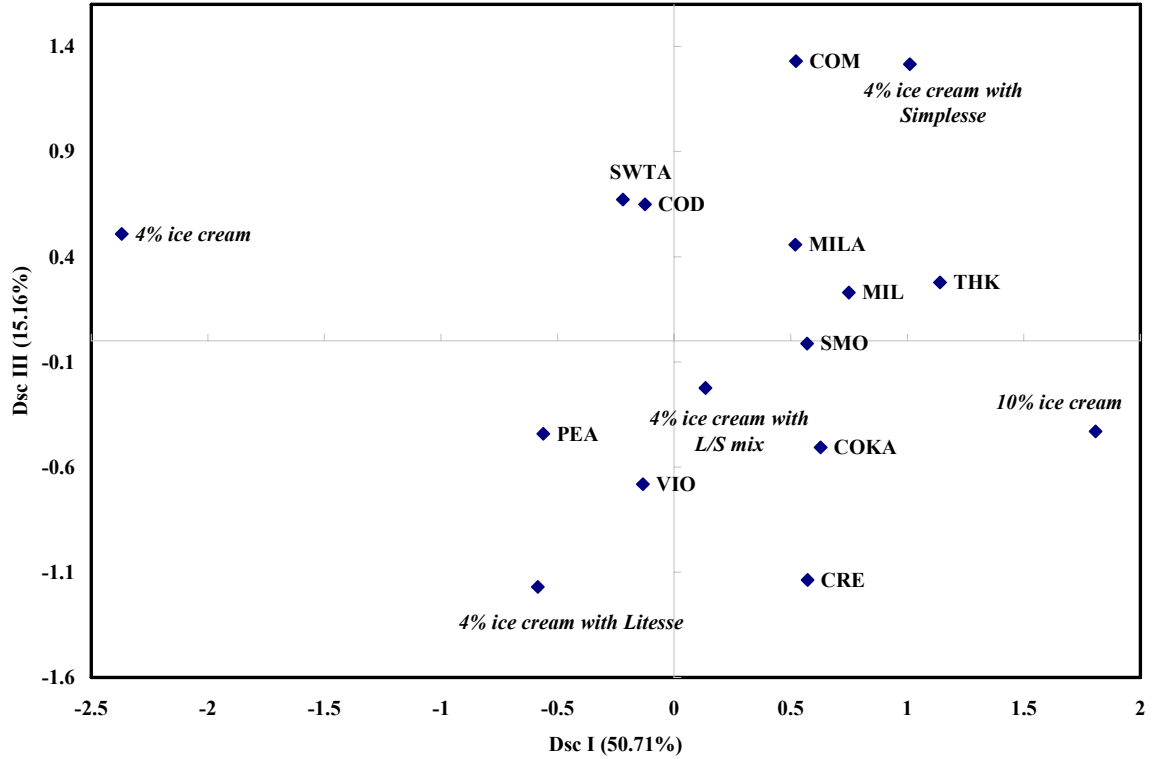


Figure 3-8. Stepwise discriminant analysis of ice cream type with stepwise selection of variables on Disc I and Disc III.

Parenthesis denotes the percent explained by the corresponding DIS dimension.

VIO	Violet flavor	PEA	Peach flavor	MIL	Milky flavor
COM	Condensed milk	COD	Coldness	SMO	Smoothness
THK	Thickness	CRE	Creaminess	COKA	Cooked sugar aftertaste
MILA	Milky aftertaste	SWTA	Sweet aftertaste		

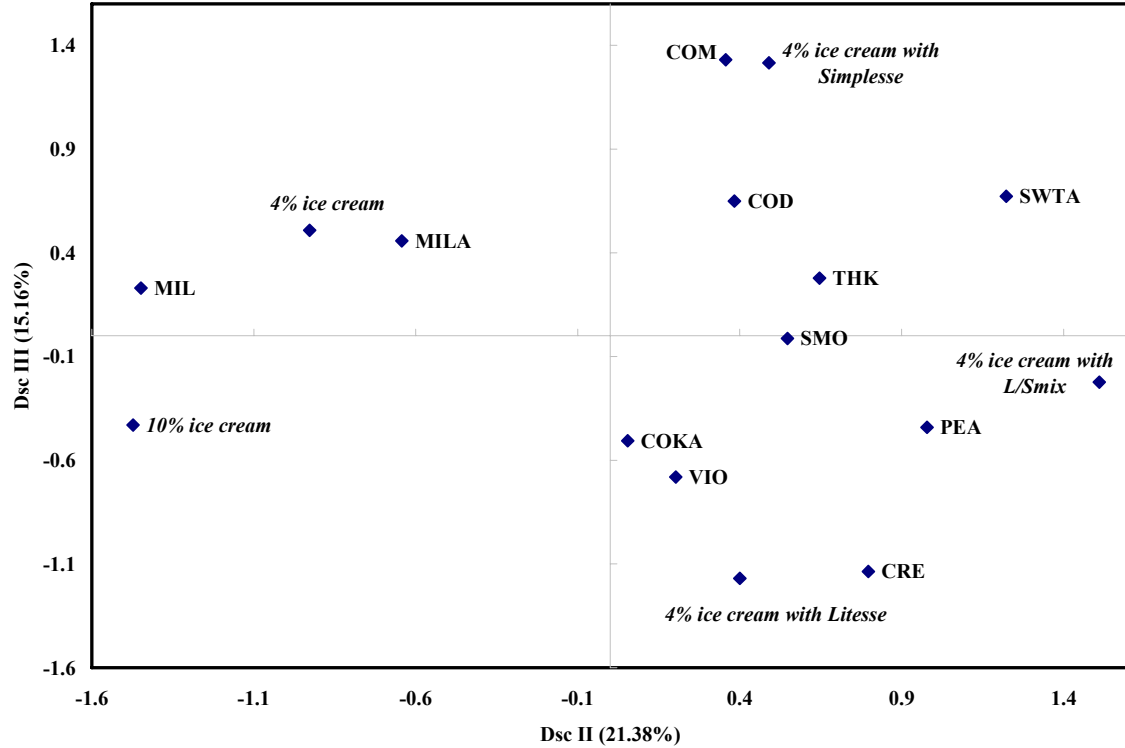


Figure 3-9. Stepwise discriminant analysis of ice cream type with stepwise selection of variables on Disc II and Disc III.

Parenthesis denotes the percent explained by the corresponding DIS dimension.

VIO	Violet flavor	PEA	Peach flavor	MIL	Milky flavor
COM	Condensed milk	COD	Coldness	SMO	Smoothness
THK	Thickness	CRE	Creaminess	COKA	Cooked sugar aftertaste
MILA	Milky aftertaste	SWTA	Sweet aftertaste		

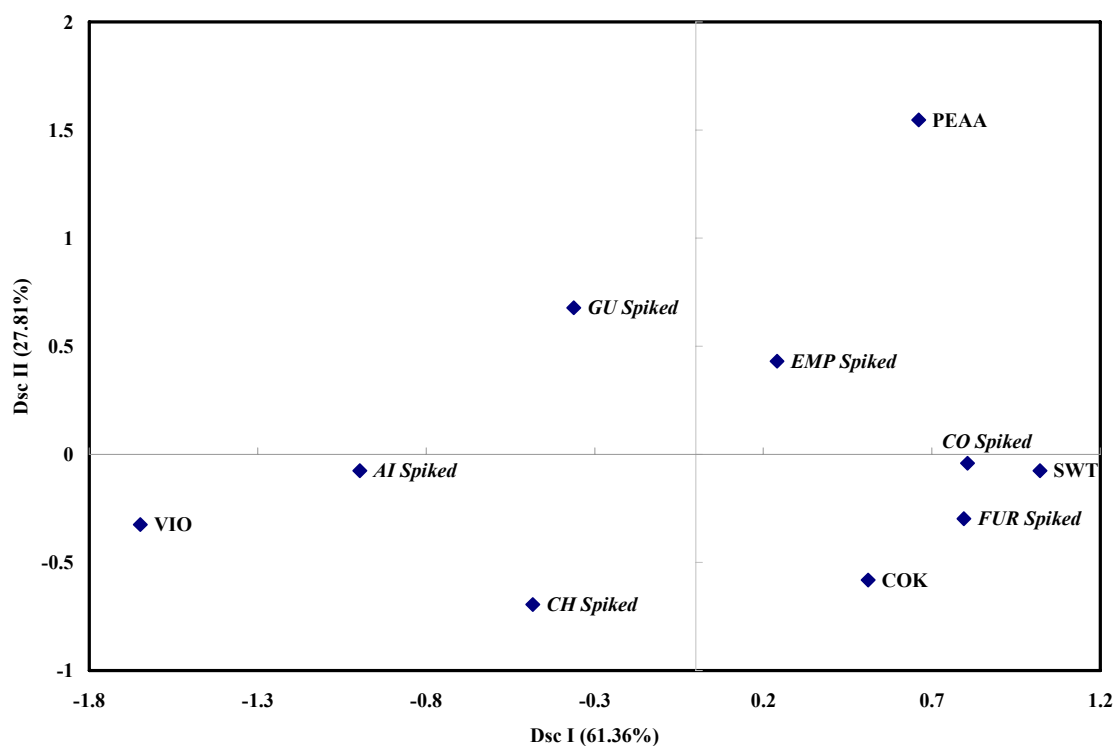


Figure 3-10. Stepwise discriminant analysis of flavor formulation with stepwise selection of variables on Disc I and Disc II.

Parenthesis denotes the percent explained by the corresponding DIS dimension.
 SWT Sweetness COK Cooked sugar flavor VIO Violet flavor
 PEAA Peach flavor aftertaste

3.4.6 Canonical Variate Analysis (CVA)

Canonical variate analysis (CVA) was performed to evaluate similarities of ice creams with or without fat mimetics for twenty six sensory attributes using the product effect. For the CVA, the original data (30 products x 3 replicate x 12 judges) were used, instead of the mean data. The axes of a CVA biplot are the characteristic vectors or dimensions, and the bubbles indicate the main effect or interaction being viewed (Maile 1997). The size of the bubble on the CVA biplot displays the 95% confidence interval of a main effect, and it is uniform if an equal number of observations were collected for all products. The bubble size is calculated using the equation below:

$$95\% \text{ confidence interval} = 2 / (\text{square root of } n)$$

n = the number of observations in the mean of the cited main effect or interaction.

In other words, the higher number of observations the smaller is the size of the bubble. If bubbles of products overlap, they are considered not to be significantly different from one another.

Figure 3-11 to Figure 3-13 show the canonical variate analysis of twenty six sensory attributes for the first three eigenvalues, which accounted for 49.34% of the total variance ratio and were significant at $P < 0.05$. The first canonical variate dimension (CVI) explained 24.60% of the variance ratio, while the second (CVII) and third (CVIII) dimensions defined 15.8% and 9.56% of the variation ratio, respectively. The CVI showed that pink color, grassy flavor, peach flavor, violet flavor, milky flavor, smoothness, and mouth coating were probably important attributes because the vectors were not significant, especially for the pink color attribute. Attributes, such as rate of melt, candy flavor candy flavor aftertaste, violet flavor aftertaste, strawberry aftertaste

sweetness and sweet aftertaste displayed less importance due to short vectors on CV I. CV II showed pink color, grassy flavor, violet aftertaste, peach aftertaste, condensed milk, milky flavor with its aftertaste and astringency as significant attributes, while candy flavor, cooked sugar flavor, condensed milk, thickness, creaminess, mouth coating and violet aftertaste were likely more important on CV III. Briefly, CVI and CVII were affected primarily by pink color, grassy flavor, violet flavor, milky flavor, smoothness, peach flavor aftertaste and astringency. Attributes, such as cooked sugar flavor, thickness, creaminess and mouth coating were represented by CVI and CV III, while candy flavor, violet flavor aftertaste and condensed milk were of greater importance to CV II and CVIII. In short, pink color, and flavor attributes like peach flavor, violet flavor with its aftertaste, grassy flavor with its aftertaste, milky flavor and condensed milk as well as texture attributes such as mouth coating, thickness, creaminess and smoothness have higher variances among thirty ice creams. Loeb (2004) analyzed strawberry flavored 4% and 10% fat ice creams using CVA and indicated pink color and milky flavor were the main opposing drivers for CV I, which explained 68.2% of the variance, while peach flavor aftertaste and smoothness are the opposing drivers for CV II explaining 9.9% of the variance. Our results showed similar conclusions for CV 1 but smoothness and peach flavor aftertaste both had positive correlations for CVII on the CVA map. The primary differences of the two CVA maps could be due to the effect of fat mimetics on texture and flavor of ice cream samples.

Figure 3-14 to Figure 3-16 show the CVA biplots for thirty ice creams with sensory attributes on CVI vs CVII, CVI vs CVIII and CVII vs CVIII, respectively. The 10% ice cream and 4% ice cream with Simplese[®] had higher intensities for milky flavor,

condensed milk, cooked sugar flavor, cooked sugar aftertaste, mouth coating and thickness but lower scores for pink color, peach flavor, violet flavor and grassy flavor than 4% ice cream with or without Litesse[®]. However, 10% ice cream had significant greater intensity in strawberry flavor, sweetness, milky flavor and creaminess than 4% ice cream with Simplese[®]. Ice cream with Simplese[®] had stronger intensities for condensed milk, cooked sugar flavor, cooked sugar aftertaste and thickness than 10% ice cream or other ice creams, which was in agreement with previous studies (Chung 2002). In 10% ice cream, the high intensity of milky flavor and creaminess causes the greatest distinction to other kinds of ice creams and CV I is the allocation of these primary variances. The primary variances of ice cream with Simplese[®] were the attributes of condensed milk and thickness compared with other ice cream. CVII and CVIII dominated the variances among the six Simplese[®] samples. The control sample and the spiked furaneol[™] in the Simplese[®] products had a stronger intensity in sweetness and condensed milk causing a different position on CVII and CV III compared to the other Simplese[®] products (Figure 3-16). In addition, the spiking of *cis*-3-hexen-1-ol, γ -undecalactone and α -ionone significantly increased the variance of the corresponding attributes, glassy, peach and violet flavor in 10% ice cream and 4% ice cream with Simplese[®]. Among them, the spiking of α -ionone in 4% ice cream with Simplese[®] had the most significant variances in violet flavor. In other words, changes in concentration of α -ionone are easily perceived in the Simplese[®] products. The spiking of furaneol[™] in 10% ice cream did not significantly increase cooked sugar flavor but gave a higher intensity in creaminess compared with the control sample. The spiking of ethyl-3-methyl-3-glycidate in 10% ice cream was loaded on CV I and CV III to a greater

extend than other 10% ice creams due to higher intensity in mouth coating and creaminess (Figure 3-15).

The 4% ice cream in the CVI vs CVII graph was loaded on the negative x dimension due to darker pink color and lower mouth coating and milky flavor aftertaste compared with other samples. CV I and CVII assigned the primary variances in 4% ice creams and the 4% control ice cream was significantly different from the other five 4% ice creams on CVI and CVII (Figure 3-14). The primary reason is due to differences in flavor intensity. The spiking of *cis*-3-hexen-1-ol, γ -undecalactone and α -ionone in 4% ice cream significantly increased the intensity of the corresponding attributes, glassy, peach and violet flavor.

Loeb (2004) also found by CVA biplot that sweetness, milky flavor, violet aftertaste and peach aftertaste were perceived better in 10% ice cream than in 4% ice cream. Our result agreed these previous studies. Loeb (2004) concluded that the 10% ice cream was perceived to have a higher intensity of candy flavor, cooked sugar flavor, and sweet aftertaste and the 4% ice cream seemed to be more influenced by violet flavor and peach flavor, which again was confirmed by our studies. On the other hand, the CVA biplot of Loeb's studies (2004) also showed that grassy flavor aftertaste had a higher intensity in the 10% ice cream and that grassy flavor was not greatly influenced by the level of fat in ice cream. Although the ANOVA results of our studies were in agreement with Loeb's studies, our CVA map showed some slight differences. These differences could be the result of using fat mimetics in the ice creams, causing greater complexity and variability of CVA biplot.

Most ice creams with Litesse[®] were loaded in the positive area of the Y-axis, and

mostly on CV I and CV II because they had more smoothness in texture and lighter pink color in appearance as well as less intensity in condensed milk in flavor attributes. CV I, CVII and CVIII dominated the variance of the Litesse[®] sample. Clearly, the variance loadings of the Litesse[®] products on the three dimensions were due mainly to the flavor intensities. CVI was much influenced by peach flavor and grassy flavor and also slightly by violet flavor aftertaste so that the spiked *cis*-3-hexen-1-ol and γ -undecalactone had a different position on CVI as compared to other Litesse[®] samples. The position on CVII was influenced by cooked sugar flavor so that there was an opposite position for the spiked furaneol[™] product. Peach and violet aftertaste had a significant influence on CVIII. The spiking of *cis*-3-hexen-1-ol, furaneol[™], γ -undecalactone and α -ionone in ice cream with Litesse[®] significantly increased the intensity of the corresponding attributes, glassy, cooked sugar, peach flavor and violet flavor. The spiked γ -undecalactone sample showed significant variances in peach flavor and peach flavor aftertaste and also had a higher variance in violet and violet aftertaste. The spiked α -ionone sample had a very high intensity in violet aftertaste. In other words, higher concentrations of γ -undecalactone could cause the increase of violet and peach flavor perception, but changes of α -ionone would only influence the violet flavor attribute in the Litesse[®] products.

Ice creams with L/S mix were widely distributed on the CVA map and loaded on CV I and CV II but were located close to ice creams with Simplese[®] on CV I and CVIII, except for the spiked grassy sample. In other words, CVI and CVII caused a significant variance on the properties of ice cream with L/S mix and the primary differences could stem from flavor perception. Ice cream with L/S mix had a similar texture property to the

Simplesse[®] ice cream but the flavor perception had closer characteristics to ice creams with Litesse[®]. The spiked ethyl-3-methyl-3-glycidate, γ -undecalactone and α -ionone samples of the L/S mix significantly increased the corresponding attributes, candy flavor, peach and violet flavor and showed a flavor profile close to that of Litesse[®] samples with γ -undecalactone and α -ionone spikes. Both the control and the spiked furaneol[™] sample had similar properties to that of Simplesse[®] sample and 10% ice cream due to the strong intensity in cooked sugar flavor and sweetness.

Overall, it seems that these influential factors on CV I were primarily affected by fat content. The ice creams with low fat content (4 %) are located on the negative X-axis of CV I, while the positive part of the X-axis includes the high fat content (10%) samples. In other words, fat had a significant influence on the pink color, peach flavor, violet flavor, mouth coating, smoothness, milky flavor aftertaste and candy flavor aftertaste. However, from CVI versus CVII graph, the results indicated that peach flavor, violet flavor and grassy flavor were perceived strongly in the lower fat environment and cooked sugar flavor and candy flavor showed a high intensity in a high fat environment. The results were slightly different from those of the mixed ANOVA and the PCA, but it was in agreement with the previous studies (Loeb 2003). In the CVA map, grassy flavor appears to be an important influential factor, although there were no significant differences in the ANOVA results and it was of less importance for the principal components in PCA. In addition, the PCA results indicated candy flavor, candy flavor aftertaste, grassy flavor and grassy aftertaste had significant positive correlations, but the CVA result showed very significant differences. On CV I and CV II, candy flavor was perceived in ice creams with high fat content but the intensity of candy flavor aftertaste was highly significant in

lower fat environment and was more important than that of candy flavor. Grassy flavor and grassy aftertaste also are on opposite sides on CVA map.

Pink color, strawberry flavor, strawberry flavor aftertaste, and violet flavor were significant attributes on CVII. The Litesse[®] samples were distributed primarily on the positive axis of CV II and the Simplese[®] samples were loaded on the negative axis of CV II. In other words, fat mimetics and the interaction between flavor and fat mimetic have an influence on CVII. For example, pink color on CV II was located on the negative position and was affected significantly by fat mimetics. Chung (2002) analyzed the effect of fat and fat mimetics (Litesse[®] and Simplese[®]) on ten artificial cherry ice creams using CVA and indicated the first CV separated the ice creams by fat and the second CV separated the ice creams based on the type of fat mimetics. From CVII and CV III it can be clearly seen that fat mimetics and some flavor aftertaste also had an influence on CV III because some texture attributes, such as thickness and smoothness as well as violet aftertaste and peach aftertaste are important influential factors. It seems that the main effect of both the violet aftertaste and peach flavor aftertaste could stem partially from fat mimetics. Fat mimetic had a greater influence on candy flavor than fat did.

Chung (2002) indicated that the type of fat mimetic is more important than the milk fat content in their influence of sensory properties of ice cream. Ice creams with identical fat mimetics but different fat contents were not significantly different from each other in their sensory properties, but they were significantly different when different fat mimetics were used. According to the CVA map, in my studies we found that the change of the five flavor profile in ice creams with Litesse[®] were greatly influenced by fat, but the effects on flavor in ice cream with Simplese[®] were more influenced by fat mimetic

than by fat.

Chung (2002) demonstrated that Simplesse[®] performed better than Litesse[®] in improving the overall texture of the low-fat ice creams, but Simplesse[®] had some adverse effect on the texture of the high fat ice creams, such as high stickiness. In addition, her studies also concluded that neither one of the fat mimetics was able to mimic the volatile profile of the low-fat reference ice cream, but protein-based fat mimetics (Simplesse[®]) came closer than carbohydrate-based fat mimetics (Litesse[®]) in mimicking the flavor release pattern of the full-fat reference sample. Schirle-Keller and others (1994) suggested that Simplesse[®] behaved more like fat in its ability to reduce the vapor pressure of many flavor compounds than did carbohydrate-based fat mimetics. Schmidt and others (1993) found that ice cream made with Simplesse[®] D-100 was more similar to full-fat ice cream in terms of rheological properties than was ice cream made with maltodextrin-based fat mimetics. However, some studies have reported that protein-based fat mimetics used in reduced-fat ice cream exhibit distinctive flavor notes, such as whey, syrupy, milk powder and cooked milk (Ohmes and others 1998; Roland and others 1999). My studies also showed that Simplesse[®] products were more similar to 10% ice cream in sensory properties than the Litesse[®] products, although there were significant differences for milky flavor and condensed milk flavor, and concluded that Simplesse[®] is a better fat mimetic than Litesse[®] in duplicating the flavor profile and mouthfeel of full-fat ice cream.

3.5. CONCLUSIONS

In this study, it was demonstrated that fat content, fat mimetics and flavor formulation had a significant influence on the perception of furaneol™, α -ionone and γ -undecalactone but there was no interaction between ice cream type and flavor formulation for the three flavors. PCA showed that *cis*-3-hexen-1-ol, α -ionone, γ -undecalactone and ethyl-3-methyl-3-phenylglycidate were perceived with greater intensity in 4% ice cream, while furaneol™ was perceived more strongly in 10% ice cream. Furaneol™ did not show significant differences between the 4% ice cream with fat mimetics and 10% ice cream, but there were significant differences in perception of α -ionone in 4% ice cream with fat mimetics compared to that of 10% ice cream. In addition, perception of γ -undecalactone in 10% ice cream was significantly different from that of 4% ice cream with Litesse® or L/S mix according to ANOVA results.

Spiking of Furaneol™, α -ionone and γ -undecalactone significantly increased the intensity of the corresponding attributes of cooked sugar, violet, and peach flavor but spiking of *cis*-3-hexen-1-ol also increased the intensity of violet flavor, instead of grassy flavor according to the result of the canonical variate analysis. The formulations spiked with 200% ethyl-3-methyl-3-phenylglycidate were not significantly different from the control formulations for the flavor profile of the five compounds.

Ice cream with Litesse® and low-fat ice creams were similar to each other in flavor profile of the five compounds. Ice cream with Simplese® had similar flavor characteristics with 10% ice cream but there were significant differences for milky flavor and condensed milk flavor. α -Ionone and γ -undecalactone were perceived to a

significantly greater degree when they were spiked.

The 4% ice cream with Simplese[®] had higher thickness intensity than 10% ice cream or the 4% ice cream with Litesse[®]. The 10% ice cream had higher intensity in smoothness, mouth coating and creaminess than 4% ice cream with Litesse[®] or Simplese[®], while 4% ice cream with Simplese[®] was significantly different in sweetness level and condensed milk flavor from the 4% ice cream with Litesse[®]. Based on flavor and textural characteristics, Simplese[®] is a better choice for reformulating the flavoring compounds of ice cream than Litesse[®] because it yields properties more similar to those of 10% ice creams.

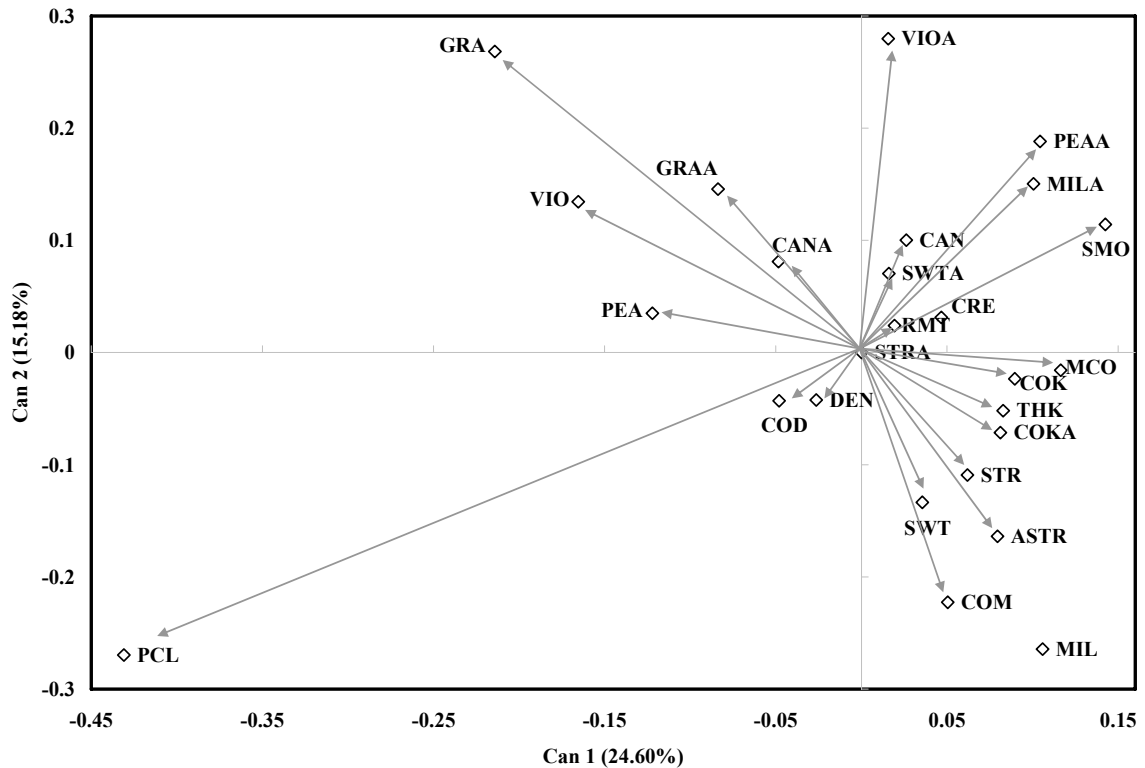


Figure 3-11. Sensory attributes space by CVA for 30 ice creams on CV I vs CV II.

Parenthesis denotes the percent explained by the corresponding CV dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste	RMT	Rate of melt		

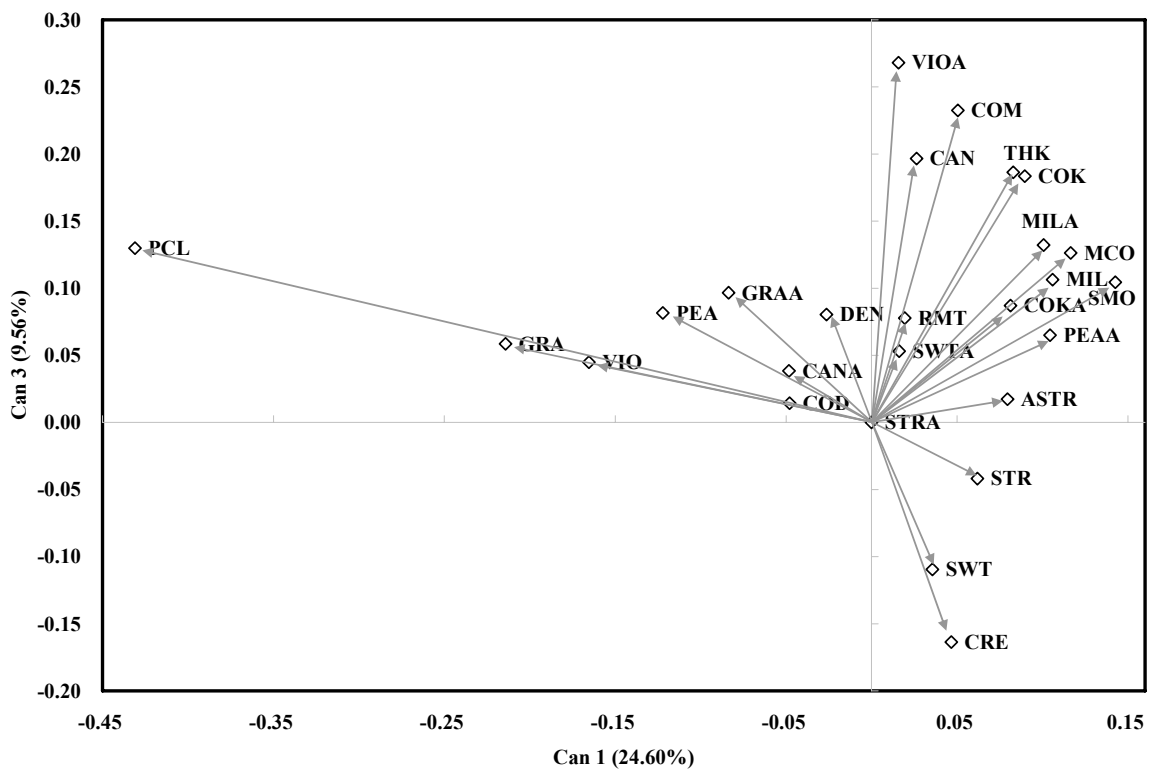


Figure 3-12. Sensory attributes space by CVA for 30 ice creams on CV I vs CV III.

Parenthesis denotes the percent explained by the corresponding CV dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste	RMT	Rate of melt		

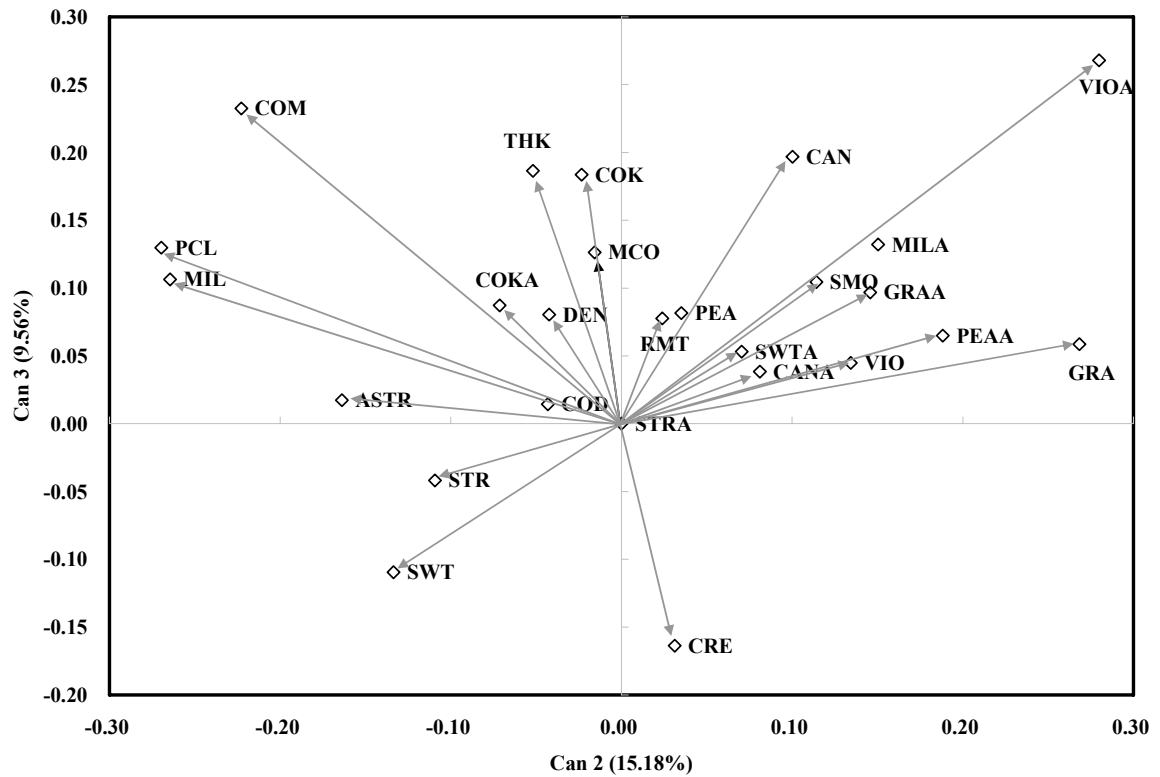


Figure 3-13. Sensory attributes space by CVA for 30 ice creams on CV II vs CV III.

Parenthesis denotes the percent explained by the corresponding CV dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste	RMT	Rate of melt		

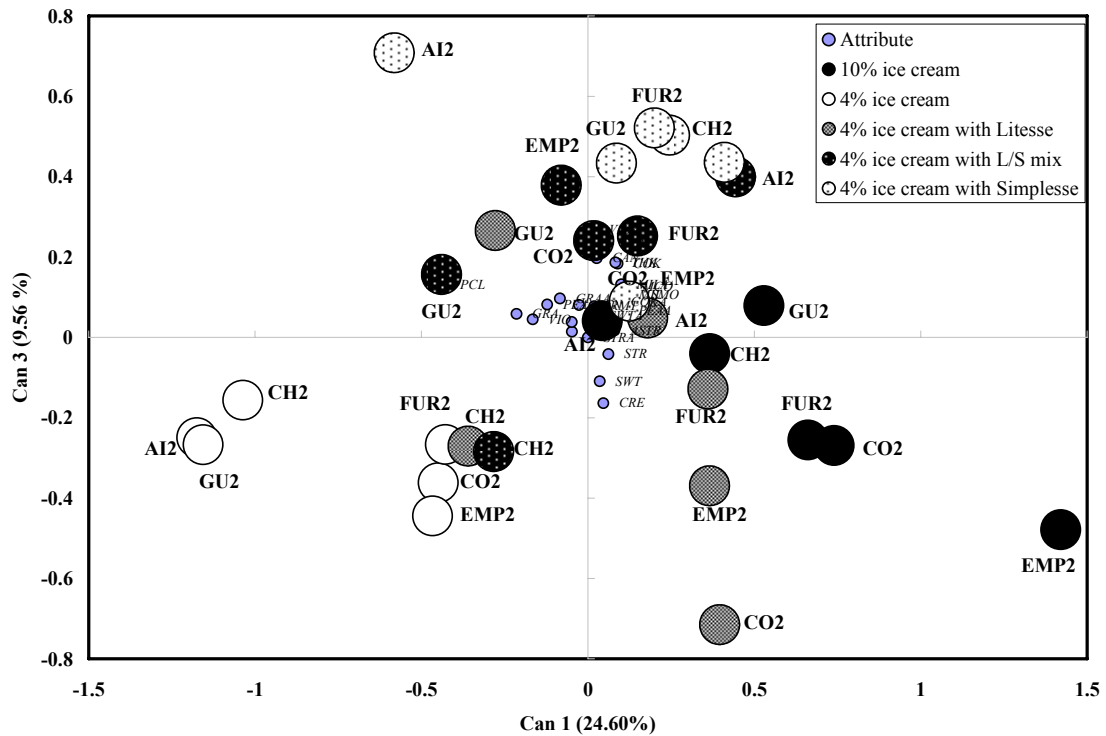


Figure 3-15. Canonical variate analysis for 30 ice creams on CV 1 vs CV III.

Parenthesis denotes the percent explained by the corresponding CV dimension. Samples that are overlapping to each other indicates no significant difference ($p < 0.05$) between the samples.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste	RMT	Rate of melt		
CO2	Control spike				
CH2	<i>cis</i> -3-Hexen-1-ol spike				
EMP2	Ethyl-3-methyl-3-phenylglycidate spike				
FUR2	Furaneol TM spike				
GU2	γ -Undecalactone spike				
AI2	α -Ionone spike				

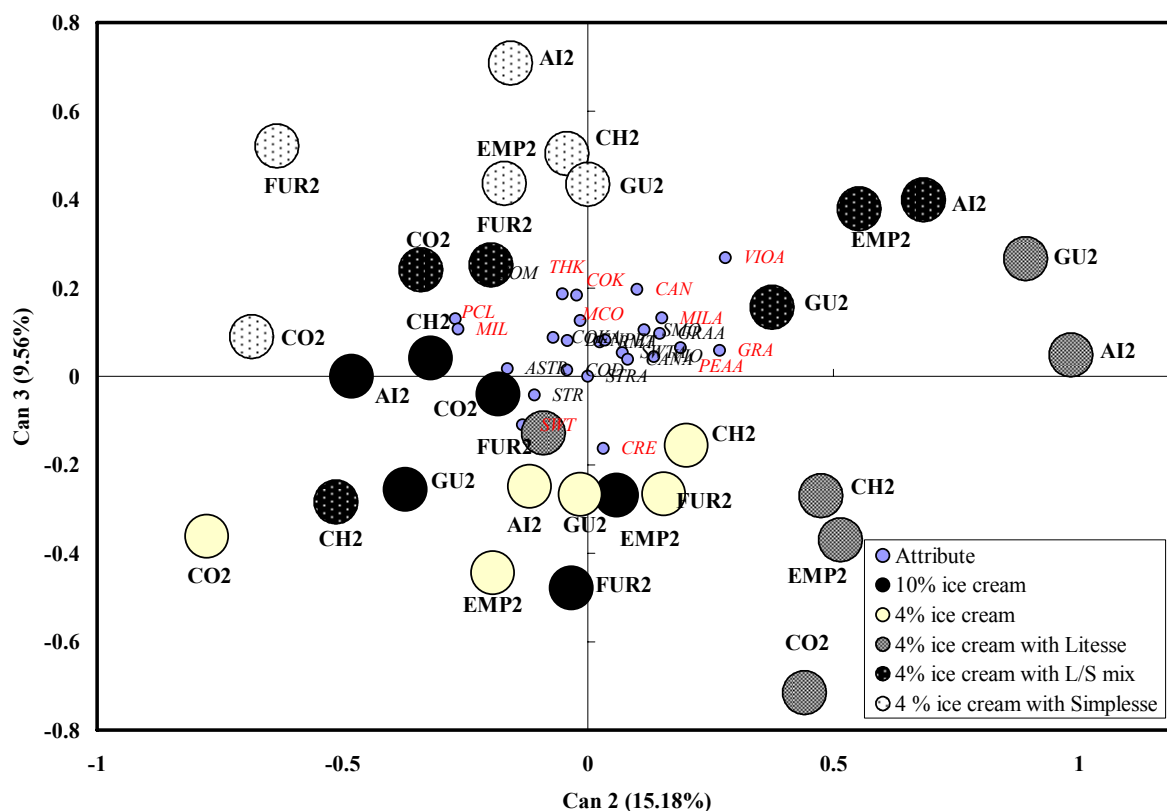


Figure 3-16. Canonical variate analysis for 30 ice creams on CV II vs CV III.

Parenthesis denotes the percent explained by the corresponding CV dimension. Samples that are overlapping to each other indicates no significant difference ($p < 0.05$) between the samples.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste	RMT	Rate of melt		
CO2	Control spike				
CH2	<i>cis</i> -3-Hexen-1-ol spike				
EMP2	Ethyl-3-methyl-3-phenylglycidate spike				
FUR2	Furaneol TM spike				
GU2	γ -Undecalactone spike				
AI2	α -Ionone spike				

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CHAPTER 4

DESCRIPTIVE SENSORY ANALYSIS OF STRAWBERRY ICE CREAMS CONTAINING SIMPLESSE[®] AND FLAVORINGS REFORMULATED FOR REDUCED FAT ICE CREAMS

4.1 INTRODUCTION

A high quality ice cream has to have proper characteristics in body, melt-down and flavor, and the amounts of fat, nonfat milk solids, sugar, stabilizer and flavoring used in the mixes are critical factors (Salam and others 1981). Fat contributes primarily texture and pleasing mouthfeel and positively imparts flavor intensity and perception in foods, and flavor characteristics are of major importance to consumer's perception of foods (Hamilton and others 2000).

Reduction of fat in ice cream causes a large adverse effect on the sensory properties. Texture and flavor are two primary issues in developing low-fat or fat-free products. Ideally, if the flavor profile of the full-fat ice cream could be analyzed, the developer could use fat mimetics or other special materials to improve the texture and mouthfeel of the low-fat ice cream, which could be reformulated until that "flavor target" is achieved (Taylor and Linfoth 1998). It is a complicated process that requires the full understanding of the functionality of a variety of ice cream ingredients, such as fat mimetics and fat, along with the use of formulation technology (Bakal 1994).

According to the suggestion of Hegenbart (1993), there are three primary cycles in formulating low-fat products, including texture cycle, flavor cycle and processing cycle. For formulating texture in foods, usually four steps need to be considered. First,

the choice of a fat mimetic has to involve evaluating existing ingredients for performance before choosing the best candidate after a series of evaluations. The choice of fat mimetics, such as carbohydrate- and protein-based, depends on the food application and on the functional properties of the fat in the specific food application. In general, fat mimetics have the capacity to act similar to fat, so they may be able to enhance the sensory properties of the product in order to mimic those of a higher fat containing product (Bakal 1994). The next step is to start combining the different ingredients to form the system and to adjust all ingredients to optimize the textural function after determining the use of fat mimetics (Hegenbart 1993). For ice cream products, it is much more difficult to replace the mouthfeel of fat in low-fat products because water contributes to texture and mouthfeel along with other factors such as processing, freezing and thawing (Alexander 1997).

For adjusting the flavor, the flavor profile of low-fat products might be compared to that of a standard product by using some techniques such as a descriptive test or a time intensity method. Factors such as fat type and content, fat mimetic type and the emulsification process may alter flavor release characteristics, overall oral perceptions and have masking properties (Hegenbart 1993; Alexander 1997). For example, Chung and others (2003) found that off-flavors, produced from aldehydes and alcohols, were considerably increased, and cream flavor (as methyl ketones) was decreased when milk fat was removed from ice cream. However, protein-based fat mimetics can chemically bind and interact with flavor compounds, such as aldehydes and ketones, which influence their perception (Kuntz 1996). On the other hand, ice cream products with higher solids content and slower melting rate could coat the mouth, which

would delay and prolong the flavor release (Shamil and Kilcast 1992). Fat mimetics also have similar functionalities but the net effect is not necessarily the same. By the information acquired using appropriate techniques, the specific flavor quality of the product can be mapped to determine where they differ and formulate the flavor accordingly (Hegenbart 1993).

The third cycle in formulating low-fat products is concerned about processing loops because the process might indicate a necessary change in either the base formula or even the flavor (Hegenbart 1993). Many fat mimetics could change the properties of products, such as viscosity and texture, during processing (Kuntz 1996). Sensory tests are a critical procedure to confirm the product quality and shelf life (Hegenbart 1993).

Previous sensory studies focused on the release behavior of five strawberry flavor compounds, including *cis*-3-hexen-1-ol (grassy flavor), furaneolTM (cooked sugar flavor), ethyl-3-methyl-3-phenylglycidate (candy flavor), γ -undecalactone (peach flavor), and α -ionone (violet flavor), in ice cream with Litesse[®], Simplese[®] or Litesse[®] and Simplese[®] mixes and found 4% ice cream with Simplese[®] had similar characteristics in flavor profile and mouthfeel properties to that of 10% ice cream. In other words, it is easier to formulate the flavor profile with Simplese[®] than with Litesse[®], which might ensure that reformulated products tested by the sensory panel are close to the desired flavor.

Fat content, fat mimetics and flavor formulation had a significant influence on the perception of furaneolTM, α -ionone and γ -undecalactone but there was no interaction between ice cream type and flavor formulation for the three flavors. In other words, furaneolTM, γ -undecalactone, and α -ionone are flavor targets for formulating low-fat

strawberry flavored ice cream. Furaneol™ had a higher intensity in 4% ice cream with Simplese® than it did in 10% ice cream. Both γ -undecalactone, and α -ionone were lower in their perceived intensity in both 4% ice cream with Simplese® and 10% ice creams and had greater changes in intensity than the other compounds when their spiked concentrations increased. Principal component analysis indicated that the three flavors, furaneol™, γ -undecalactone, and α -ionone, in ice cream with Simplese®, had a higher intensity compared to 10% ice cream and the increased spiking of *cis*-hexen-1-ol appeared to increase the perception of violet flavor in ice cream. In addition, descriptive analysis showed that ice cream with Simplese® had more sweetness, condensed milk flavor and thickness but less creaminess than did 10% ice cream.

The objective of the present study was to investigate the formulation of ice cream with Simplese® more closely to match approximately the sensory characteristics of 10% ice cream by evaluating thirty six kinds of flavor formulation using descriptive analysis method.

4.2 MATERIALS AND METHODS

4.2.1 Materials

Simplese®100, microparticulated whey protein concentrate 53 (CP Kelco, San Diego, CA, USA) was used in the study. The five flavor compounds were food grade, and included *cis*-3-hexen-1-ol, ethyl-3-methyl-3-phenylglycidate, furaneol™, α -ionone and γ -undecalactone. They were procured from the Flavor and Fragrance division of Sigma Aldrich (St. Louis, MO, USA). Skim milk and heavy whipping cream were purchased

from Prairie Farms Inc. (Carlinville, Illinois, USA). Nonfat dry milk (spray process grade A) made from pasteurized milk came from Dairy America (Fresno, CA, USA). Pure cane sugar was purchased from United States Sugar Co. (Clewiston, FL, USA) or from Wal-Mart (Bentonville, AR, USA). Nonfat ice cream stabilizer #19 was purchased from Opta Food Ingredient Inc. (Bedford, MA, USA). Clear sweet 36/48 corn syrup was purchased from Cargill Inc. (Minneapolis, MN, USA) and) and strawberry red liquid color, composed of water, citric acid, sodium benzoate, red 40 and blue 1, was procured from Sensient flavors Inc. (Fenton, MO).

4.2.2 Methods

4.2.2.1 Flavor Formulation

In this study, 10% fat and 4% fat with Simplese[®] were used to make the different ice creams. Due to the great difficulty in predicting the correlation of the concentration of flavor compounds with the intensity of the corresponding attributes, the effect of masking, and texture and flavor interaction, the five flavor compounds were adjusted only by gradual increases or decreases for the individual flavor concentrations. In order to compare the flavor profiles in 10% ice cream with that of Simplese[®] products, the formulating flavor system was designed according to the following principles:

- (1) Ethyl-3-methyl-3-phenylglycidate remained at the same concentration
- (2) *cis*-Hexen-1-ol was either kept at the same concentration or decreased by 25%.
- (3) Furaneol[™] was either kept at the same concentration or decreased by 25%.
- (4) γ -Undecalactone and α -ionone, two key flavor compounds, were spiked in

three levels (100%, 75% and 50% of original base flavoring formulation)

Their composition based on weight percentage is shown in Table 4-1. A total of thirty six flavor formulations containing all five artificial flavors (*cis*-3-hexen-1-ol at 2 levels, ethyl-3-methyl-3-phenylglycidate at 1 level, furaneolTM at 2 levels, γ -undecalactone at 3 levels and α -ionone at 3 levels; $2 \times 2 \times 1 \times 3 \times 3 = 36$) were used in ice cream with Simplese[®] for this study as shown in Table 4-2, and propylene glycol was used as the base for all the flavor formulations. The 10% ice cream was used as a control.

4.2.2.2 Ice Cream Manufacture

All ice creams were prepared in the Dairy Pilot Plant of the Food Science department at the University of Missouri-Columbia. Table 4-2 lists the basic formulations for both 4% and 10% fat ice cream mixes. A ten gallon batch was prepared for 10% ice cream and a twenty gallon batch for 4% ice cream with Simplese[®].

All dry ingredients, which were weighed out in advance, were mixed thoroughly with the weighed liquid ingredients (skim milk and cream) in a mixing vat and then agitation and heating were started. The 36/48 DE corn syrup was added slowly to the mix. The mixes were pasteurized using high temperature short time (HTST) at 81.5 °C for 25 s (Processing Machinery and Supply Co., Philadelphia, PA). Then, the pasteurized mixtures were homogenized in a two-stage homogenizer (APV-Gaulin GmbH, Philadelphia, PA) at 20.70 MPa for the first stage and 3.45 MPa at the second stage, respectively. The pasteurized ice cream mixes were cooled rapidly to below 10 °C and then aged overnight at 4 °C.

Each of the aged ice cream mixes was poured individually into a one gallon

bucket for the addition of flavor and color. Table 4-2 lists the thirty-six flavoring formulations. Each bucket was flavored with one of the flavor formulations (0.1%, v/v). Strawberry red liquid color was added to each bucket at the rate of 0.4 ml/L and mixed fully before freezing. A Taylor[®] freezer (Rockton, IL) was used to freeze the mixes to soft ice creams. Aliquot of the frozen ice creams were packed in 4oz Styrofoam containers with semi-transparent lids for sensory test. Lastly, the soft ice creams were stored at -40°C for hardening. Ice cream samples were made in triplicate according to Appendix D.

4.2.2.3 Sensory Evaluation of Ice Cream

4.2.2.3.1 Descriptive Panel and Training of Panelists

Thirty-seven ice cream samples were evaluated by eleven trained panelists. The panelists, who were all graduate students at the University of Missouri Columbia, were recruited and chosen based on their availability and willingness to participate in the project, and all signed a consent form for their participation (Appendix H). The eleven panelists were ballot-trained for four 2-hour training sessions on three consecutive days. In this study, the sensory attributes and related references were initially decided upon by the panel leader, according to previous studies, instead of the panelists. During the training period, the entire descriptive panel received instructions regarding the attributes, the references and the test procedures from the panel leader. Test samples, containing the products of 4% ice cream and 10% ice cream, were chosen for training by the panel leader. Panelists were instructed to understand that the perceived intensities of each reference provided were to be considered as being equal to 12 (i.e. 12 cm), and were asked to make a vertical line at the perceived intensities of the attributes for sampled ice cream across the 15 cm unstructured line scales anchored at the two ends with low

intensity = 0 and high intensity =15 using a paper ballot (Appendix I). To reduce carry-over effect, panelists were instructed to cleanse their palates by chewing a small piece of unsalted crackers and by rinsing with water between samples.

These attributes and references for the ice creams were slightly modified based in panelist feedback after panelists had participated in the first training session. Finally, a total of twenty five attributes containing appearance, flavor, texture and aftertaste, and fifteen references were used in the test. The attributes are listed in Table 3-3 together with their definitions and reference materials, where they were supplied.

Before the actual testing, an informal pretest was performed by a computerized sensory testing system to evaluate if all panelists had thoroughly understood these attributes and was able to communicate their perceptions correctly. The other purpose of this informal pretest was for the panelists to gain experience with a computerized test before performing the actual testing. The descriptive panel evaluated three randomly selected ice creams in duplicate in the pretest. After the pretest, the informal data were analyzed immediately by some statistical methods to evaluate significant differences for attributes. A personal training sessions focusing on inconsistent panelists were performed according to the results of the pretest.

4.2.2.3.2 Computerized Descriptive Test

Once the actual descriptive analysis was conducted, samples were evaluated in individual booths under normal light. A complete randomized block design was used for all tests. Each ice cream was made and evaluated in three replications; and for each study, the panelists evaluated each replication in three sub-replications. The order of presenting the thirty seven samples was determined by the Compusense five 4.6 program. Then the

thirty seven samples were divided into six sessions. Two sessions were held per day. Six samples were given in each of the first five sessions and seven samples were offered in the sixth session. Each sample was evaluated in triplicate, and all tests for the three replications were finished with a two week time period (See Appendix B). To avoid positional biases, the Compusense five 4.6 program (Guelph, Ontario, Canada) was employed to create three-digit random numbers for each sample and to perform randomized product presentation arrangements across each session. Prior to analysis, the ice cream samples were stored at least 24 hours at -13°C to -15 °C and served between -11°C to -15 °C. A series of six/seven samples were served nomadically per session. The perceived intensity of each attribute for each product was evaluated on the computer monitor controlled by the Compusense five 4.6 systems.

4.3 DATA ANALYSIS

In this study, each single replicate was finished before the next one was started, the replicate effect has a time interpretation. Mixed models of analysis of variance (ANOVA) were applied for the analysis of sensory data to determine significant differences among the products at $p < 0.05$. The main effect of product was designed a fixed effect and assessor, replicate, assessor-product interaction, assessor-replicate interaction and product-replicate interaction were considered random (Brockhoff 2001). LSMEANS with a pdiff procedure (a pairwise *t*-test) and a macro for converting mean score to letter groupings in Proc Mixed developed by Saxton (1998) were used to determine if there were significant differences between products based on a p -value < 0.05 level. Multivariate analysis of variance (MANOVA) using the Wilk's lambda

statistic was used to determine if there was an overall significant difference among products when comparison was based on using all the dependent variables.

A principal component analysis (PCA) was performed on the covariance matrix of the mean values of 37 ice creams (n=37) for all sensory attributes. Pearson's correlation coefficient with the average ratings of the original attributes (n=37) also was calculated to aid interpretation of the individual PCs in terms of the original attributes. Dissimilarity matrix using Euclidean distance for a rectangular array by comparing the rows or the columns was established to determine the similarity among products. Canonical variate analysis (CVA) of the raw data (n=37x3x11) was conducted to analyze the descriptive data and used to map treatments and attributes in a data space for predicting similarity. Cluster analysis (CA) was used to classify the ice cream products (via Ward's inertia method) on the basis of a combination of flavor, texture and aftertaste attributes for similarity comparison.

Descriptive data were analyzed using the SAS statistical software 8.2 version package (SAS Institute, Cary, NC, USA), and CA and Dissimilarity matrix were conducted using XLSTAT-Pro 2006 (XLSTAT, Addinsoft, USA). All SAS programs used are shown in Appendix G.

Table 4-1. Flavor formulation and its percentage for 10% and 4% ice creams with Simplese®

Formulation	Compound	Compound									
		Percentage of Original Formulation					Weight (g/100g Propylene Glycol)				
		<i>cis</i> 3-Hexeno-1-ol	Ethyl-3-methyl-3-phenylglycidate	Furaneol™	γ-Undecalactone	α-Ionone	<i>cis</i> 3-Hexeno-1-ol	Ethyl-3-methyl-3-phenylglycidate	Furaneol™	γ-Undecalactone	α-Ionone
Control	100	100	100	100	100	0.375	3.75	1.875	0.5	0.375	
Ice cream with Simplese®	S1	100	100	100	100	100	0.375	3.75	1.875	0.5	0.375
	S2	100	100	100	100	75	0.375	3.75	1.875	0.5	0.28
	S3	100	100	100	100	50	0.375	3.75	1.875	0.5	0.188
	S4	100	100	100	75	100	0.375	3.75	1.875	0.375	0.375
	S5	100	100	100	75	75	0.375	3.75	1.875	0.375	0.28
	S6	100	100	100	75	50	0.375	3.75	1.875	0.375	0.188
	S7	100	100	100	50	100	0.375	3.75	1.875	0.25	0.375
	S8	100	100	100	50	75	0.375	3.75	1.875	0.25	0.28
	S9	100	100	100	50	50	0.375	3.75	1.875	0.25	0.188
	S10	100	100	75	100	100	0.375	3.75	1.4	0.5	0.375
	S11	100	100	75	100	75	0.375	3.75	1.4	0.5	0.28
	S12	100	100	75	100	50	0.375	3.75	1.4	0.5	0.188
	S13	100	100	75	75	100	0.375	3.75	1.4	0.375	0.375
	S14	100	100	75	75	75	0.375	3.75	1.4	0.375	0.28
	S15	100	100	75	75	50	0.375	3.75	1.4	0.375	0.188
	S16	100	100	75	50	100	0.375	3.75	1.4	0.25	0.375
	S17	100	100	75	50	75	0.375	3.75	1.4	0.25	0.28
	S18	100	100	75	50	50	0.375	3.75	1.4	0.25	0.188
	S19	75	100	100	100	100	0.28	3.75	1.875	0.5	0.375
	S20	75	100	100	100	75	0.28	3.75	1.875	0.5	0.28
	S21	75	100	100	100	50	0.28	3.75	1.875	0.5	0.188
	S22	75	100	100	75	100	0.28	3.75	1.875	0.375	0.375
	S23	75	100	100	75	75	0.28	3.75	1.875	0.375	0.28
	S24	75	100	100	75	50	0.28	3.75	1.875	0.375	0.188
	S25	75	100	100	50	100	0.28	3.75	1.875	0.25	0.375
	S26	75	100	100	50	75	0.28	3.75	1.875	0.25	0.28
	S27	75	100	100	50	50	0.28	3.75	1.875	0.25	0.188
	S28	75	100	75	100	100	0.28	3.75	1.4	0.5	0.375
	S29	75	100	75	100	75	0.28	3.75	1.4	0.5	0.28
	S30	75	100	75	100	50	0.28	3.75	1.4	0.5	0.188
	S31	75	100	75	75	100	0.28	3.75	1.4	0.375	0.375
	S32	75	100	75	75	75	0.28	3.75	1.4	0.375	0.28
S33	75	100	75	75	50	0.28	3.75	1.4	0.375	0.188	
S34	75	100	75	50	100	0.28	3.75	1.4	0.25	0.375	
S35	75	100	75	50	75	0.28	3.75	1.4	0.25	0.28	
S36	75	100	75	50	50	0.28	3.75	1.4	0.25	0.188	

Table 4-2. Ice cream formulation per 100g basis for 10% and 4% ice cream with Simplese[®]

Product Ingredient	10%	4%
	Regular	Simplese [®] (S) ^g
Nonfat Dry milk (0% fat; 97%NFMS) ^a	6	6.4
Skim milk (0% fat; 8.25% NFMS) ^b	44.9	55.6
Cream (35% fat; 5.5% NFMS) ^c	28.6	11.5
Cane Sugar (100% Total Solids) ^d	12.0	12.0
Corn Syrup (80% Total Solids) ^e	8.0	8.0
Stabilizer ^f	0.5	0.5
Fat replacer	0	6
Total Milk Fat	10.01	4.025
Total Non-fat Milk Solids (NFMS)	11.1	11.1
Total Solids	40.05	40.05

^a Nonfat dry milk (Dairy America, Inc., CA): Spray process grade A nonfat dry milk made by pasteurized milk

^b Skim milk (Prairie Farms Dairy, Prairie farms Inc., IL)

^c Cream (Prairie Farms Dairy, Inc., IL) Heavy whipping cream

^d Cane sugar (United State Sugar Corporation, DL) Pure cane sugar

^e Corn Syrup (Cargill Incorporated, MO) Clear sweet 36/48 corn syrup

^f Stabilizer (Opta Food Ingredient Inc., MA) Nonfat ice cream stabilizer #19

The composition of Stabilizer /emulsifier 19 is whey protein, microcrystalline cellulose, sodium carboxyl-methyl cellulose, mono-, di-glycerides, carrageenan maltodextrin and polysorbate 80.

^g Simplese[®] (CP Kelco, San Diego, CA) Microparticulated whey protein concentrate 53 (53 grams retained on the sieve while Simplese[®] was heat treated).

Table 4-3. Attribute reference and definition for descriptive panel

Attribute		Definition / Direction	Reference
	Pink color	Light pink to dark pink under white light.	0.08 % strawberry red in skim milk
	Dense	Degree of the sample holding together as being scraped off	
Flavor	Sweetness	Taste on the tongue elicited by sugars or other high potency sweeteners	20% (w/v) sugar solution
	Strawberry flavor	The intensity or strength of strawberry flavor during mastication	Strawberry syrup
	Candy flavor	The intensity of candy flavor	0.0014% candy flavored in whole/ ice cream
	Cooked sugar flavor	The intensity of cooked sugar flavor	0.0007% furaneol TM in whole milk/10% ice cream
	Grassy flavor	The intensity of grassy flavor as reference	0.00014% <i>cis</i> -3-hexanol in skim milk
	Violet flavor	The intensity of violet flavor as reference	1.86x 10 ⁻⁴ % α -ionone in skim milk
	Peach flavor	The intensity of peach flavor as reference	0.00014% γ -undecalactone in skim milk
	Milky flavor Condensed milk flavor	The intensity of whole milk flavor as reference The intensity of condensed milk as reference	Whole milk Carnation [®] Condensed milk
Texture	Coldness	A chilling of the tongue and palate soon after the sample is placed in the mouth	Heavy whipping cream Pudding Heavy whipping cream Marshmallow cream
	Thickness	Degree of thickness of the ice cream after melting in mouth	
	Smoothness	The force necessary to compress sample against the roof of the mouth	
	Creaminess	Degree of fat-like, full-bodied liquids after melting in mouth	
	Mouth coating	Degree of fatty mouth or coated mouth after swallowing	
Aftertaste	Sweet aftertaste	The intensity of sugar taste residue after swallowing	The same reference with sweetness
	Strawberry aftertaste	The intensity of strawberry flavor residue after swallowing	The same reference with strawberry flavor
	Candy aftertaste	The intensity of candy flavor residue after swallowing	The same reference with candy flavor
	Grassy aftertaste	The intensity of grassy flavor residue after swallowing	The same reference with glassy flavor
	Cooked sugar aftertaste	The intensity of cooked sugar flavor after swallowing	The same reference with cooked sugar flavor
	Violet aftertaste	The intensity of violet flavor residue after swallowing	The same reference with violet flavor
	Peach aftertaste	The intensity of peach flavor residue after swallowing	The same reference with peach flavor
	Milky aftertaste	The intensity of coating mouth after swallowing	The same reference with milky flavor
	Astringency	The intensity of dry mouth after swallowing	1 bag brewed tea in 250 ml hot water

Table 4-4. Summary of mixed-ANOVA of 37 ice creams for each attribute measure

Effect		Num DF	Den DF	F-Ratio	Effect		Num DF	Den DF	F-Ratio	
Appearance	PCL	36	68	2.96***	Texture	COD	36	360	0.66	
	DEN	36	72	0.84		SMO	36	84.3	1.34	
Flavor	SWT	36	62.8	1.01		THK	36	76.6	0.74	
	STR	36	62.6	0.66		CRE	36	72.1	1.15	
	CAN	36	65.4	0.65		MCO	36	72	1.11	
	COK	36	72	1.32		Aftertaste	SWTA	36	79.1	1.15
	GRA	36	1152	1.31			STRA	36	75	0.74
	VIO	36	360	1.31			CANA	36	72.3	0.81
	PEA	36	56.6	1.09			GRAA	36	71.7	0.75
	MIL	36	360	1.27	VIOA		36	1152	1.16	
	COM	36	1152	1.21	PEAA		36	72	0.93	
* ** *** Significant at P<0.05, 0.01, and 0.001, respectively					COKA		36	1152	1.53*	
					ASTR		36	67.2	0.72	
					MILA		36	1152	0.96	

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

4.4 RESULTS AND DISCUSSION

4.4.1 Analysis of Variance (ANOVA)

A mixed model was used to understand the differences among attributes for the various products. Results in Table 4-4 show that there were no significant differences for most attributes except for pink color ($P < 0.01$) and cooked sugar flavor aftertaste ($P < 0.05$). In comparison with the result of the fixed model ANOVA, products differed in the attributes pink color, dense, cooked sugar flavor, thickness, smoothness, mouth coating, sweetness aftertaste and cooked sugar flavor aftertaste. In addition, according to the F-values, texture attributes and flavor attributes differentiated between samples. Smoothness and cooked sugar flavor were the most important attributes in ice cream products.

In the thirty-seven ice cream products, four flavor compounds were adjusted in different levels except for ethyl-3-methyl-3-phenylglycidate. In a previous study, the five flavor compounds were spiked separately at 200% of base concentration in full-fat ice cream and low-fat ice cream with or without fat mimetics and it was found that cooked sugar flavor had a stronger intensity in the 4% ice cream with Simplese[®] and the 10% ice cream products, and that peach flavor and violet flavor had weak intensities in both ice creams. In addition, the intensities of the peach and violet flavor attributes were sensitive to the change in spiking concentration of γ -undecalactone and α -ionone, and ice creams with Simplese[®] had slightly higher intensities in both flavors, compared with 10% ice cream. That was the primary reason why γ -undecalactone and α -ionone were adjusted to 100%, 75%, and 50% of base concentration. *cis*-Hexen-1-ol was reduced by 25% of base concentration because of its potential influence for increasing violet flavor intensity, although its corresponding attribute grassy was not significantly affected by changes in

fat content and flavor concentration.

In general, panelists could not distinguish the differences among the corresponding attributes of the five flavor compounds when the flavor concentrations were changed in the study. Several reasons could explain this situation, including (1) cooked sugar flavor was perceived very strong in Simplese[®] and 10% ice cream products so that it was difficult to differentiate the slight differences by judge evaluations. (2) Sweetness intensity usually affected flavor profile. The Simplese[®] products were too sweet or had a high intensity in mouthfeel causing changes in flavor perception by the judges. (3) Due to a high intensity in violet and peach flavor in low fat environment (without fat mimetics), the two flavor intensities could be masked by the cooked sugar flavor in Simplese[®] products. (4) These samples were similar in many attributes causing a biased evaluation by judges. (5) Psychological effects at the cognitive level (Stampanoni 1993). Judges did not use a wide range of the scale, and the texture intensity of the products could have affected taste and flavor perception (Stampanoni and others 1996)

Overall, among products, 10% ice cream showed on average less intensity in attributes, such as pink color, sweetness, strawberry flavor, candy flavor, cooked sugar flavor, milky flavor, condensed milk, coldness, thickness, smoothness, creaminess, mouth coating, sweetness aftertaste, strawberry aftertaste, candy flavor aftertaste, cooked sugar aftertaste and milky aftertaste (Appendix F). These results are in partial agreement with previous studies. Comparing these results with another group of judges from previous studies, the primary differences were the three textural attributes smoothness, creaminess and mouth coating as well as milky flavor and milky flavor aftertaste. Previous studies indicated smoothness, creaminess and mouth coating had higher intensities in 10% ice cream than

in 4% ice cream with Simplese[®], although there were no significant differences. Additionally, 10% ice cream had significantly higher intensity in milky flavor than 4% ice cream with or without fat mimetics. Ohmes and others (1998) reported ice cream made with Simplese[®] was scored lower in smoothness and mouth coating than ice cream containing milk fat but they were no significant differences either. In this study, the results showed Simplese[®] products had higher intensities in milky flavor, smoothness, creaminess and mouth coating than did 10% ice cream. Apparently, milky flavor had a positive correlation with creaminess, smoothness and mouth coating. Stampanoni and others (1996) indicated that caramel, which is similar to cooked sugar flavor, was highly correlated with milky flavor and sweetness. Thus, cooked sugar flavor could be an influential factor for milky flavor intensity. In addition, the variation of panel evaluations of these attributes could be due to either unbalanced product distributions (36 Simplese[®] products and one 10% ice cream) causing a biased scale or different understanding for the mentioned descriptive terms.

4.4.2 Multivariate Analysis of Variance (MANOVA)

Twenty-five attributes, including two appearance attributes, nine flavor attributes, five texture attributes and nine aftertaste attributes, were used to describe the differences in the sensory properties of the thirty-six ice cream with Simplese[®] and 10% ice cream as control sample. A mixed model multivariate analysis of variance (MANOVA) was performed to evaluate whether significant differences existed among products (Appendix G).

The p-value of Wilk's lambda F Statistic test for products ($P < 0.001$) is less than 0.05 which showed they were significant (Table 3-13). Compared with the ANOVA results, the differences could come from pink color attributes and cooked sugar flavor aftertaste. MANOVA also was measured by using only flavor and texture attributes without pink color and the p-value of Wilk's lambda F Statistic test was 0.0062. In other words, the thirty-seven products still were significantly different when only flavor and texture attributes were considered.

Table 4-5. Statistics and significance of various effects on all attribute measures for 37 ice creams

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.048	1.24	900	7055.8	<.0001
Pillai's Trace	2.683	1.20	900	9000	<.0001
Hotelling-Lawley Trace	3.478	1.29	900	4646.3	<.0001
Roy's Greatest Root	0.819	8.19	36	360	<.0001

4.4.3 Principal Component Analysis (PCA)

Principal component analysis was used to describe the interrelationships among multiple dependent variables and among the thirty seven ice cream products. Because the descriptive data were all measured on the same scale and the limited variance, covariance matrix was used because it is more appropriate for the performed PCA and also accounts for judges' different usage of scales. In general, a two dimensional graph is suggested to display visual representation of loaded attributes and products in PCA technique (Borgogone and others 2001). Only heavily loaded attributes should be used to describe the nature of each principal component. Although all loadings are meaningful in PCA, small loadings mean that the factor is not related to those variables (Lawless and Heymann 1998).

Figure 4-1 to Figure 4-3 summarize the first three PCs, which accounted for 57.27% of the total variance in the data set. The first dimension explained 29.74% of the variance and PCII and PCIII described the remaining 15.58% and 11.95%, respectively. PCA result showed pink color and texture attributes were more crucial than flavor attributes among products. For the corresponding attributes of the five flavor compounds, cooked sugar flavor was more important than others in this study due to a strong intensity in both 10% ice cream and Simplese[®] products. The first axis was dominated primarily by pink color, thickness, mouth coating, smoothness, candy flavor, candy flavor aftertaste, cooked sugar flavor, cooked sugar aftertaste and astringency. The second dimension controlled pink color, dense, creaminess, coldness, violet flavor, milky flavor, milky favor aftertaste, condensed milk, strawberry flavor aftertaste, candy flavor aftertaste and sweetness flavor aftertaste. On the third axis, violet flavor, violet flavor aftertaste, peach flavor, peach flavor aftertaste and grassy flavor are the influential attributes. In other

words, PCA result showed that these products have great variations in cooked sugar flavor and cooked sugar aftertaste instead of violet flavor and peach flavor, which were the important attributes in the previous study. Reviewing the result of the ANOVA, 10% ice cream was significantly different from twenty Simplese[®] products (Appendix F), and the Simplese[®] products did not differ significantly amongst each other for cooked sugar aftertaste. Further analysis demonstrated that candy flavor, cooked sugar flavor and cooked sugar aftertaste are mainly loaded on PC I. By contrast, the primary drivers of violet flavor and peach flavor are found in PCII vs PC III and PC I vs PC III graphs, respectively.

Most texture attributes were drivers in the PC I vs PC II plot, except for coldness. Coldness was loaded in the opposite direction of other texture attributes on PC II and PC III. In this study, smoothness, creaminess, thickness and mouth coating were highly correlated with each other as shown in Table 4-6 ($p < 0.05$ at Pearson coefficients). In addition, milky flavor, milky flavor aftertaste and condensed milk flavor had positive correlations with mouth coating. Milky favor and milky flavor aftertaste also had significant positive correlations with creaminess.

The flavor attributes were positively correlated with their corresponding aftertaste attributes. For example, sweetness, strawberry, candy flavor, grassy flavor, cooked sugar flavor, violet and peach flavor had significant positive correlations with their aftertastes, respectively. However, a positive significant correlation also exists between sweetness and strawberry flavor, condensed milk flavor or candy flavor aftertaste. Violet flavor and violet flavor aftertaste were also positively correlated with peach flavor and peach flavor aftertaste. Grassy flavor was correlated positively with violet and peach flavor. Previous studies showed that these relationships also existed among these attributes of ice cream

with or without the three fat mimetics except for sweetness and candy flavor aftertaste.

Most loadings were positioned in the positive X dimension except for grassy flavor aftertaste. The PCA biplot indicated that grassy flavor aftertaste is significantly different between 10% ice cream and the Simplese[®] products. On average, the 10% ice cream had a higher intensity in grassy flavor aftertaste. Panelists evaluated the grassy flavor aftertaste from a high of 3.6 (10% ice cream) to a low of 2.8 (S35). In a previous study, another panelist group judged grassy flavor aftertaste in ice cream with Simplese[®] to be slightly higher in intensity (2.36) than in 10% ice cream (2.29), although no significant differences existed between the two products. From the PCA map (Figure 4-1), grassy flavor aftertaste is not an important factor among these products due to the short length of its loading. It is clear that products such as S1, S4, S23, S24, S25 and S30 have a positive correlation with grassy favor aftertaste (Figure 4-4). However, compared with the average data, S1 (3.48) and S4 (3.5) were more similar to 10% ice cream (3.6) in the intensity of grassy flavor aftertaste than was S23 to S25 (3.14 to 3.3). Consequently, grassy flavor aftertaste is not a primary influential factor and other attributes have a greater influence on the Simplese[®] products.

The 10% ice cream was loaded at the opposite direction of most Simplese[®] products on the PCA map (Figure 4-4). From the ANOVA results, the 10% ice cream was on average lower in intensity for most of attributes except for dense, grassy flavor, peach flavor, violet flavor, grassy flavor aftertaste, peach flavor aftertaste and astringency. In other words, 10% ice cream was loaded on the left side of the map primarily due to a low intensity in attributes, such as pink color, sweetness, cooked sugar flavor, cooked sugar flavor aftertaste, milky flavor, thickness, smoothness, creaminess, mouth coating and milky flavor aftertaste.

Products, such as S33, S36, S26, S27, S16 and S18 were loaded at the top right side of the PCA map in the PC I vs PCII plot (Figure 4-4). Both S33 and S36 were high in intensity of cooked sugar flavor, milky flavor, sweet aftertaste, cooked sugar aftertaste, smoothness and mouth coating. However, S36 was significantly higher in intensity of sweetness, candy flavor and candy flavor aftertaste (Figure 4-5) and had lower intensity in creaminess (Figure 4-6) than did S33. Both S26 and S27 had higher intensities in milky flavor, thickness, smoothness, creaminess, mouth coating, sweetness aftertaste, strawberry flavor aftertaste and astringency (Figure 4-5). Both S16 and S18 had higher intensities in sweetness, strawberry flavor and lower intensity in grassy flavor. In addition, S16 had higher intensities in condensed milk flavor, strawberry flavor aftertaste and cooked sugar aftertaste. The primary properties of S33 and S36 were strong cooked sugar flavor, smoothness and mouth coating. The S26 and S27 had more highly perceived texture attributes.

Nine products, including S10, S29, S35, S13, S15, S8, S2, S34 and S11 were positioned at the right-bottom side of the PCA map (PC I vs PCII; Figure 4-4). Their characteristics show roughly higher intensities in pick color, astringent attributes and relatively low intensities in creaminess, mouth coating, and milky flavor and milky flavor aftertaste. Among these nine products, S29, S10, S11 and S2 had the opposite direction compared to the other five products for PC III (Figure 4-6), probably because the four products had strong astringent intensity.

Figure 4-6 shows S3 and S5 had stronger peach flavor than the other samples, and S1, S4, S7, S10 and S11 had a stronger violet flavor and violet flavor aftertaste. Products, such as S23, S24, S25, S34 and S35, were weaker in peach flavor and peach flavor

aftertaste but stronger in intensity of violet flavor and violet flavor aftertaste (Figure 4-6).

Figure 4-4 indicated S4 was the closest in characteristics to 10% ice cream. S4, S24, S1, S25, S23 and S30 were loaded in the left bottom quarter on the PCA map. These six Simplese[®] products had lower intensities in cooked sugar flavor, cooked sugar flavor aftertaste, mouth coating, smoothness and thickness. Figure 4-5 (PC I vs PC III) showed S4, S21, S20 and S22 had characteristics closer to that of 10% ice cream.

The primary difference between S4 and S6 was the violet flavor intensity. S4 had a higher violet intensity than S6 or the 10% ice cream. In addition, although S4, S21 or S22 and S6 or S24 had different properties in violet flavor intensity, they have a very similar intensity in cooked sugar flavor. On the other hand, eleven products such, as S6, S22, S32, were loaded at the top right side on PC I and PC II (Figure 4-4). They had similar properties in texture attributes, cooked sugar favor, cooked sugar aftertaste and sweetness with products, such as S1, S4, S24 and S25, but they had a weak violet flavor or peach flavor intensity.

Overall, the six products S4, S24, S21, S22, S6 and S32 had similar characteristics to 10% ice cream because they had lower intensities in cooked sugar flavor, cooked sugar aftertaste, sweetness, and condensed milk. Among them, S4, S21 and S22 had a similar violet flavor and peach flavor intensity to 10% ice cream, while S6, S32 and S24 had lower violet flavor and peach flavor compared to the 10% ice cream. When comparing the correlation matrix for dissimilarity, using Euclidean distance, among the thirty seven ice cream with flavor and texture attributes (Table 4-7), S4, S30, S1, S21, S6, S24 had lower dissimilarities with 10% ice cream, which is in general agreement with the PCA analysis.

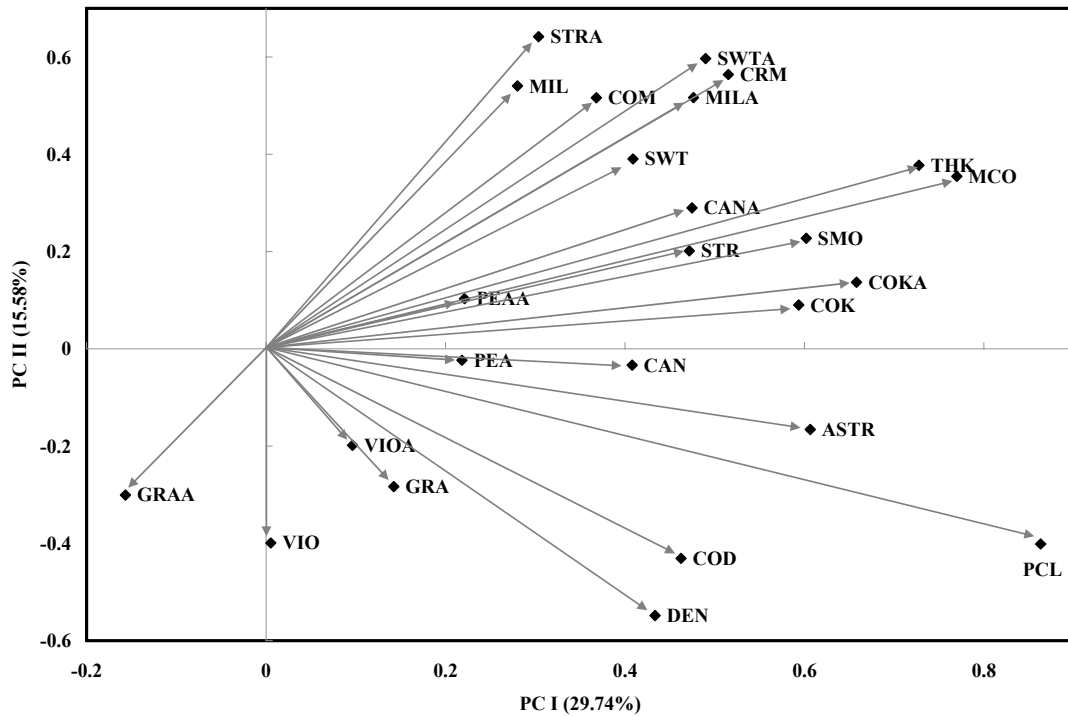


Figure 4-1. Principal component analysis of 25 sensory attributes for 37 ice creams on PC I vs PC II (Covariance model).

Parenthesis denotes the percent explained by the corresponding PC dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

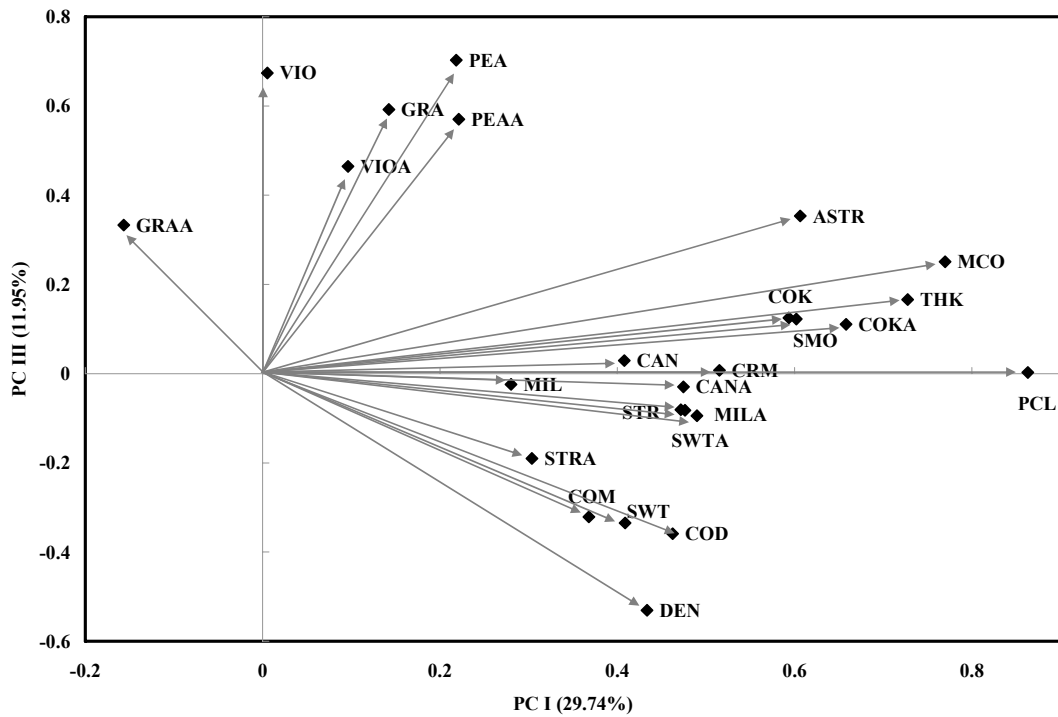


Figure 4-2. Principal component analysis of 25 sensory attributes for 37 ice creams on PC I vs PC III (Covariance model).

Parenthesis denotes the percent explained by the corresponding PC dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

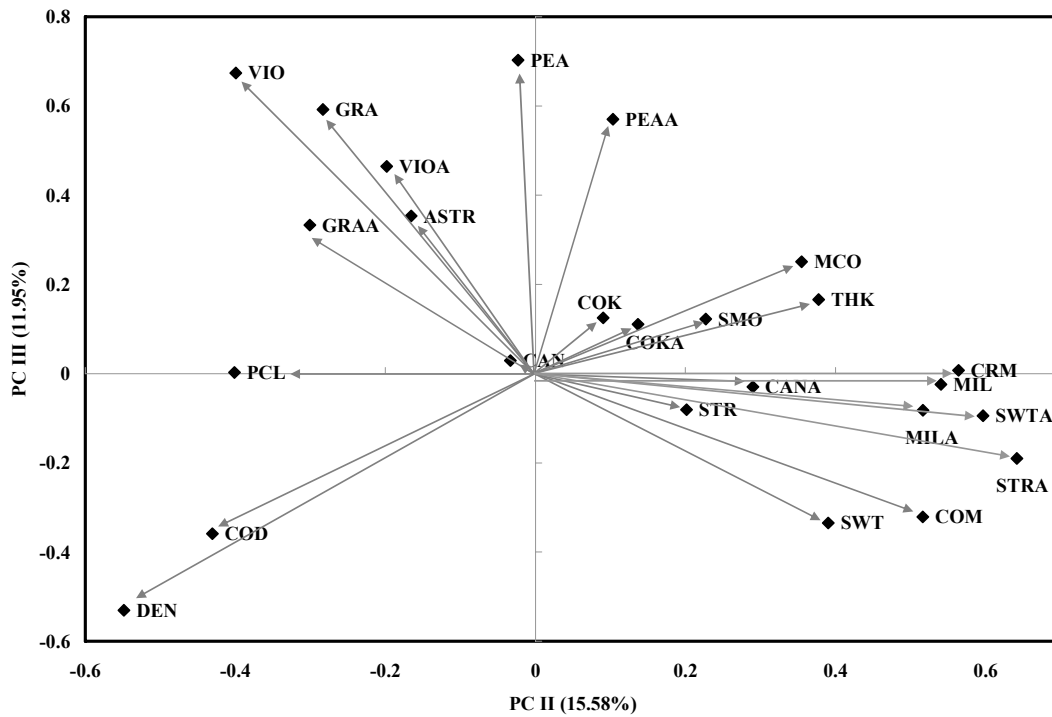


Figure 4-3. Principal component analysis of 25 sensory attributes for 37 ice creams on PC II vs PC III (Covariance model).

Parenthesis denotes the percent explained by the corresponding PC dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

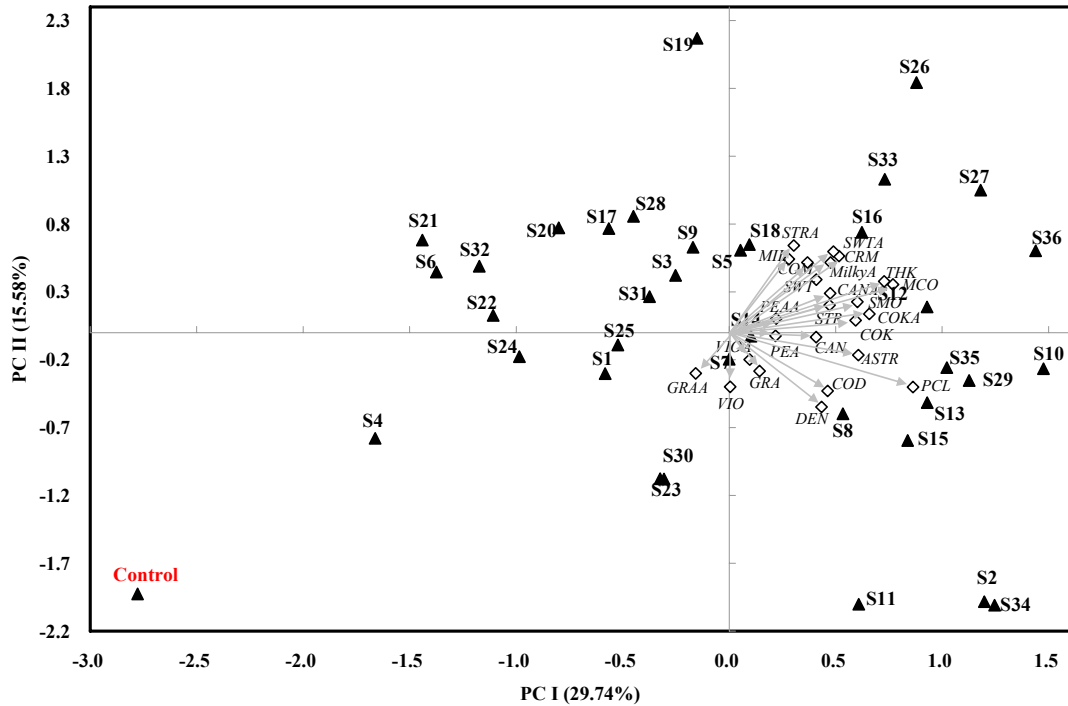


Figure 4-4. Principal component analysis of 37 ice creams with sensory attributes on PC I vs PC II (Covariance model).

Parenthesis denotes the percent explained by the corresponding PC dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

Control 10% ice cream S (Numeric Value): Different flavored ice cream with Simplesse® (See Table 4-1)

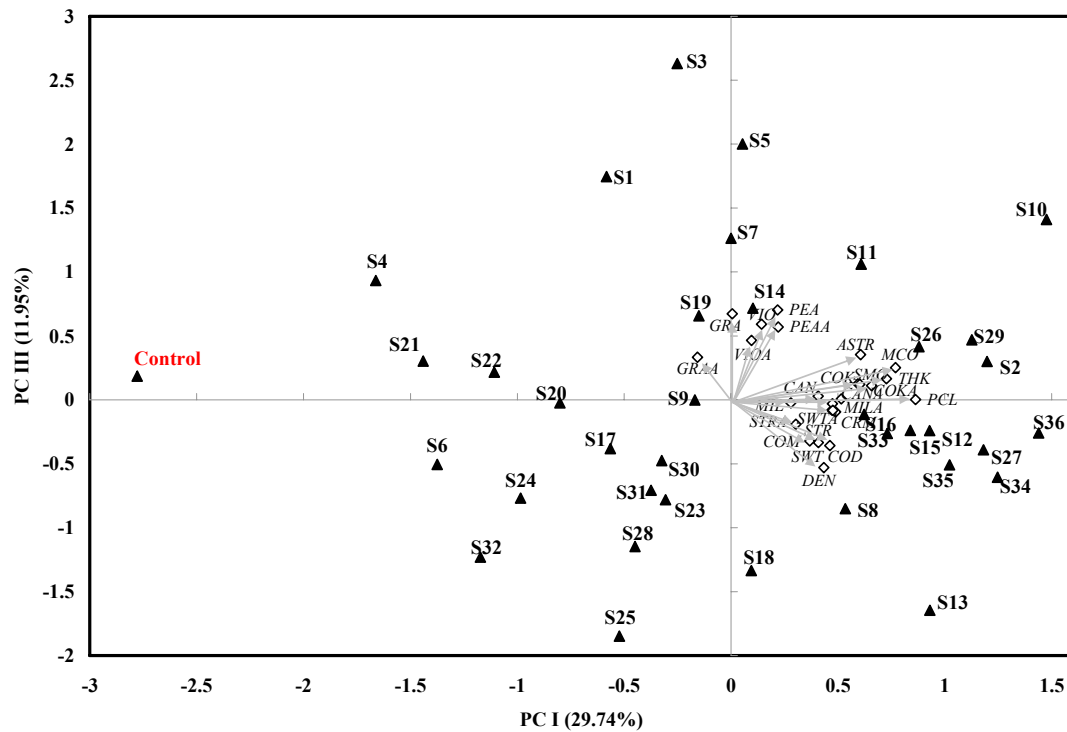


Figure 4-5. Principal component analysis of 37 ice creams with sensory attributes on PC I vs PC III (Covariance model).

Parenthesis denotes the percent explained by the corresponding PC dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

Control 10% ice cream S (Numeric Value): Different flavored ice cream with Simplese[®] (See Table 4-1)

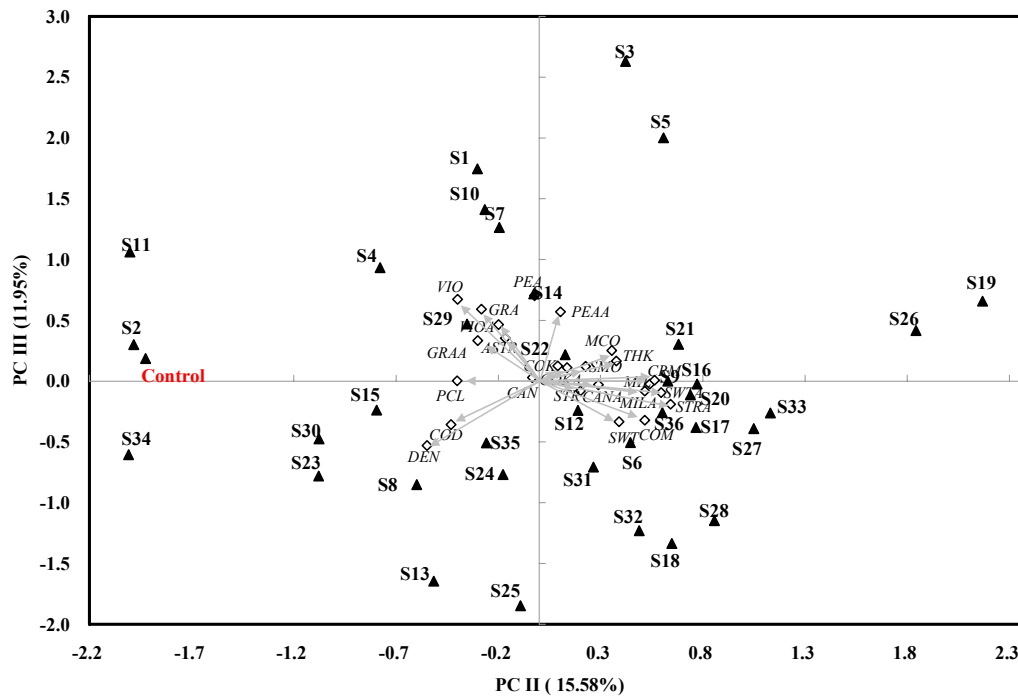


Figure 4-6. Principal component analysis of 37 ice creams with sensory attributes on PC II vs PC III (Covariance model).

Parenthesis denotes the percent explained by the corresponding PC dimension.

\$PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

Control 10% ice cream S (Numeric Value): Different flavored ice cream with Simplexse®
(See Table 4-1)

Table 4-6. Pearson correlation of 25 sensory attributes for ice cream and ice cream with Simplesse® (n=37)

	PCL	DEN	SWT	STR	GRA	CAN	COK	VIO	PEA	MIL	COM	COD	SMO	THK	CRE	MCO	SWTA	STRA	GRAA	CANA	COKA	VIOA	PEAA	MILA	ASTR	
PCL	1.00																									
DEN	0.47	1.00																								
SWT	0.33	-0.08	1.00																							
STR	0.38	0.11	0.39	1.00																						
GRA	0.23	-0.05	-0.30	-0.02	1.00																					
CAN	0.33	0.18	0.21	0.33	-0.06	1.00																				
COK	0.43	0.07	0.21	0.10	0.01	0.27	1.00																			
VIO	0.14	-0.06	-0.26	-0.06	0.36	0.23	-0.08	1.00																		
PEA	0.17	-0.13	-0.23	0.16	0.40	0.06	0.03	0.50	1.00																	
MIL	-0.02	-0.02	0.32	0.35	-0.04	0.22	0.07	-0.13	0.32	1.00																
COM	0.10	0.15	0.51	0.38	-0.13	0.06	0.12	-0.29	0.04	0.54	1.00															
COD	0.63	0.53	0.32	0.29	-0.12	0.15	0.09	0.00	-0.03	-0.01	0.04	1.00														
SMO	0.34	0.15	0.10	0.06	0.02	0.15	0.39	-0.11	0.21	0.26	0.09	0.10	1.00													
THK	0.48	0.01	0.29	0.26	0.17	0.16	0.50	-0.11	0.21	0.31	0.31	0.04	0.51	1.00												
CRE	0.15	0.02	0.20	0.24	-0.11	0.12	0.26	-0.19	0.05	0.33	0.30	-0.09	0.62	0.72	1.00											
MCO	0.52	0.06	0.23	0.48	0.30	0.17	0.39	0.00	0.32	0.44	0.40	0.03	0.59	0.76	0.68	1.00										
SWTA	0.21	-0.07	0.64	0.49	-0.20	0.24	0.24	-0.09	0.03	0.44	0.70	0.13	0.22	0.45	0.48	0.49	1.00									
STRA	0.05	-0.13	0.56	0.54	-0.23	0.19	0.13	-0.25	-0.15	0.39	0.62	-0.13	0.08	0.35	0.39	0.45	0.78	1.00								
GRAA	-0.07	0.07	-0.28	-0.07	0.65	-0.26	-0.19	0.21	0.28	-0.14	-0.09	-0.21	-0.09	-0.23	-0.29	-0.08	-0.20	-0.21	1.00							
CANA	0.33	0.05	0.52	0.26	-0.07	0.43	0.13	0.08	0.09	0.39	0.44	0.12	0.26	0.32	0.31	0.35	0.62	0.42	-0.19	1.00						
COKA	0.43	0.16	0.25	0.12	0.03	0.26	0.78	-0.06	0.12	0.08	0.19	0.09	0.47	0.62	0.36	0.45	0.24	0.19	-0.19	0.15	1.00					
VIOA	0.13	-0.06	-0.13	0.07	0.11	0.10	0.17	0.61	0.21	-0.17	-0.18	0.06	-0.05	-0.05	-0.04	0.07	0.17	0.06	0.17	0.15	0.05	1.00				
PEAA	0.07	-0.10	-0.23	0.07	0.22	0.18	0.18	0.35	0.63	0.08	0.11	-0.22	0.23	0.18	0.14	0.31	0.13	0.05	0.15	0.06	0.37	0.20	1.00			
MILA	0.17	0.02	0.32	0.41	0.02	0.12	0.17	-0.31	0.03	0.31	0.45	0.11	0.31	0.54	0.58	0.57	0.52	0.42	-0.16	0.30	0.42	-0.14	0.24	1.00		
ASTR	0.52	0.19	-0.05	0.15	0.35	0.33	0.52	0.18	0.22	-0.03	-0.17	0.12	0.50	0.44	0.31	0.45	0.10	-0.10	0.14	0.17	0.48	0.23	0.35	0.31	1.00	

In bold, significant values (except diagonal) at the level of significance alpha=0.050 (two-tailed test)
 PCL: Pink color, DEN: Dense, RMT: Rate of melt. SWT: Sweetness, STR: Strawberry flavor, CAN: Candy flavor, COK: Cooked sugar flavor, GRA: Grassy flavor, VIO: Violet flavor, PEA: Peach flavor, MIL: Milky flavor, COM: Condensed milk flavor, COD: Coldness, THK: Thickness, SMO: Smoothness, CRE: Creaminess, MCO: Mouth coating, SWTA: Sweet aftertaste, STRA: Strawberry aftertaste, CANA: Candy aftertaste, GRAA: Grassy aftertaste, VIOA: Violet aftertaste, PEAA: Peach aftertaste, COKA: Cooked sugar aftertaste, ASTR: Astringency, MILA: Milky aftertaste

Table 4-7. Proximity matrix (Euclidean distance) of ice cream and ice cream with Simplesse® with flavor, texture and aftertaste attributes

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	S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36		
S0	0.00																																						
S1	1.83	0.00																																					
S2	2.17	0.96	0.00																																				
S3	2.20	0.73	0.99	0.00																																			
S4	1.72	1.30	1.57	1.61	0.00																																		
S5	2.45	1.13	1.02	0.83	1.69	0.00																																	
S6	1.92	1.59	1.52	1.63	1.72	1.67	0.00																																
S7	2.30	1.12	0.91	1.00	1.56	1.12	1.47	0.00																															
S8	2.25	1.33	1.23	1.34	1.76	1.38	0.96	1.12	0.00																														
S9	2.38	1.69	1.48	1.63	1.90	1.63	1.03	1.43	0.85	0.00																													
S10	2.77	1.48	1.43	1.29	2.32	1.27	1.86	1.60	1.48	1.80	0.00																												
S11	2.07	0.92	1.23	0.99	1.56	1.23	1.94	1.37	1.69	1.88	1.86	0.00																											
S12	2.56	1.49	1.46	1.43	2.16	1.50	1.73	1.53	1.34	1.47	1.50	1.76	0.00																										
S13	2.45	1.46	1.26	1.50	1.89	1.38	1.28	1.28	0.83	1.04	1.54	1.74	0.99	0.00																									
S14	2.41	1.29	1.24	1.32	1.80	1.40	1.64	1.31	1.26	1.45	1.75	1.40	1.78	1.48	0.00																								
S15	2.46	1.34	1.23	1.42	1.62	1.38	1.56	1.30	1.16	1.39	1.97	1.35	1.74	1.31	1.00	0.00																							
S16	2.75	1.35	1.27	1.30	1.91	1.21	1.55	1.33	1.02	1.29	1.45	1.58	1.29	0.91	1.24	1.05	0.00																						
S17	2.22	1.36	1.55	1.57	1.97	1.70	1.72	1.68	1.47	1.67	2.02	1.72	1.36	1.33	1.45	1.51	1.46	0.00																					
S18	2.60	1.71	1.58	1.66	1.99	1.36	1.47	1.56	1.15	1.25	1.92	1.73	1.52	0.98	1.58	1.19	1.03	1.48	0.00																				
S19	2.82	1.49	1.63	1.46	2.16	1.37	1.94	1.70	1.53	1.76	1.63	1.76	1.42	1.36	1.39	1.36	1.10	1.12	1.33	0.00																			
S20	2.27	1.25	1.29	1.47	1.56	1.40	1.35	1.23	1.11	1.46	1.66	1.74	1.66	1.18	1.54	1.15	1.18	1.49	1.25	1.42	0.00																		
S21	1.91	1.30	1.56	1.41	1.52	1.38	1.47	1.50	1.40	1.73	2.04	1.61	1.70	1.55	1.68	1.46	1.58	1.38	1.37	1.60	1.20	0.00																	
S22	2.12	1.24	1.36	1.37	1.46	1.39	1.22	1.08	1.15	1.34	1.80	1.48	1.83	1.46	1.22	1.21	1.37	1.67	1.49	1.74	1.07	1.33	0.00																
S23	2.06	1.27	1.27	1.49	1.53	1.61	1.28	1.27	1.30	1.66	1.99	1.69	1.91	1.48	1.53	1.29	1.51	1.49	1.60	1.74	0.97	1.11	1.23	0.00															
S24	1.94	1.31	1.32	1.55	1.52	1.62	1.26	1.41	1.26	1.48	2.15	1.69	1.75	1.31	1.48	1.31	1.46	1.08	1.36	1.65	1.16	1.04	1.28	0.81	0.00														
S25	2.28	1.58	1.54	1.75	1.62	1.71	1.50	1.43	1.30	1.43	2.24	1.73	1.62	1.14	1.48	1.17	1.36	1.25	1.06	1.54	1.16	1.32	1.25	1.34	1.00	0.00													
S26	3.17	1.85	1.67	1.60	2.61	1.46	1.92	1.55	1.49	1.81	1.52	2.04	1.40	1.36	1.60	1.61	1.22	1.71	1.55	1.23	1.65	1.88	1.83	1.87	1.97	1.84	0.00												
S27	2.95	1.71	1.51	1.54	2.28	1.37	1.69	1.62	1.27	1.53	1.34	2.01	1.09	0.97	1.60	1.52	0.95	1.56	1.28	1.05	1.45	1.79	1.86	1.80	1.80	1.67	0.98	0.00											
S28	2.46	1.50	1.59	1.64	1.79	1.65	1.50	1.60	1.26	1.38	2.08	1.76	1.63	1.20	1.24	1.05	1.00	1.03	1.02	1.09	1.18	1.36	1.40	1.33	1.05	0.91	1.65	1.40	0.00										
S29	2.78	1.29	1.34	0.98	2.02	1.09	2.04	1.32	1.47	1.94	1.48	1.55	1.62	1.56	1.39	1.45	1.22	1.56	1.63	1.16	1.52	1.54	1.69	1.62	1.68	1.77	1.40	1.35	1.56	0.00									
S30	1.80	1.19	1.34	1.36	1.42	1.45	1.18	1.25	1.17	1.20	1.78	1.54	1.67	1.29	1.53	1.46	1.43	1.55	1.39	1.70	1.11	1.25	1.01	1.26	1.16	1.27	2.07	1.81	1.36	1.70	0.00								
S31	2.25	1.23	1.31	1.35	1.56	1.38	1.37	1.17	1.13	1.45	1.89	1.63	1.43	1.09	1.47	1.20	1.12	1.02	1.14	1.24	0.92	0.94	1.21	0.90	0.77	0.89	1.56	1.44	0.88	1.28	1.12	0.00							
S32	2.09	1.61	1.65	1.92	1.74	1.83	1.39	1.75	1.46	1.55	2.28	1.90	1.67	1.39	1.86	1.38	1.58	1.30	1.33	1.66	1.15	1.21	1.41	1.30	1.08	1.04	2.01	1.83	1.21	2.08	1.32	1.04	0.00						
S33	2.97	1.66	1.66	1.45	2.14	1.22	1.76	1.58	1.33	1.51	1.27	1.96	1.28	1.20	1.63	1.62	1.00	1.77	1.37	1.21	1.48	1.82	1.68	2.00	1.99	1.78	1.25	0.83	1.56	1.37	1.71	1.54	1.98	0.00					
S34	2.32	1.37	1.04	1.23	1.58	1.12	1.28	0.98	1.05	1.44	1.57	1.46	1.73	1.20	1.42	1.25	1.22	1.85	1.34	1.77	1.28	1.55	1.27	1.28	1.41	1.50	1.62	1.51	1.56	1.43	1.42	1.30	1.77	1.59	0.00				
S35	2.63	1.72	1.39	1.53	2.08	1.39	1.39	1.50	1.17	1.30	1.43	1.92	1.53	1.16	1.73	1.62	1.24	1.80	1.16	1.68	1.28	1.66	1.55	1.60	1.54	1.53	1.58	1.26	1.53	1.65	1.53	1.44	1.75	1.45	1.12	0.00			
S36	3.10	1.67	1.55	1.45	2.16	1.27	1.89	1.36	1.31	1.56	1.58	1.82	1.25	1.08	1.64	1.46	0.76	1.77	1.23	1.33	1.51	1.75	1.73	1.82	1.83	1.61	1.13	0.98	1.45	1.25	1.77	1.33	1.95	0.92	1.42	1.43	0.00		

Bold font means dissimilarity threshold = 0.95;

S1 (Numeric Value): Different flavored ice cream with Simplesse® (See Table 4-1)

4.4.4 Canonical Variate Analysis (CVA)

Canonical variate analysis (CVA) was conducted to evaluate similarities of thirty seven ice creams for twenty five sensory attributes using the product effect. For the CVA, the original data (37 products x 3 replicate x 11 judges) was calculated in CVA. The axes of a CVA biplot are the characteristic vectors or dimensions and the bubble indicate the main effect or interaction being viewed (Maile 1997). The size of the bubble on the CVA biplot displays the 95% confidence interval of a main effect, and it is uniform if an equal number of observations were collected for all products. The bubble size is calculated using the equation below:

$$95\% \text{ confidence interval} = 2 / (\text{square root of } n)$$

n = the number of observations in the mean of the cited main effect or interaction.

In other words, the higher number of observations the smaller is the size of the bubble. If bubbles of products overlap, they are considered not to be significantly different from one another. In the study, the bubble size is 0.348.

Figure 4-7 to Figure 4-9 show the canonical variate analysis of twenty five sensory attributes using the first three eigenvalues, which accounted for 42.06% of the total variance ratio, and which were significant at $P < 0.05$. The first canonical variate dimension (CVI) explained 23.97% of the variance ratio, while the second (CVII) and third (CVIII) dimensions defined 9.38% and 8.71% of the variance ratio, respectively. The CVA map indicated great variances of sensory attributes among products including pink color, dense, mouth coating, smoothness, creaminess, sweetness, sweet aftertaste, grassy flavor, grassy aftertaste, cooked sugar flavor aftertaste, violet flavor, peach aftertaste, candy flavor aftertaste and astringency. The attributes showed important variances among products, and

there were only slight difference in results compared with PCA, specifically for cooked sugar flavor and thickness. CVI was driven mainly by pink color. Other attributes such as mouth coating, smoothness, cooked sugar aftertaste, astringency, creaminess and grassy flavor aftertaste also have some variance loading in CV I. Dense, mouth coating, cooked sugar aftertaste, grassy flavor, peach flavor aftertaste, violet flavor, creaminess and sweetness are primary drivers in CV II. Peach flavor aftertaste, sweet aftertaste and grassy flavor aftertaste were likely to be more important for CV III. In addition, the CVA map simply indicated that condensed milk, creaminess and sweetness were highly correlated with each other. Mouth coating, smoothness, cooked sugar flavor and cooked sugar aftertaste had a high correlation with each other.

Figure 4-10 to Figure 4-12 show the CVA biplot for thirty seven ice creams with sensory attributes plotting CVI vs CVII, CVI vs CVIII and CVII vs CVIII. Three groups were classified by the CVA map. One group, including eleven products, can be described by having less pink color, another group, located at the middle of the map, had sensory characteristics that were less significant, and the last group was characterized by a dark pink color.

S4, S6, S19, S21 and S22 were similar to 10% ice cream on CV I and CV II. S4 was the closest product to 10% ice cream. S19 had a high intensity in sweetness aftertaste. The other four products showed no significant differences on the map of CVI and CV II. These products had lower pink color, mouth coating, smoothness, cooked sugar aftertaste and a higher grassy flavor, violet flavor and peach flavor aftertaste. S17, S24, S28, S32 and S25 were grouped together, and they had more sweetness, condensed milk and creaminess and less pink color (Figure 4-10).

Figure 4-11 shows that it is significant that Simplese[®] products had a stronger sweetness aftertaste than did 10% ice cream as they are loaded higher (less negative) on the CV III axis than the control. The biplot of CV II and CV III can be summarized to show that Simplese[®] products had lower grassy flavor aftertaste than the control (Figure 4-12).

The difference of the flavor formulation between S13 and S4 is only the spiking of furaneol[™]. S13 was spiked 75% furaneol[™] of base concentration whereas S4 was spiked 100%. However, there were significant differences in flavor profile. S13 had lower violet flavor and peach flavor, stronger cooked sugar flavor and was very much sweeter than S4. In other words, it seems the Simplese[®] products with the lower furaneol[™] spike and with the lower γ -undecalactone and α -ionone spikes were sweeter and had greater cooked sugar intensity. For example, when comparing S22 with S31, S6 with S15 and S24 with S33, the formulation with the lower furaneol[™] spike, S31, S15 and S33 had higher cooked sugar intensities.

Reviewing the three CVA biplot, S4 was the nearest product to the 10% ice cream. The result is in agreement with the results of the dissimilarity matrix and the PCA. In addition, it appears that CVA is better than PCA in showing the similarity among products in the study.

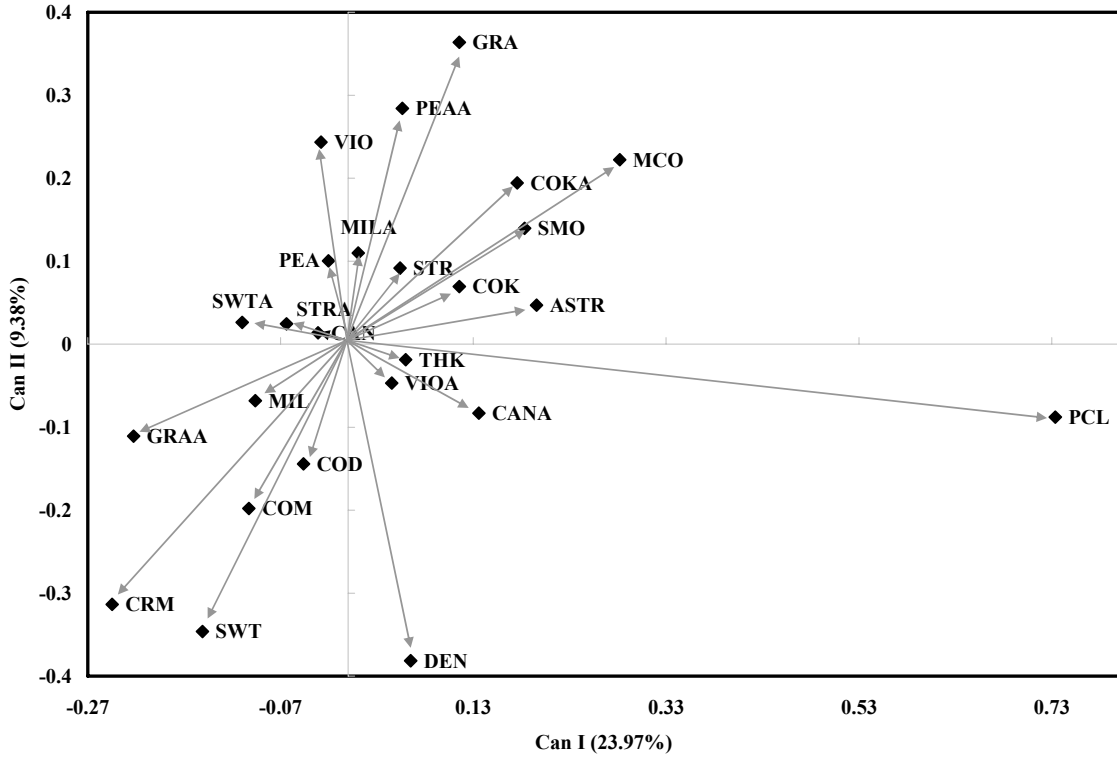


Figure 4-7. Sensory attributes space by CVA for 37 ice creams on CVI vs CV II.

Parenthesis denotes the percent explained by the corresponding CV dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

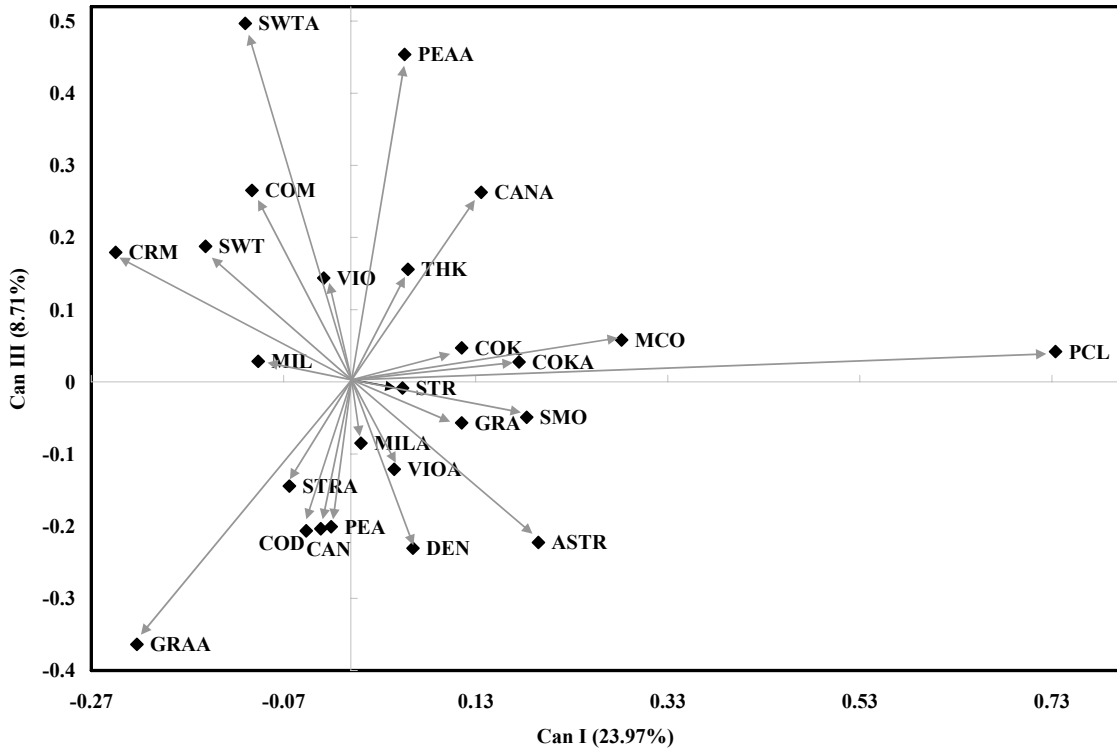


Figure 4-8. Sensory attributes space by CVA for 37 ice creams on CVI vs CV III.

Parenthesis denotes the percent explained by the corresponding CV dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

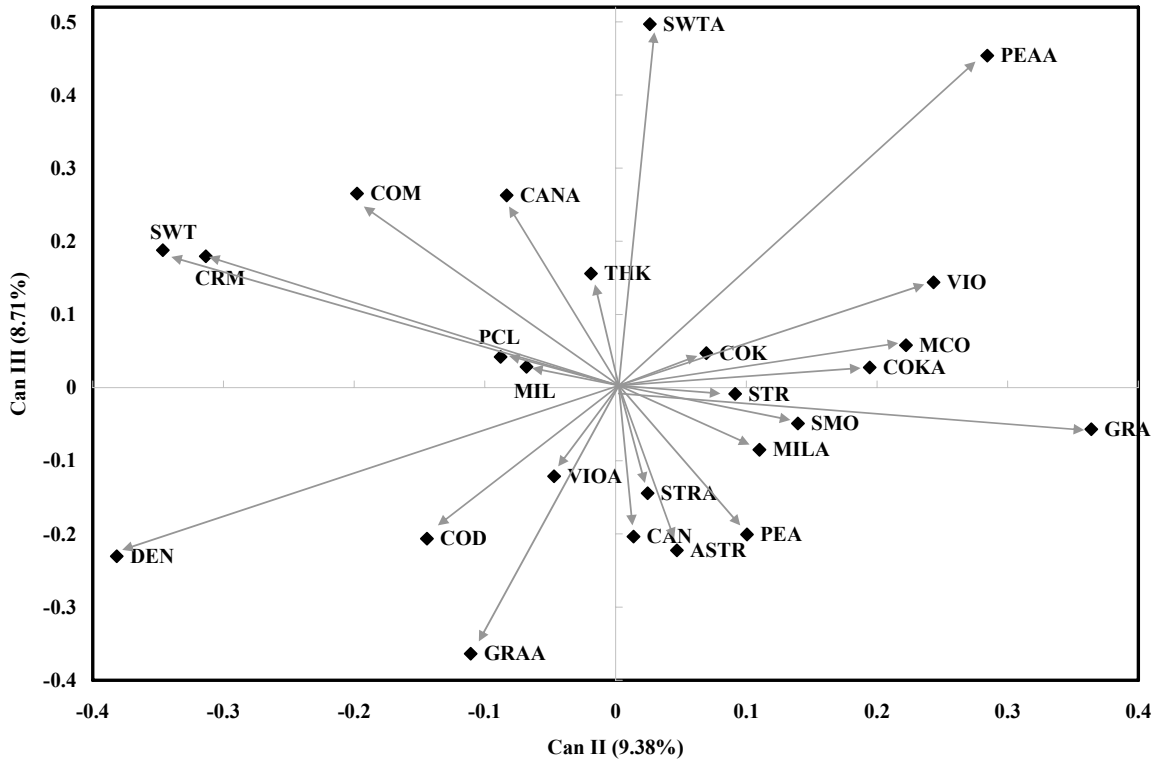


Figure 4-9. Sensory attributes space by CVA for 37 ice creams on CVII vs CV III.

Parenthesis denotes the percent explained by the corresponding CV dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

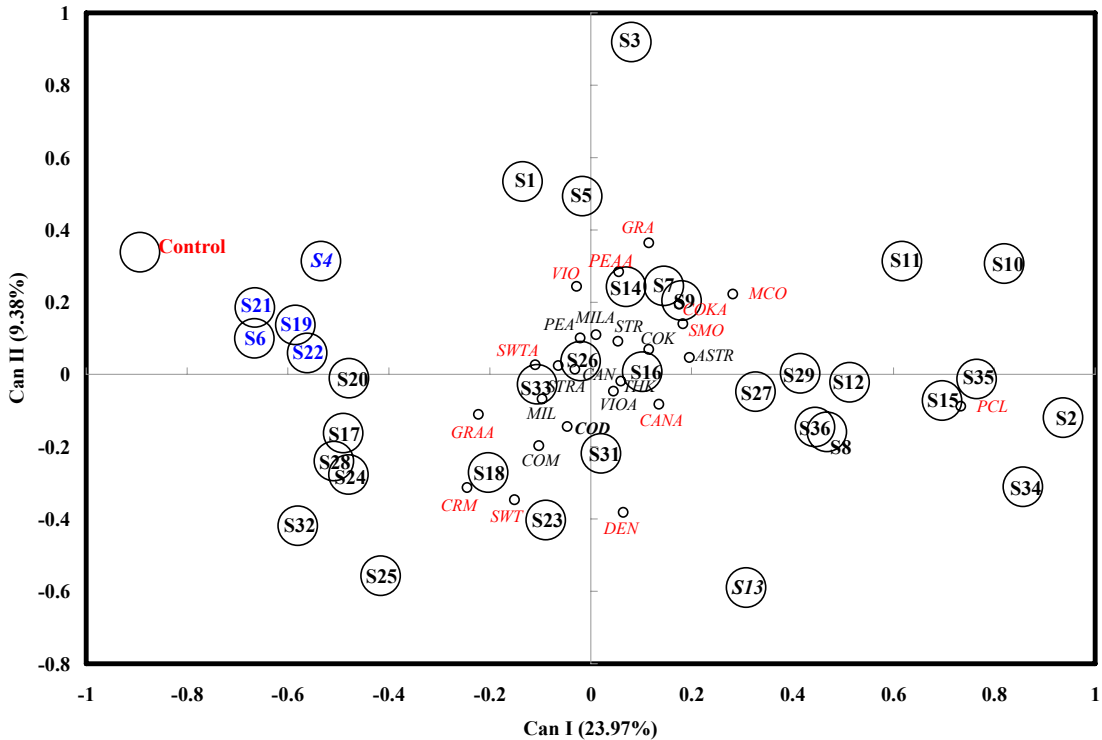


Figure 4-10. Canonical variate analysis for 37 ice creams on CV I vs CV II.

Parenthesis denotes the percent explained by the corresponding CV dimension. Samples that are overlapping to each other indicates no significant difference ($p < 0.05$) between the samples.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

Control 10% ice cream S (Numeric Value): Different flavored ice cream with Simplese®
(See Table 4-1)

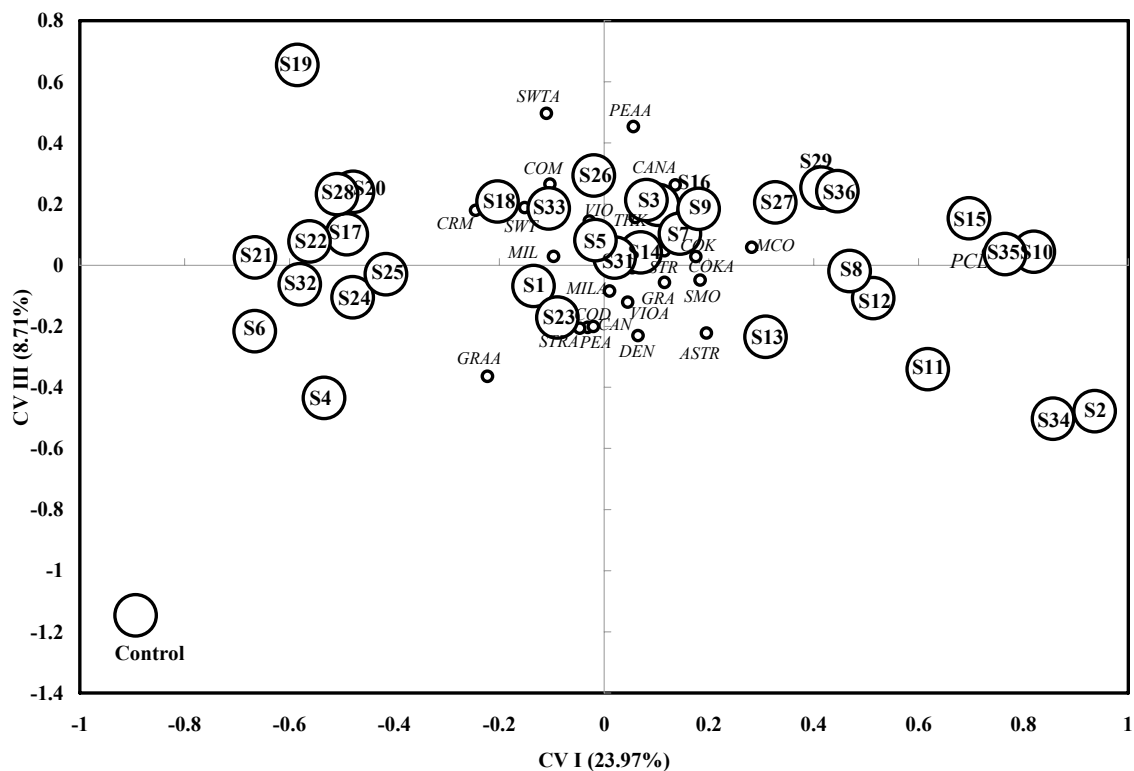


Figure 4-11. Canonical variate analysis for 37 ice creams on CV I vs CV III.

Parenthesis denotes the percent explained by the corresponding CV dimension. Samples that are overlapping to each other indicates no significant difference ($p < 0.05$) between the samples.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

Control 10% ice cream S (Numeric Value): Different flavored ice cream with Simplese®
(See Table 4-1)

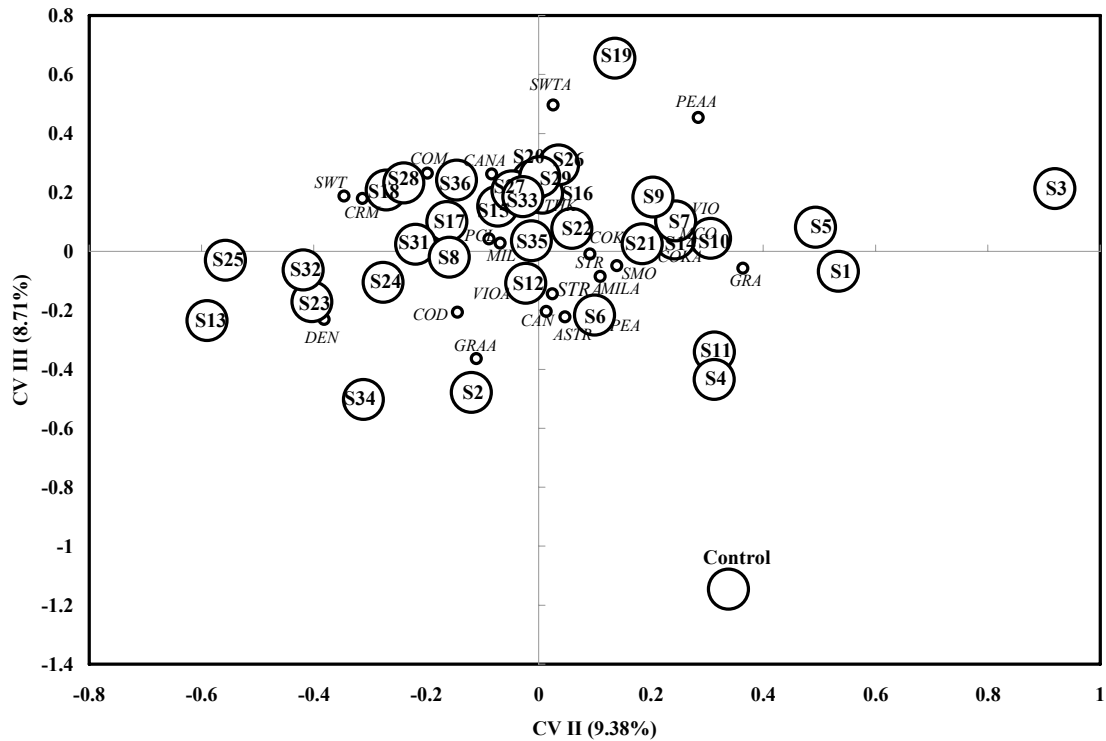


Figure 4-12. Canonical variate analysis for 37 ice creams on CV II vs CV III.

Parenthesis denotes the percent explained by the corresponding CV dimension. Samples that are overlapping to each other indicates no significant difference ($p < 0.05$) between the samples.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

Control 10% ice cream S (Numeric Value): Different flavored ice cream with Simplese[®] (See Table 4-1)

4.4.5 Cluster Analysis (CA)

The dendrogram obtained from agglomerative hierarchical cluster analysis, which included flavor, texture and aftertaste attributes showed the sensory characteristics as reflected by the logistics model parameters, and identified distinct clusters. Attributes on larger scales will cause stronger effects on the clusters' form, thus, a "center/reduce" option in the XLSTAT software was selected to avoid having group creation influenced by scaling effect. In addition, the automatic truncation option also was marked to show the groups and to decide when to stop aggregating observations. In Figure 4-13, the vertical distances indicated dissimilarity between clusters as measured by the Euclidean linkage distance between ice cream products. Automatic truncation uses this criterion.

Two distinctly dissimilar clusters were seen; one consists of 10% ice cream with seventeen of the Simplesse[®] products, while the other consisted of the remaining nineteen ice cream samples. These two clusters were classified principally by several significant attributes, including cooked sugar flavor cooked sugar aftertaste, peach flavor, peach flavor aftertaste, condensed milk and thickness. In other words, ice creams in a cluster composed of eighteen products, including 10% ice cream, had lower intensities in cooked sugar flavor, cooked sugar aftertaste, peach flavor and peach aftertaste. This 18-sample group was subdivided further into two more clusters. One cluster, which was composed of only 10% ice cream, had less intensity in sweetness, sweetness aftertaste, condensed milk and candy flavor aftertaste, as well as a higher intensity in grassy flavor than the other seventeen samples. The 10% ice cream was the most different from the following eight products, S26, S16, S36, S19, S27, S33, S10 and S35, due to low intensity for cooked sugar flavor, milky

flavor, smoothness, thickness, creaminess, and cooked sugar aftertaste. Finally, eight clusters were subdivided further by the dotted line which represented the automatic truncation. The first group only contains 10% ice cream. The next group, including S22, S30, S6, S8 and S9, is not very distant from the first group, but the differences remained noticeable. The primary difference between the five products and 10% ice creams is due to the attributes sweetness, sweetness aftertaste, candy flavor aftertaste and cooked sugar flavor. The 10% ice cream had a lower intensity of these attributes. The sixth group contains eight products which is the largest group among these clusters. Overall, 10% ice cream was the closest sensory characteristics in taste with S30 and S22 products. The significant differences among the three products were cooked sugar flavor, sweetness and condensed milk. S30 and S22 had a higher intensity in the three attributes than 10% ice cream.

Figure 4-14 is the dendrogram which only included the corresponding attributes from the five flavor compounds. The dotted line displayed the automatic truncation leading to three groups. The first cluster contained eight samples which had higher intensities in all corresponding flavors compared with other twenty nine samples. However, grassy flavor, peach flavor and violet flavor had a great variation than cooked sugar flavor and candy flavor. The difference between the next two groups is due to cooked sugar flavor. Eight samples, including 10% ice cream, had lower intensity in cooked sugar flavor than the other twenty one samples. The 10% ice cream and S17 formed a cluster because they had more similar characteristics in regard to grassy flavor and cooked sugar flavor than other six products. The 10% ice cream and S17 had mainly a higher intensity in grassy flavor and a lower intensity in cooked sugar flavor compared with other six products. However, 10%

ice cream had a lower intensity in candy flavor aftertaste than did S17. Compared with the results in Figure 4-13, S17 was not highly similar in taste to 10% ice cream, although the sensory properties of corresponding attributes, derived from the five flavor compounds, between the two products were close to each other. S17 had high intensity in sweetness, sweet aftertaste, candy flavor aftertaste, astringency, condensed milk and milky flavor compared with 10% ice cream. In addition, S17 was principally higher intensity in strawberry flavor, milky flavor, milky flavor aftertaste, mouth coating and sweetness as well as a lower in cooked sugar flavor than the S30 product. In other words, milky flavor, strawberry flavor and mouth coating could play a role in determining the similarity between Simplese[®] products and full fat ice cream.

In summary, flavor attributes are more important than texture attributes in the classification of ice cream with Simplese[®] and 10% ice cream. Sweetness, condensed milk, milky flavor and cooked sugar flavor are the important attributes to determine similarity. Ice cream with Simplese[®] was sweeter than 10% ice cream, and the sweetness usually had a significantly positive correlation with cooked sugar flavor and condensed milk flavor. For taste perception, the two Simplese[®] products S30 and S22 are close to 10% ice cream but still have a stronger cooked sugar flavor, condensed milk flavor and sweetness. S17, which is composed of 100% *cis*-3-hexen-1-ol, 75% furaneol[™], 50% γ -undecalactone, 100% ethyl-3-methyl-3-phenylglycidate, and 75% α -ionone of base concentration was the closest in corresponding flavor intensity of the five flavor compounds with 10% ice cream. Clearly, the result is significantly different from the conclusions drawn from PCA and CVA primarily due to distinct statistical application differences.

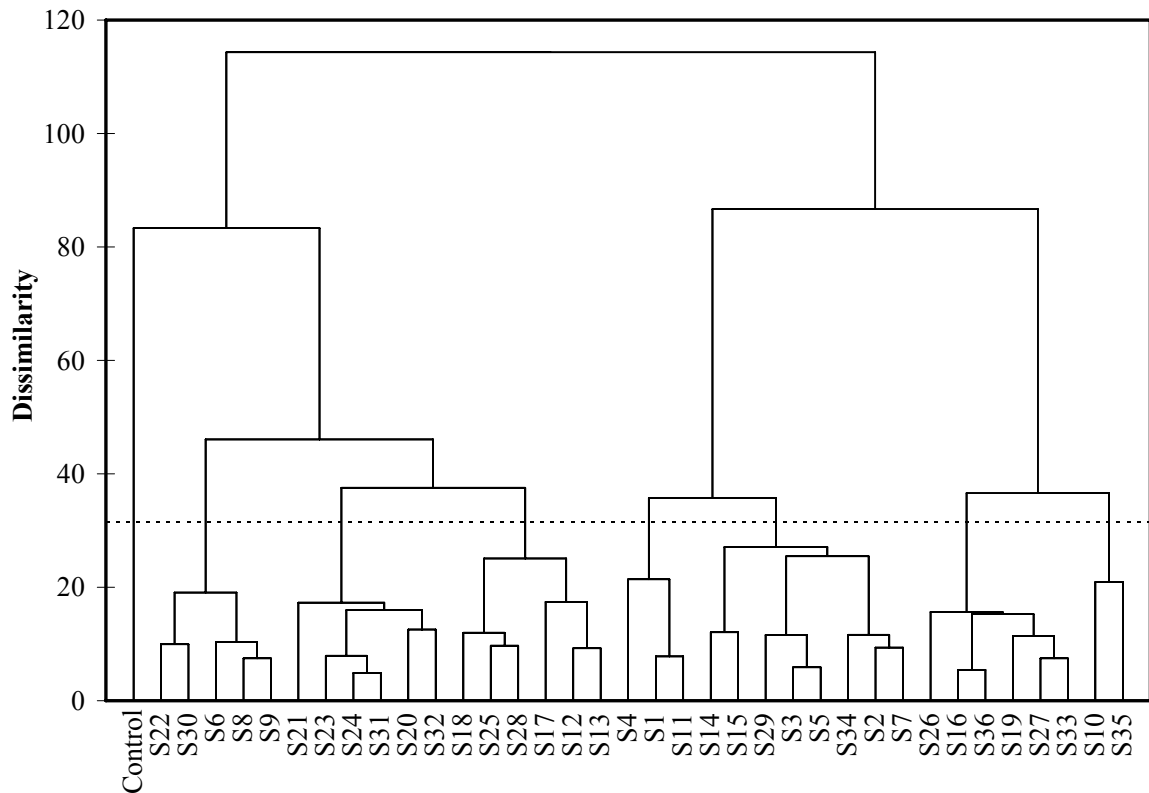


Figure 4-13. Cluster analyses of 37 ice cream products including 23 attributes categorized by flavor, texture and aftertaste attributes.

Twenty three attributes include sweetness, strawberry flavor, candy flavor, cooked sugar flavor, grassy flavor, peach flavor, violet flavor, milky flavor, condensed milk flavor, coldness, thickness, smoothness, creaminess, mouth coating, sweet aftertaste, strawberry aftertaste, candy aftertaste, grassy aftertaste, violet aftertaste, peach aftertaste, cooked sugar aftertaste, astringency and milky aftertaste.

The code name of products:

S (Numeric Value): Different flavored ice cream with Simplese® (See Table 4-1)
 Control 10% ice cream

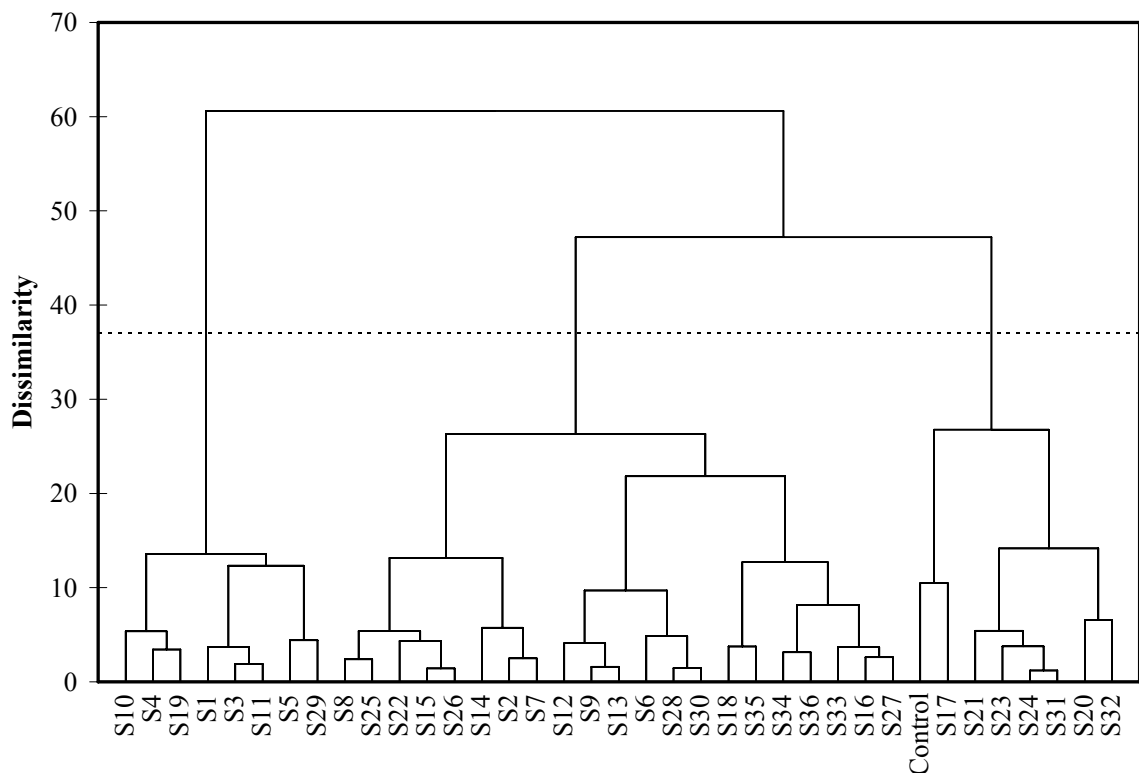


Figure 4-14. Cluster analyses of 37 ice cream products including 10 corresponding attributes from the five flavor compounds.

Five flavor compounds with their corresponding attributes
 cis-3-hexen-1-ol: grassy flavor and grassy flavor aftertaste
 ethyl-3-methyl-3phenylglycidate: candy favor and candy flavor aftertaste
 furaneolTM : cooked sugar flavor and cooked sugar flavor aftertaste
 γ -undercalactone: peach flavor and peach flavor aftertaste
 α -ionone: violet flavor and violet flavor aftertaste

The code name of products:

S (Numeric Value): Different flavored ice cream with Simplese[®] (See Table 4-1)
 Control 10% ice cream

4.5 CONCLUSIONS

In this study, thirty six ice cream flavor formulations with Simplese[®], including five artificial strawberry flavor compounds, which were either maintained at original concentrations or decreased individually by 25% in concentration for *cis*-3-hexen-1-ol and furaneol[™], or decreased 25% and 50% for α -ionone and γ -undecalactone, was used to formulate the flavoring mix for mimicking the flavor profile of 10% ice cream.

First, ANOVA results showed that there were no significant differences for most of flavor and texture attributes among the thirty six Simplese[®] products and 10% control sample, except for cooked sugar aftertaste. The 10% ice cream had relatively lower cooked sugar aftertaste intensity. PCA and CVA indicated that low fat ice cream with Simplese[®] had a high intensity in sweetness and cooked sugar flavor, and the intensity of the two attributes was a determinant in similarity of taste with 10% ice cream, instead of the violet flavor and peach flavor that were indicated in the previous study.

CVA and PCA complementarily revealed S4, which contains the 25% reduction of γ -undecalactone of base concentration, was the closest product to 10% ice cream. Dissimilarity matrix using Euclidean distance also provided a similar conclusion. However, cluster analysis indicated both S22, reduced 25% γ -undecalactone and 25% *cis*-hexen-1-ol, and 10% ice cream had the smallest dissimilarity to each other. The result indirectly indicated that cooked sugar flavor could be masked in the presence of other flavors such as peach flavor and violet flavor. In addition, the sweetness also was inhibited in Simplese[®] ice cream when the intensity of cooked sugar flavor was decreased.

On the other hand, in this study, it was demonstrated that canonical variate

analysis is better than principal component analysis in analyzing the similarities of ice cream products. Sweetness, cooked flavor and cooked sugar aftertaste in ice cream with Simplese[®] might need to be further reformulated for optimizing low fat ice cream similarities to 10% fat ice creams.

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CHAPTER 5

CONSUMER SENSORY ANALYSIS OF STRAWBERRY ICE CREAMS CONTAINING SIMPLESSE[®] AND FLAVORINGS REFORMULATED FOR REDUCED FAT ICE CREAMS

5.1 INTRODUCTION

Consumer purchase of ice cream is based primarily on taste, health benefits (low calories) and budgets (Guinard and others 1996; El-Nagar and others 2002). However, it still is a challenge for the ice cream industry to produce ice cream products of high quality, with greater health benefits (low-fat, low-carb products) and high consumer acceptance. Flavor, body and texture, color and shrinkage are primary targets for quality characteristics in ice cream. Bodyfelt (1983) indicated that the composition of ice creams, such as milk fat, overrun, total solids and flavoring type and level, and the differentiation of products, such as package, advertising and promotion, are two primary factors to affect consumers' impression of ice creams. Among them, quality of dairy ingredients and of flavoring system, rate of freezing and storage condition are the key factors to ensure high quality ice creams (Guinard and others 1996). The amount and type of ingredients have a great influence on the texture quality of ice cream. For example, a low total solid and a low stabilizer could cause a crumbly texture or a flaky quality in ice cream (Lee and others 2005). Regarding flavor quality, whether the ice cream has too much or lack flavor or has an unnatural flavor (Goff 1996), whether the ice cream is too sweet or not sweet enough (Bronet 1994) and whether the ice cream produces some flavor defects, such as whey flavor, rancid and off-flavors during processing or storage condition (Goff 1995)

significantly affect consumer acceptance and product quality.

The use of any fat mimetics in a food product would require changes in flavor formulation, and a consumer test should be performed to understand whether consumers like these reformulated products (Schlich 1995). Consumer study in sensory science concentrates mainly on consumer acceptance and consumer preference and usually follows descriptive tests or discrimination tests (Yackinous and others 1999). Participants in a consumer test usually are asked to taste samples and indicate degree of liking or purchase intent using 9-point hedonic ratings or categorical scales. Much of the previous research on consumer preference and acceptance of ice cream has focused on two primary segments, including effects of ingredients of ice creams such sugar, fat and fat mimetics (Pearson and Ennis 1979; Guinard and others 1996; Bordi and others 2004) and new product development such as low-fat, reduced fat or non-fat ice creams with a fat mimetic such as Simplesse[®], Litesse[®], MAG-nifique Mouthfeel, and Tara gum (Menon 1995; Prindiville and others 2000; Krueel 2004). Guinard and others (1996) stated sugar was a more important contributor for consumer acceptance than fat in vanilla ice cream. Menon (1995) found that fat-free ice creams with Simplesse[®] were not acceptable to consumers. Prindiville and others (2000) indicated that no significant differences in consumer acceptance existed for nonfat, low fat, reduced fat and full fat chocolate ice cream. Krueel (2004) indicated there were no significant differences in consumer acceptance among several strawberry flavored ice creams with or without fat mimetics, including 4% fat ice cream, 4% fat ice cream with Litesse[®], 7% fat ice cream with MAG-nifique Mouthhhfeel, and 10% fat ice cream. Only a few research projects have looked at consumer group prediction and consumer behavior in the choice of ice cream

products (Opdahl and Baer 1991; Bower and Baxter 2000; Stokols and others 2006).

A developer of a new product not only needs to understand consumer acceptance but also what it is about a product that people like and dislike and how these attributes might be modified to increase acceptability. Based on these reasons, several multivariate statistical techniques that combine descriptive sensory attributes and consumer hedonic data or instrumental data, such as partial least square regression (PLSR) and preference mapping, have been implemented to understand the relationship between sensory characteristics and physical properties or sensory affective data for many foods (Elmore and others 1999; Chung and others 2003; Tang 2003; Lengard and Kermit 2006). These techniques help R&D teams to explore consumers' attitude and preference patterns and take that information into account for creating new products or improving existing products (Xiong and Meullenet 2004). In the past, partial least square regression has been applied widely in ice cream research for correlating descriptive data with instrumental data and provided a good overview regarding the effect of fat on sensory properties of ice creams (Chung and others 2003; Loeb 2004; Krueel 2004; Frøst and others 2005) but has found less application in correlating descriptive data with consumer data or hedonic judgments. In addition, only few publications are available in which preference mapping or related multivariate statistical methods for analyzing consumer data of ice cream studies have been used (Bower and Baxter 2003).

Previous studies about the reformulation of five flavor compounds of strawberry flavor in low fat (4%) ice cream with Simplese[®] using descriptive tests found that α -ionone (violet flavor) and γ -undecalactone (peach flavor) are key flavors for reformulating the flavoring to match the flavor profile of full-fat ice cream. In addition,

we noted that cis-3-hexen-1-ol did not have a significant influence on its corresponding attribute, grassy flavor, but could affect the perception of violet flavor. Canonical variate analysis indicated that lowering the amount of γ -undecalactone by 25% from that used in the original base flavor formulation, while α -ionone remained at the 100% or was reduced to the 50% level in 4% ice cream with Simplese[®] resulted in similar characteristics in flavor profile of the low-fat ice cream to that of full-fat ice cream. The purpose of this study was to evaluate consumer acceptance of and preference for six strawberry flavored ice creams, including four low-fat reformulated ice creams with Simplese[®] and two control samples, by a consumer panel and to correlate consumer acceptance with descriptive information of these six ice creams using partial least square regression and preference mapping techniques. These findings will help in understanding whether the reformulation of the strawberry flavoring results in reduced fat ice cream with Simplese[®] to better meet consumer demand.

5.2 MATERIALS AND METHODS

5.2.1 Materials

Simplese[®]100, microparticulated whey protein concentrate 53 (CP Kelco, San Diego, CA, USA) was used in the study. The five flavor compounds were food grade, and included cis-3-hexen-1-ol, ethyl-3-methyl-3-phenylglycidate, furaneol[™], γ -undecalactone and α -ionone. They were procured from the Flavor and Fragrance division of Sigma Aldrich (St. Louis, MO, USA). Skim milk and heavy whipping cream were purchased from Prairie Farms Inc. (Columbia, MO, USA). Nonfat dry milk (spray process grade A) made from pasteurized milk came from Dairy America (Fresno, CA, USA). Pure cane

sugar was purchased from United States Sugar Co. (Clewiston, FL, USA) or from Wal-Mart (Bentonville, AR, USA). Nonfat ice cream stabilizer #19 was purchased from Opta Food Ingredient Inc. (Bedford, MA, USA). Clear sweet 36/48 corn syrup was purchased from Cargill Inc. (Minneapolis, MN, USA) and strawberry red liquid color, composed of water, citric acid, sodium benzoate, red 40 and blue 1, was procured from Sensient flavors Inc. (Fenton, MO).

5.2.2 Sample Choices and Preparation

The six ice creams, including a 10% ice cream (positive control), a 4% ice cream with Simplese[®] (negative control) and four ice creams with Simplese[®] and reformulated flavors were chosen according to the information gained from the previous studies. The four reformulated ice creams had sensory properties very close to those of the 10% ice cream and their flavor formulation is showed in Table 5-1.

All ice creams were prepared in the Dairy Pilot Plant of the Food Science department at the University of Missouri-Columbia. Table 5-2 lists the basic formulations for both 4% and 10% fat ice cream mixes. A ten gallon batch was prepared for 10% ice cream and a twenty gallon batch for 4% ice cream with Simplese[®].

All dry ingredients, which were weighed in advance, were mixed thoroughly with the weighed liquid ingredients (skim milk and cream) in a mixing vat and then agitation and heating were started. The 36/48 DE corn syrup was added slowly to the mix. The mixes were pasteurized using high temperature short time (HTST) at 81.5 °C for 25 s (Processing Machinery and Supply Co., Philadelphia, PA). Then, the pasteurized mixtures were homogenized in a two-stage homogenizer (APV-Gaulin GmbH,

Philadelphia, PA) at 20.70 MPa for the first stage and 3.45 MPa at the second stage, respectively. The pasteurized ice cream mixes were cooled at the ambient temperature for a while and then aged overnight at 4 °C.

Each of the aged ice cream mixes was poured individually into a one gallon bucket for the addition of flavor and color. Table 5-2 lists the thirty-six flavoring formulations. Each bucket was flavored with one of the flavor formulations (0.1%, v/v). Strawberry red liquid color was added to each bucket at the rate of 0.4 ml/L and mixed fully before freezing. A Technogel 80 freezer (Milan, Italy) was used to freeze the mixes to soft ice creams. Aliquot of the frozen ice creams were packed in 4oz Styrofoam containers with semi-transparent lids for sensory test. Lastly, the soft ice creams were stored at -40°C for hardening.

Table 5-1. Flavor formulation for 10% ice cream and 4% ice creams with Simplese®

Formulation Compound		Compound									
		Percentage					Weight (g/100g)				
		cis 3-Hexeno-1-ol	Ethyl-3-methyl-3-phenylglycidate	Furaneol™	γ-Undecalactone	α-Ionone	cis 3-Hexeno-1-ol	Ethyl-3-methyl-3-phenylglycidate	Furaneol™	γ-Undecalactone	α-Ionone
10% ice cream		100	100	100	100	100	0.375	3.75	1.875	0.5	0.375
4% ice cream with Simplese®	SC	100	100	100	100	100	0.375	3.75	1.875	0.5	0.375
	S4	100	100	100	75	100	0.375	3.75	1.875	0.375	0.375
	S6	100	100	100	75	50	0.375	3.75	1.875	0.375	0.188
	S22	75	100	100	75	100	0.28	3.75	1.875	0.375	0.375
	S24	75	100	100	75	50	0.28	3.75	1.875	0.375	0.188

Propylene glycol was added to all flavor formulations to a total weight of 100 g/bottle.

Table 5-2. Ice cream formulation per 100g basis for 10% and 4% ice cream with Simplese®

Product Ingredient	10% ice cream	4% ice cream with Simplese®
Nonfat Dry milk (0% fat; 97%NFMS) ^a	6	6.4
Skim milk (0% fat; 8.25% NFMS) ^b	44.9	55.6
Cream (35% fat; 5.5% NFMS) ^c	28.6	11.5
Cane Sugar (100% Total Solids)	12.0	12.0
Corn Syrup (80% Total Solids) ^d	8.0	8.0
Stabilizer ^e	0.5	0.5
Fat replacer ^f	0	6
Total Milk Fat	10.01	4.025
Total Non-fat Milk Solids (NFMS)	11.1	11.1
Total Solids	40.05	40.05

^a Nonfat dry milk (Dairy America, Inc., CA): Spray process grade A nonfat dry milk made by pasteurized milk

^b Skim milk (Prairie Farms Dairy, Prairie farms Inc., IL)

^c Cream (Prairie Farms Dairy, Inc., IL) Heavy whipping cream

^d Corn Syrup (Cargill Incorporated, MO) Clear sweet 36/48 corn syrup

^e Stabilizer (Opta Food Ingredient Inc., MA) Nonfat ice cream stabilizer #19
The composition of Stabilizer /emulsifier 19 is whey protein, microcrystalline cellulose, sodium carboxyl-methyl cellulose, mono-, di-glycerides, carrageenan maltodextrin and polysorbate 80.

^f Simplese® (CP Kelco, San Diego, CA) Microparticulated whey protein concentrate 53 (53 grams retained on the sieve while Simplese® was heat treated).

5.2.3 Consumer Tests

The consumer study was advertised by posting flyers and via the e-mail distribution list of the Division of Food and Bioengineering at the University of Missouri-Columbia and several campus students associations for recruiting the consumer panels after approval by Campus Institutional Review Board. A total of seventy four volunteers participated in the consumer study, which was held on two consecutive days from 9:00 a.m. - 4:30 p.m. When consumer panels arrived at the sensory lab, they were asked to read and sign the consent form (Appendix J) if they were willing to participate in the study. Consumer evaluation of the ice cream samples was conducted in isolated booths illuminated with incandescent light, and evaluations were conducted using the computerized sensory program Compusense Five 4.6 (Guelph, Ontario, Canada). Six strawberry flavored ice creams coded with three digit random numbers were evaluated using a hedonic test (acceptance) and then the ranking test (preference). Panelists evaluated each of samples monadically (one after the other) and indicated the degree of liking of the flavor (DOF), texture (DOT) and appearance (DOA), as well as overall liking (DOL), using a nine-point hedonic scale where 1= dislike extremely to 9= like extremely) (Peryam and Pilgrim 1957) (Appendix K).

A randomized complete block design was used, and the presentation order of samples was generated by Compusense five 4.6 as shown in Appendix L. Panelists were asked to masticate a piece of cracker and then rinse their mouth with water at the beginning of the test and between the samples to minimize carry-over and fatigue effects. After evaluating the overall degree of liking and answering the questionnaires for each of samples, panelists were instructed to place the sample on an appropriate number of a tray

labeled with number 1-6 in order to rank the products in the order from “the most favorite” being the number 1 and the least favorite being the number 6. Tied rankings were not allowed. The panelists were then asked to enter the sample order on the tray into the computerized system

5.3 DATA ANALYSIS

A mixed model Analysis of Variance (ANOVA) was performed to the ratings of the DOL, DOF, DOT and DOA in order to determine significant differences among the products at $p < 0.05$. Panel was considered a random effect in the model. LSMEANS with a pdiff procedure (a pairwise *t*-test) and a macro for converting mean score to letter groupings in Proc Mixed developed by Saxton (1998) were used to determine if there were significant differences between products based on a p -value < 0.05 level (Appendix G). Wilcoxon rank sum (Kruskal-Wallis) test and Friedman’s test were used to evaluate significant differences in the preference ranking of products by the SAS software 8.2 (SAS Institute., Cary, NC) (Appendix G).

Partial least square regression (PLS) as a predictive multivariate tool was conducted to determine the relationship between sensory characteristics and the DOL of products using CAMO Unscrambler software version 9.1 (CAMO Inc., Oslo, Norway). The descriptive study data corresponded to the X-data set whereas consumer hedonic data was operated as the Y-data set in PLS. Agglomerate hierarchical clustering was performed to cluster consumers together based on their liking of ice creams using XLSTAT (Addinsoft SARL., New York, NY). Internal preference mapping, based on a PCA performed on consumer acceptability scores with the products as observations and

the consumers as variables, was analyzed using Unscrambler software version 9.1. (CAMO Inc., Oslo, Norway). External preference mapping using the result of agglomerate hierarchical clustering (Y-data set) and principal component analysis (PCA) (X-data set) was conducted by XLSTAT-MX (Addinsoft SARL., New York, NY).

5.4. RESULTS AND DISCUSSION

5.4.1 Consumer Acceptance for Hedonic Test

Seventy four consumers evaluated six ice creams using a nine-point hedonic scale (1 = like extremely to 9 = dislike extremely). A mixed model of ANOVA was used to analyze the hedonic data set to determine if there were significant differences for overall liking (DOL), liking of flavor (DOF), liking of texture (DOT) and liking of appearance (DOA) among products (Table 5-3). DOL ($P=0.0149$), DOT ($P<0.001$) and DOA ($P=0.0449$) but not DOF showed significant differences at $P<0.05$. The score of DOL had the highest positive significant correlation with that of DOT according to Pearson coefficient's result (0.965 $P=0.002$). In other words, the texture of ice cream is an important, most likely more important than flavor and appearance, determinant in consumer acceptability of these ice creams. Guinard and others (1996) indicated that overall liking was composed of liking of flavor and liking of texture in ice creams. In this study, consumer acceptance of the six ice creams ranged on average between like slightly and like modestly. 10% ice cream had the highest mean hedonic rating of 6.41 for DOL and S22 had the lowest mean hedonic rating (DOL) of 5.5 most likely because it also had to the lowest DOT (Table 5-4). The 10% ice cream had a significantly higher acceptability rating than both S22 and S24. In addition, although DOF showed no significant differences, consumers appeared to like the 10% ice cream more than the S4 and S22 ice creams, which had similar flavor formulation (Table 5-4). Clearly, the results showed that the changes in the flavoring system did not make a significant difference to the liking of the flavor, but the liking of the texture of the ice creams differed significantly, maybe partially due to the supposition that ice cream texture changes rapidly during

assessment or due to storage conditions.

On the other hand, the highest mean hedonic rating for the low fat ice creams was given to S6 and S22 scored the lowest. From the result of DOF, it appears that lowering the spiking of *cis*-3-hexenol could reduce the DOF. Previous studies found increasing the spike of *cis*-3-hexenol could result in a stronger perception of violet flavor. Therefore, it could be supposed that the perception of violet flavor is a key for DOL and DOF. In addition, the ratio of peach flavor and violet favor is critical for the quality of strawberry flavor in ice cream.

Guinard and others (1996) found that sugar concentrations in ice cream had a greater effect on liking than fat concentration but no such relationship existed for frozen dessert and frozen yogurt. In general, fat content is a primary determinant for DOT and mouthfeel, while sugar content is an important factor for DOF. By looking at the descriptive data, it is interesting to note that the 10% ice cream was significantly lower in sweetness and sweetness aftertaste than ice cream with Simplese[®], which had higher intensities. Considering the high sugar concentration (18.5%), it appears that with a mean hedonic rating of 6 (like slightly) these six ice creams are sweet enough so that differences in sweetness do not cause significant differences in DOL. Guinard and others (1996) indicated the ideal vanilla ice cream should contain moderate amounts of sugar (14.3% w/w). A similar study done by Krueel (2004) on consumer acceptance of several low-fat (4% or 7%) strawberry ice creams found there were no significant differences among full-fat ice creams and low-fat ice creams with fat mimetics, all receiving mean hedonic rating around 6. These ice creams also had a high sugar concentration (18.5%) in the formulation.

On the other hand, a rating of “like slightly” is a relatively low hedonic rating for ice cream, which could have been due to psychological biases or to the similarity of the products across the experimental design according to Guinard and others (1996). However, the most likely reason is that a strawberry flavoring made of only five flavor chemicals simply provides not a very good, rounded strawberry flavor. Commercially available strawberry flavorings contain at least twice the number of chemicals.

Table 5-3. F value and significance of the effects of source of variation (product) for the analysis of variance in fixed and mixed model for the 6 ice creams

Effect of Product	Fixed Model				Mixed
	DF	ANOVA SS	MS	F-value	F-value
DOL	5	35.903	7.181	2.29*	2.87*
DOF	5	25.099	5.020	1.58	1.93
DOT	5	110.777	22.155	6.16***	7.61***
DOA	5	21.315	4.263	1.63*	2.30*

* ** *** Significant at P<0.05, 0.01, and 0.001, respectively

DOL=degree of overall liking; DOF=degree of flavor liking; DOT= degree of texture liking; DOA= degree of appearance liking

Table 5-4. Mean score of overall liking, overall flavor, overall texture and overall appearance derived from mixed ANOVA model for consumer hedonic data of the 6 ice creams

Product	Mean Score			
	Overall flavor	Overall texture	Overall appearance	Overall liking
10% ice cream	6.41 ^a	6.77 ^a	6.74 ^a	6.41 ^a
SC	6.00 ^{ab}	6.22 ^b	6.19 ^b	6.03 ^{ab}
S4	5.86 ^{bc}	6.41 ^{ab}	6.59 ^{ab}	6.08 ^{ab}
S6	6.22 ^{ab}	6.26 ^{ab}	6.57 ^{ab}	6.22 ^{ab}
S22	5.66 ^c	5.15 ^c	6.16 ^b	5.5 ^{bc}
S24	6.04 ^{abc}	5.97 ^b	6.31 ^{ab}	5.86 ^c
	6.03	6.13	6.43	6.02

There are no significant differences at p<0.05 among the samples with the same superscript letter.

5.4.2 Consumer Preference

Preference rankings were analyzed using either Wilcoxon rank sum (Kruskal-Wallis) test or Friedman's test by the SAS software 8.2 to evaluate significant differences in the preference ranking of products. The Kruskal-Wallis test, a nonparametric procedure, has been suggested for use in consumer preference tests (Robbins, 2003). The chi-square for the rank means, as performed by the Kruskal-Wallis test, found no significant differences at $P < 0.05$ between the rank means ($p = 0.0794$). Friedman's test is a traditional method in handling the ranked data of sensory analysis. It is relatively powerful and can be applied to any data set (Lawless and Heymann 1998). The chi-square to calculate the rank total showed no significant ($p = 0.144$) differences among the products either and was, thus, in agreement with the Kruskal-Wallis test. ANOVA showed that ice creams made with Simplese[®] did not show significant differences in preference and were not significantly less preferred than the 10% ice cream, except for S22. However, rank sum with the Kruskal-Wallis test showed S4 is significantly more preferred than S22, which was the only difference between the two rank analysis methods. In this study, consumer preference has a highly positive correlation with consumer acceptance for the six products.

Table 5-5. Analysis of consumer ranking data by Friedman test with LSRD test and Wilcoxon rank sum with Kruskal-Wallis test

Product	N	Friedman						Wilcoxon Scores		
		Frequency						Rank Total	Sum of Scores	Mean Score
		1	2	3	4	5	6			
10% ice cream	74	19	14	12	8	13	8	228 ^a	14171	191.5 ^a
S4	74	9	14	19	13	13	6	247 ^{ab}	15577	210.5 ^a
SC	74	15	15	5	12	10	17	260 ^{ab}	16539	223.5 ^{ab}
S6	74	12	12	13	10	14	13	263 ^{ab}	16761	226.5 ^{ab}
S24	74	13	10	12	11	15	13	266 ^{ab}	16983	229.5 ^{ab}
S22	74	6	9	13	20	9	17	290 ^b	18759	253.5 ^b

There are no significant differences at $p < 0.05$ among the samples with the same superscript letter.

Calculated chi-square value for Friedman test is 8.232.

Calculated chi-square value for Kruskal-Wallis test is 9.856.

Critical chi-square value is 11.07 at $\alpha = 0.05$, $df = 5$.

5.4.3 Partial Least Square (PLS)

Partial Least Square (PLS) Regression was conducted on the descriptive analysis data and the consumer hedonic test data to study relationships between the two data sets using the Unscrambler 9.1 software program. The X-data set corresponded to the 25 sensory attributes of the 6 ice creams and the DOL of the consumer hedonic test was used as the Y-data set. PLS regression will obtain a map that simultaneously includes the descriptive data set, the overall liking data set and the products (Figure 5-1). Due to multiple independent variables (X-data set, descriptive data) and a single dependent variable (Y-data set, consumer data), the PLS1 option of regression was chosen to obtain the model solution. Additional analyses determined the relationships between texture attributes and DOT (Figure 5-2), flavor attributes and DOF (Figure 5-3), and appearance attributes and DOA (Figure 5-4). The PLS regression using the Unscrambler correlated the X- dataset and Y- data sets so that two ellipses were produced. The inner and outer ellipses represent 50% and 100% of explained variance, respectively. In other words, X and Y variables located either outside the outer ellipses or in between the inner and outer ellipsis are considered as important variables for the model. Contrarily, X and Y variables on the inside of the inner ellipse are regarded as insignificant attributes for the adopted model solution.

Figure 5-1 shows the PLSR correlation loading plot describing 50% of the descriptive data and 100% of the consumer data variance. 37% and 13% of the independent X-variables (descriptive data) were explained by dimension 1 and dimension 2, respectively. For consumer data, dimension 1 explained 79% of variance and dimension 2 accounted for 21%. In other words, both data sets were better described by

dimension 1 of the PLS plot than by dimension 2. The PLS plot differentiated significantly two products, which is the 10% ice cream from S22, while the other 4 products were not significantly different. The 10% ice cream had a significantly positive correlation and S22 was negatively correlated to overall liking. The result matched the consumer acceptance analysis. The 12 sensory attributes, including strawberry flavor, strawberry aftertaste, sweetness, sweetness aftertaste, pink color, dense, condensed milk, smoothness, candy flavor aftertaste, cooked sugar flavor aftertaste, grassy flavor aftertaste and violet aftertaste, were significant attributes because they were located between the inner and outer ellipsis or near the edge of the outer ellipse. The 10% ice cream had a high intensity in dense, grassy flavor aftertaste compared with other samples. S24 had a strong strawberry flavor, sweetness, candy favor and related aftertaste attributes compared with other samples. However, somewhat unexplainable, the correlation loading showed consumers disliked these seemingly desirable attributes, such as sweetness, strawberry flavor, and smoothness and preferred grassy flavor aftertaste (Figure 5-1).

For the correlation of texture attributes and DOT, S4 had a higher DOT than S6 and S22 (Figure 5-2), and for the correlation of flavor related attributes with DOF as shown in Figure 5-3, 10% ice cream, which was highly positively correlated with DOF, was significantly different from S24. S22 showed the most negative correlation with DOF. For appearance, the 10% ice cream was significantly different from S24 (Figure 5-4).

Clearly, the PLS results of the study could not appropriately explain consumer liking using the sensory attributes. For example, sweetness should have a positive correlation in the DOL (Guinard and others 1996) but our results do not show that. One

of the possible reasons could be due to there not being any significant differences among the products, so that it was improper to correlate the variances of some attributes with DOL. One example of that is the 10% ice cream. It had a strong grassy flavor, astringency and grassy flavor aftertaste but that is a relative result. In fact, the 10% product also had strong smoothness, creaminess, milky flavor and other positive attributes. In addition, some attributes such as hardness in texture, which could cause significant differences among products, was not included in descriptive test.

In summary, the PLS methodology seems not to be appropriate for trying to explain overall liking with descriptive attributes in this study most likely because the differences among products were not significant. Other alternative techniques, such as external preference mapping, or studying relationships between hedonic judgments and product characteristics by the PLS methodology (Tenenhaus and others 2005) could be considered for identifying attributes that influence consumer's preferences.

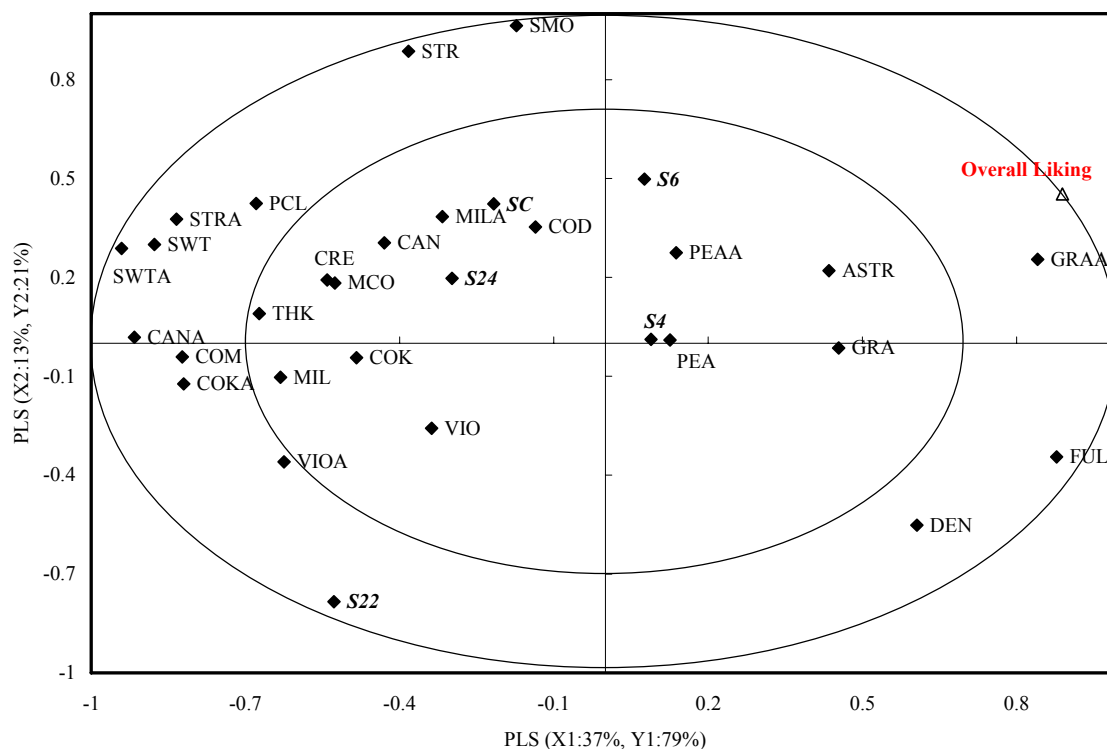


Figure 5-1. PLS regression of the integrated data of descriptive (all 25 sensory attributes) and hedonic data (overall liking) for the 6 ice cream products.

X1:37%, 13% Y1:79%, 21% indicate the percent explained by the corresponding PC dimension for X and Y variables.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

Full: 10% ice cream; SC: Ice cream with Simplese® (Control)

S (Numeric Value): Different flavored ice cream with Simplese® (See Table 5-1)

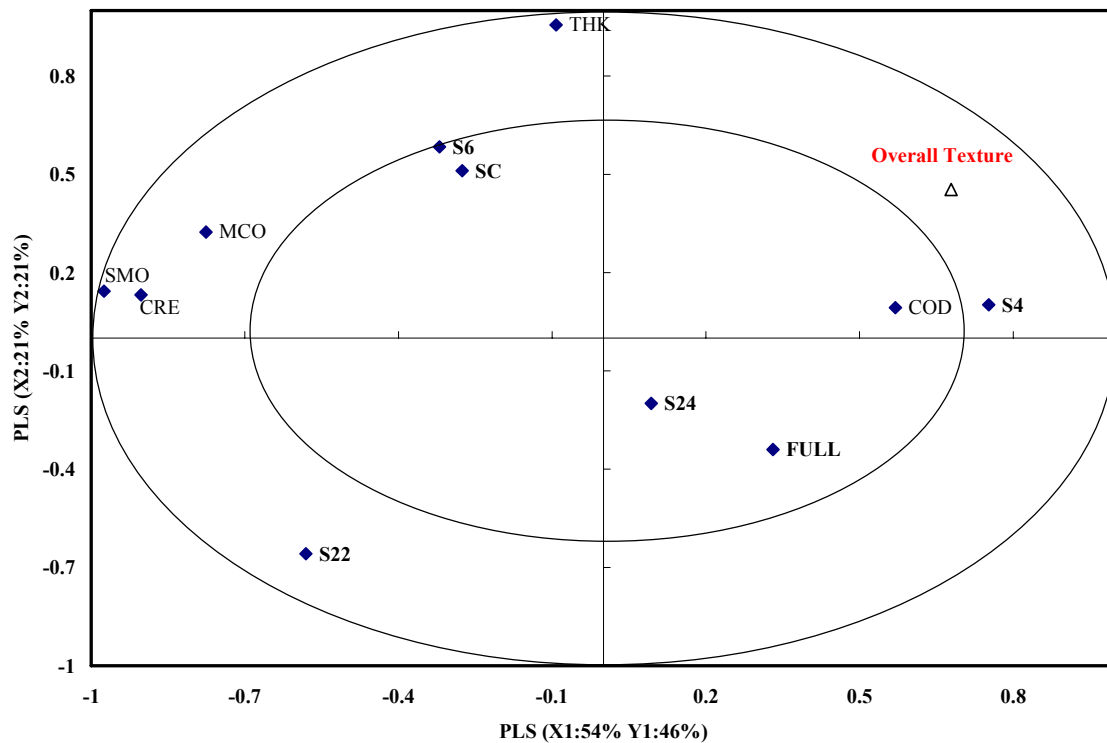


Figure 5-2. PLS regression of the integrated data of descriptive (5 texture attributes) and hedonic data (overall texture) for the 6 ice cream products.

X1:54%, 21% Y1:46%, 21% indicate the percent explained by the corresponding PC dimension for X and Y variables.

Parenthesis denotes the percent explained by the corresponding PC dimension.

COD Coldness SMO Smoothness THK Thickness

CRE Creaminess MCO Mouth coating

Full: 10% ice cream; SC: Ice cream with Simplese[®] (Control)

S (Numeric Value): Different flavored ice cream with Simplese[®] (See Table 5-1)

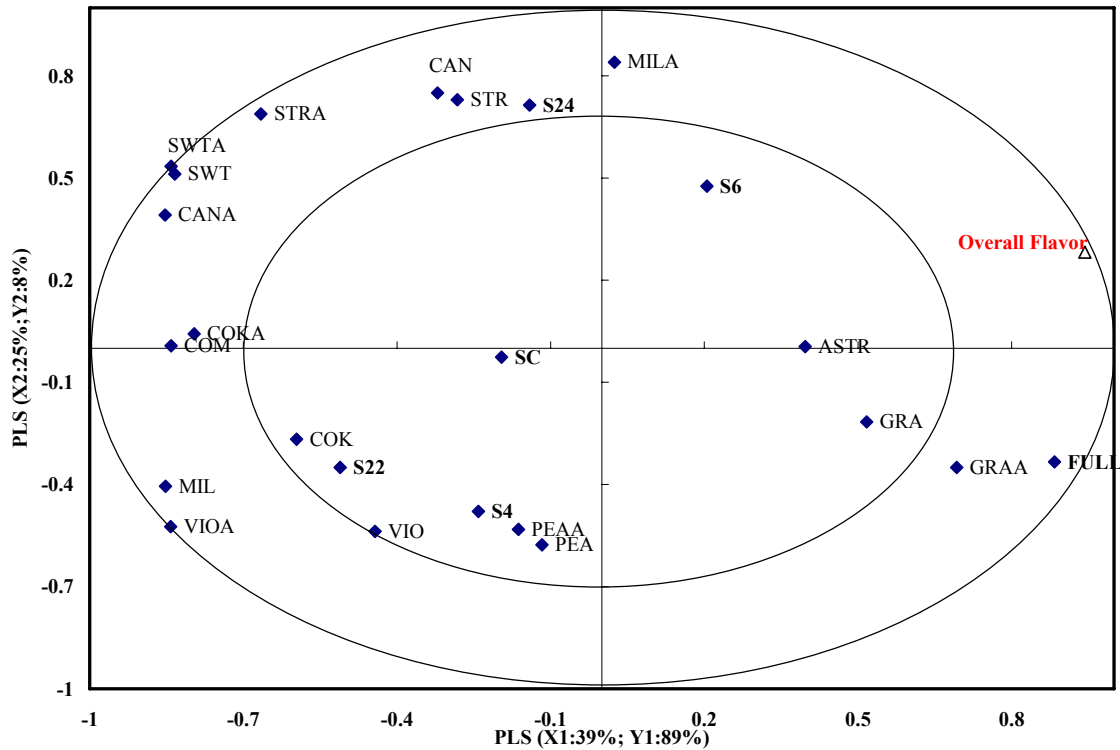


Figure 5-3. PLS regression of the integrated data of descriptive (18 flavor attributes) and hedonic data (overall flavor) for the 6 ice cream products.

X1:39%, 25% Y1:89%, 8% indicate the percent explained by the corresponding PC dimension for X and Y variables.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk		
CANA	Candy aftertaste	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
PEAA	Peach aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
MILA	Milky aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
Full: 10% ice cream; SC: Ice cream with Simplese® (Control)					
S (Numeric Value): Different flavored ice cream with Simplese® (See Table 5-1)					

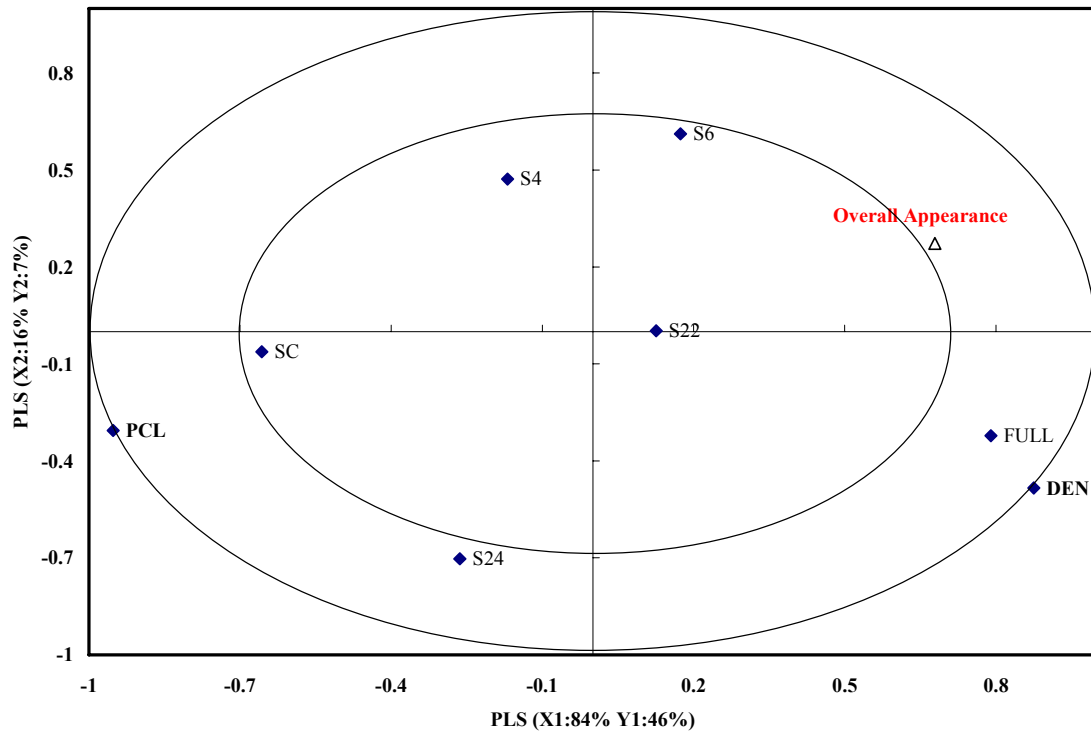


Figure 5-4. PLS regression of the integrated data of descriptive (2 appearance attributes) and hedonic data (overall appearance) for the 6 ice cream products.

X1:84%, 16% Y1:46%, 7% indicate the percent explained by the corresponding PC dimension for X and Y variables.

PCL Pink color DEN Dense

Full: 10% ice cream; SC: Ice cream with Simplese® (Control)

S (Numeric Value): Different flavored ice cream with Simplese® (See Table 5-1)

5.4.4 Internal Preference Mapping

Internal preference mapping, which is used on a set of samples, is based on a PCA method performed on a series of consumer scores, which are the variables, and the products, which are the observations, into a set of preference dimensions to determine consumer preference patterns and the differences among samples (Lawlor and Delahunty 2000). The preference map usually is a biplot of the observations (products) and the variables (consumers).

The first two dimensions accounted for 52% of total variance in the degree of liking scores with 27% of the variance explained in dimension 1 and dimension 2 explained another 25% of the variance (Figure 5-5). In other words, the two dimensions are essentially equal. The preference vector for each consumer was plotted on the two dimensions. The internal preference map shows 49 of 74 (66.2%) consumers are located on the positive side of the Y-axis and 25 of 74 (33.8%) consumers are located on the negative side of the Y-axis. Among them, 26 consumers (35%) had a high correlation with product S6, and 23 consumers (31%) were inclined to like the 10% ice cream product. Only few consumers preferred the S22 and S24 products in the DOL (Figure 5-5). Further analysis indicated that about 40 consumers (54%) are considered important drivers in the determination of the DOL, and that 10% ice cream and S22 were significantly different.

For DOF, the 10% ice cream was loaded on the negative Y-dimension and had an opposite direction of the SC loading. S4 and S6 clustered together and had a negative correlation with S22 and S24 (Figure 5-6). Consumer preference was evenly distributed in the four quadrants of the internal preference map (Figure 5-6). This means that either

consumers could not discriminate the products by differences in flavor (Kruel 2004) or that consumers were more closely grouped around samples, which had higher intensities of certain flavor attributes causing great variations in individual preference (Bower and Baxter 2003) so that the mean score of the consumer acceptability scores for the DOF showed no significant differences among the 6 ice creams.

For the DOT map, the ice cream products can be classified into three clusters. Consumer preference was similar for S4, S6 and SC products. Only very few consumers gave a high hedonic rating for product S22 (Figure 5-7). Regarding overall texture, consumers were inclined to choose the S4, S6 and SC group, or they preferred the 10% ice cream and S24. In other words, it can be concluded that most of the consumers liked the products that provided more mouth coating, smoothness and creaminess. In addition, 10% ice cream was significantly different from S22 in the DOT map (Figure 5-7).

In the DOA map, 10% ice cream differed significantly from SC products, which is in complete agreement with the ANOVA results (Figure 5-8). About 40 consumers were loaded in the positive X-dimension, which means consumers preferred the appearance of the 10% ice cream and S6 products. Consumers might like denser ice creams with a lighter pink color for strawberry ice creams.

Bower and Baxter (2003), using internal preference mapping to compare home-made and commercial ice creams, found that such attributes as denseness, mouth coating and viscosity had positive effects on DOL. Kruel (2004) also indicated that thickness, smoothness, gumminess, milky flavor, milky flavor aftertaste and mouth coating in ice cream products had a high correlation with consumer hedonic ratings. In addition, consumers most likely dislike icy, hardness and stale and astringent flavor. In

this study, it is difficult to clearly determine the relationship of the sensory attributes with DOL due to very similar characteristics among products. Basically, some consumers prefer products with more smoothness, mouth coating sweetness, strawberry flavor and milky flavor or high fat ice creams. However, some consumers could not discriminate the differences among products so that there were wide ranges in the DOL.

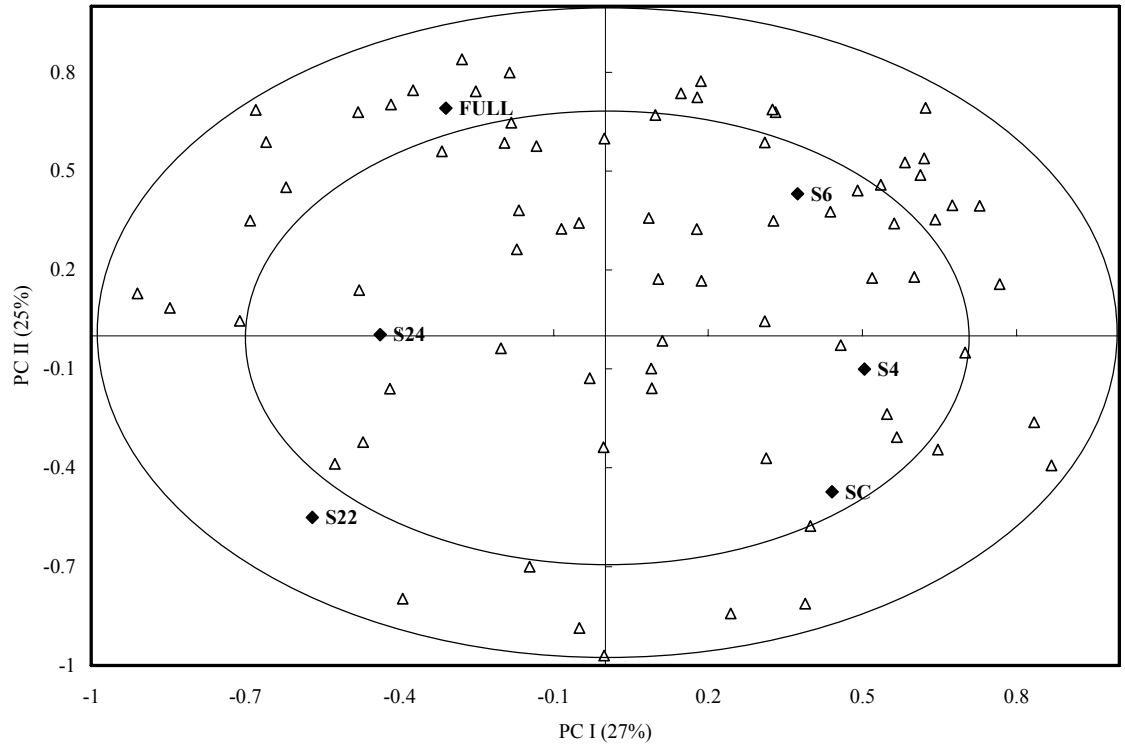


Figure 5-5. Internal preference mapping of overall degree of liking of six ice creams for all consumer panels.

Parenthesis denotes the percent explained by the corresponding PC dimension.

Full: 10% ice cream; SC: Ice cream with Simplese® (Control)

S (Numeric Value): Different flavored ice cream with Simplese® (See Table 5-1)

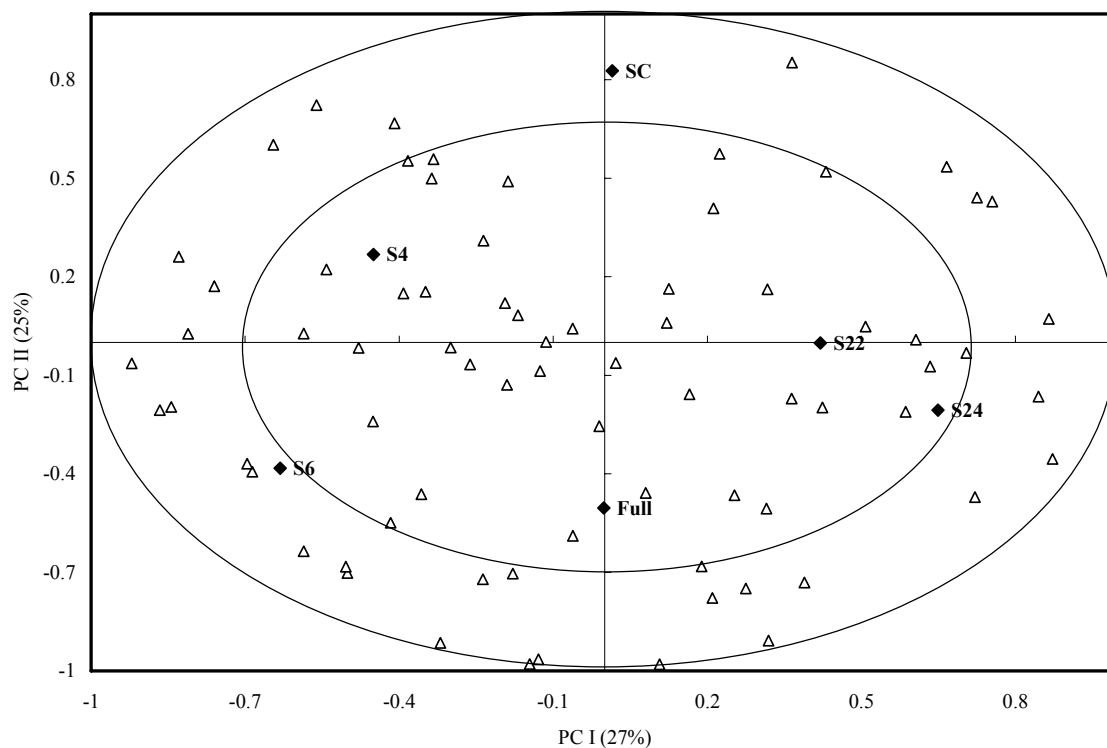


Figure 5-6. Internal preference mapping of degree of flavor liking of six ice creams for all consumer panels.

Parenthesis denotes the percent explained by the corresponding PC dimension.

Full: 10% ice cream; SC: Ice cream with Simplesse® (Control)

S (Numeric Value): Different flavored ice cream with Simplesse® (See Table 5-1)

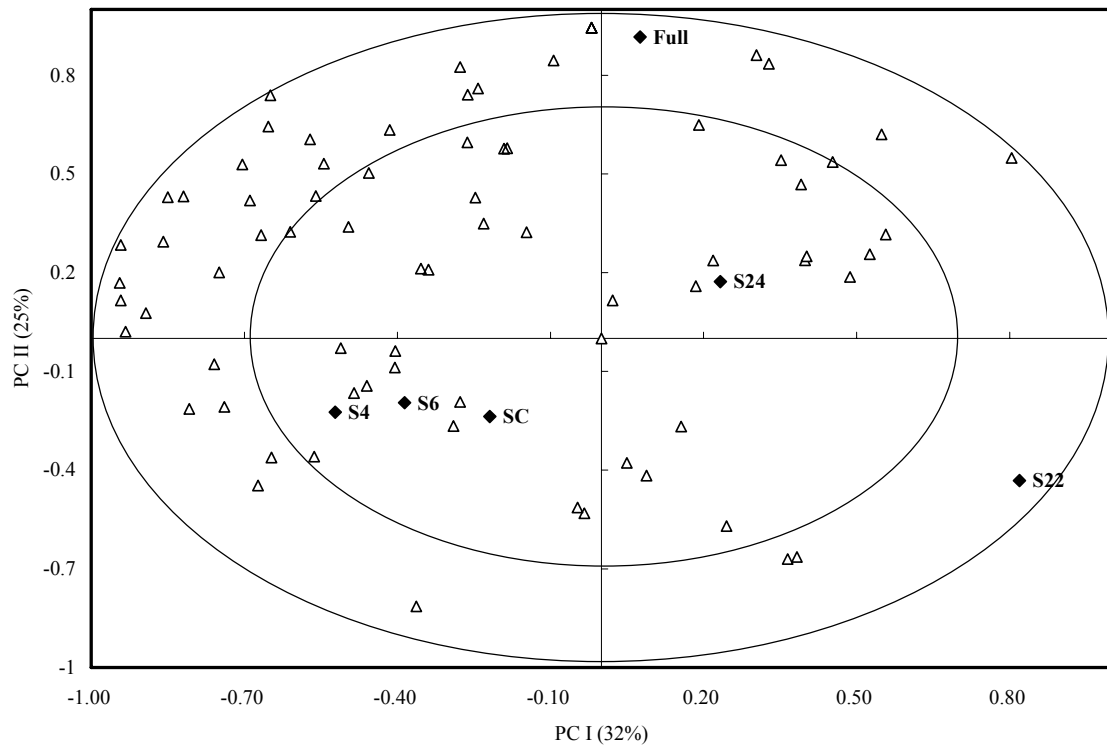


Figure 5-7. Internal preference mapping of degree of texture liking of six ice creams for all consumer panels.

Parenthesis denotes the percent explained by the corresponding PC dimension.

Full: 10% ice cream; SC: Ice cream with Simplese[®] (Control)

S (Numeric Value): Different flavored ice cream with Simplese[®] (See Table 5-1)

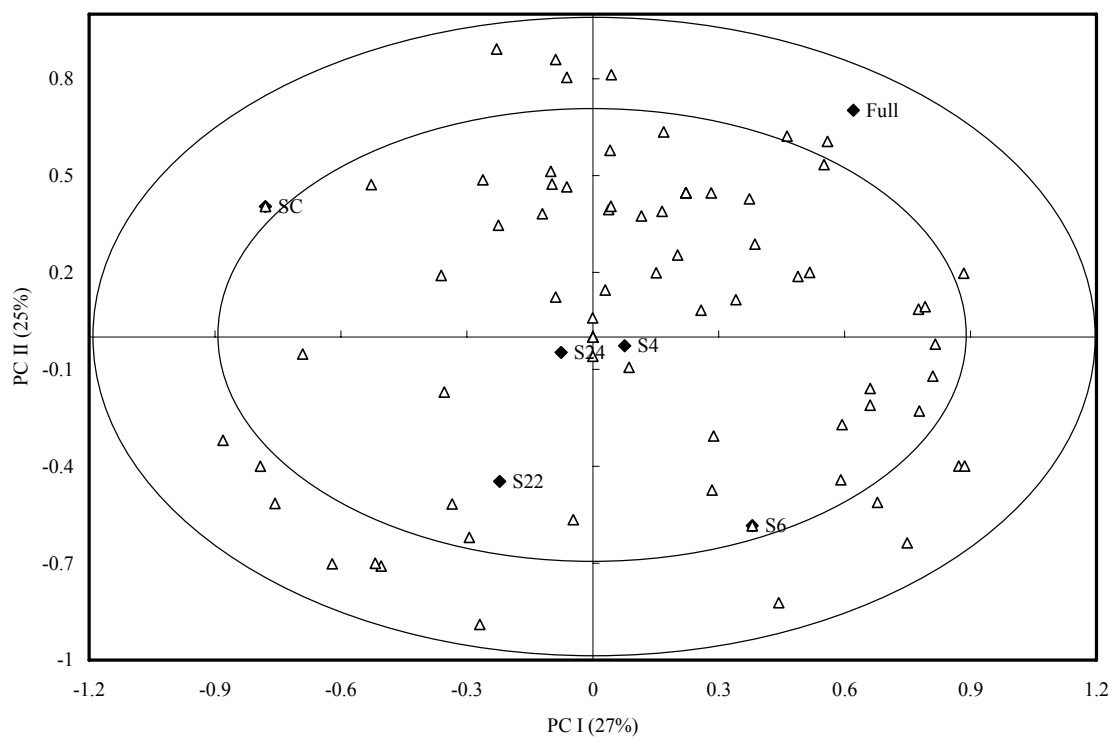


Figure 5-8. Internal preference mapping of degree of appearance liking of six ice creams for all consumer panels.

Parenthesis denotes the percent explained by the corresponding PC dimension.

Full: 10% ice cream; SC: Ice cream with Simplese[®] (Control)

S (Numeric Value): Different flavored ice cream with Simplese[®] (See Table 5-1)

5.4.5 External Preference Mapping

External preference mapping (PREFMAP) allows relating consumer preferences with the sensory characteristics of products. The method can help create or adapt products that will correspond to the consumer preference. PREFMAP has three different models, including the circular preference, the elliptical preference and the vector preference model. However, the first two preference models require at least 8 products, whereas a minimum of 6 products will be sufficient to run the vector preference model (Tang 2003). In this study, only 6 ice creams were chosen for consumer test so the vector model was used. The vector model allows displaying the observations (consumer cluster) on a sensory map as vectors. The size of the vectors can be related to the R^2 of the model. That is to say that the longer the vector is, the better is the underlying model. The first step for external preference mapping was to obtain the characteristics of the products by running a principal component analysis or generalized procrustes analysis (GPA). In this study, principal component analysis was performed using Unscramber software because it can correlate the sensory attributes and products. The second step was to group the consumers in order to make the PREFMAP results easier to interpret. The hedonic ratings by the 74 consumers were computed by Agglomerative Hierarchical Clustering (AHC) using XLSTAT-MX software. Finally, 8 clusters were chosen based on the dendrogram for the DOL and DOF and 4 clusters were grouped for DOT.

Figure 5-9 summarizes the PREFMAP using the factor scores of the 6 ice creams from the PCA on X-axis and the ratings for the 8 clusters from the AHC on the Y-axis both of which accounted for 67% of the total variance. The result showed the vector model is well fitted for cluster number 2 ($R^2= 0.985$ $p=0.002$) and cluster number 6 ($R^2=$

0.867 $p=0.049$). For the other clusters, it will be more risky to interpret the results. Cluster 2 (10% consumers) validated to fit the vector preference model actually preferred ice cream products that have pink color, sweetness, strawberry flavor, milky flavor, violet flavor and violet aftertaste, condensed milk, thickness and mouth coating. Cluster 2 preferred these attributes as opposed to Cluster 6. The consumer grouped in cluster 2 liked SC sample and disliked full-fat ice creams. The preference orders of consumers in cluster 2 are as follows: SC > S24 > S4 > S22 > S6 > 10% ice cream. Consumers in cluster 6 (10% consumers) favored product S6 and 10% ice cream but disliked SC products. In other words, this group of consumers could prefer more creaminess and milky flavor aftertaste. In addition, the map also found that 10% ice cream was preferred by consumers in clusters 1, 3, 4, 5 and 7, which contained about 80% of the consumers. The main difference is that these clusters choose 10% ice cream as their most preferred ice cream, while the most favorite product for cluster 6 is S6. It can be concluded that most consumers preferred 10% ice cream and S6 products. Cluster 1 and 5 (31% consumers) preferred S6 products after 10% ice cream, while cluster 3, 4 and 7 (49% consumers) liked the S4 product.

The PREFMAP for the flavor characteristics of ice creams is shown in Figure 5-10. The result showed cluster 5 (15% consumers) is well fitted for the model ($R^2=0.935$, $P=0.017$) and these consumers liked more the flavor profile of S6 than that of 10% ice cream while clusters 1, 3, 4, 6 and 7 (76% consumers) were the opposite, they liked more the flavor profile of 10% ice cream than that of S6. Comparing cluster 6 consumers for DOL and cluster 5 consumers for DOF, the consumers who overall liked mostly S6 products also preferred the flavor profile of S6. Only 3 consumers (5 %) chose 10% ice

cream as their favorite product, while choosing S6 to have the preferred flavor. Cluster 2 (8% consumers) is the opposite of other clusters because they disliked mostly the 10% ice cream. The 10% ice cream had a strong grassy flavor and grassy flavor aftertaste compared with the other products, and S6 had the weakest intensity in peach flavor. However, strictly speaking, 10% ice cream and S6 were not significantly different in flavor profile according to ANOVA results. S22 was significantly different from the 10% ice cream in cooked sugar aftertaste. It could be speculated that some consumers dislike too strong of a cooked sugar flavor in ice creams.

Figure 5-11 shows the PREFMAP for texture attributes with DOT. The cluster 2 had a high correlation ($R^2= 0.694$), although the 4 clusters did not show sufficient significance to fit the model. Consumers in the 4 clusters liked mostly either S4 or 10% ice cream and disliked either S22 or SC. Reviewing the ANOVA results, there were no significant differences among the 6 ice creams in these texture attributes except for creaminess between S22 and S4. S22 had more creaminess than S4, but there were no significant differences between S4 and 10% ice cream. It could be inferred from the results that some consumers disliked too much creaminess of ice creams. On the other hand, the map showed consumers would like more coldness. A partial reason might be insufficient temperature control prior to serving causing soft textures in ice creams and insufficient coldness feelings in the mouth. King and Arents (1994) also stated that the composition and the temperature of ice cream have a significant influence on texture variables.

As mentioned previously, in this study, it is difficult to compare the relationship between sensory characteristics and DOL due to similar characteristics among products.

Consumers might not have the ability to discriminate differences in ice cream samples. PERFMAP is a powerful tool compared with other multivariate statistical methods. Using several preference techniques it can be concluded that DOL, as perceived by consumers, is positively correlated with 10% ice cream and S6 (Simplese[®] products). In other words, the most influential factors for DOL were related to flavor and texture attributes.

5.5 CONCLUSIONS

In the present experiment it was found that consumers were able to accept the four reformulated flavor ice creams, and that there were no significant differences in consumer preference compared to the full fat ice cream. Among the Simplese[®] products, the product S6, whose flavor is formulated by lowering peach flavor (γ -undecalactone) by 50% and violet flavor (α -ionone) by 25% to match the flavor profile of full-fat ice cream, achieved the highest mean hedonic rating of 6.22. The intensity of violet flavor could play an important role in DOF and DOL of strawberry ice creams.

External preference mapping is a more powerful tool than other multivariate statistical tools for understanding the relationship between sensory characteristics and overall liking. The reason the one consumer group liked S6 and full fat ice cream would be due to strong milky flavor aftertaste and weak peach flavor. The other consumer group would prefer strawberry ice creams to have more pink color, sweetness, strawberry flavor, milky flavor, violet flavor, violet flavor aftertaste, condensed milk, thickness and mouth coating, while some consumers were not able to distinguish any differences in taste among the products.

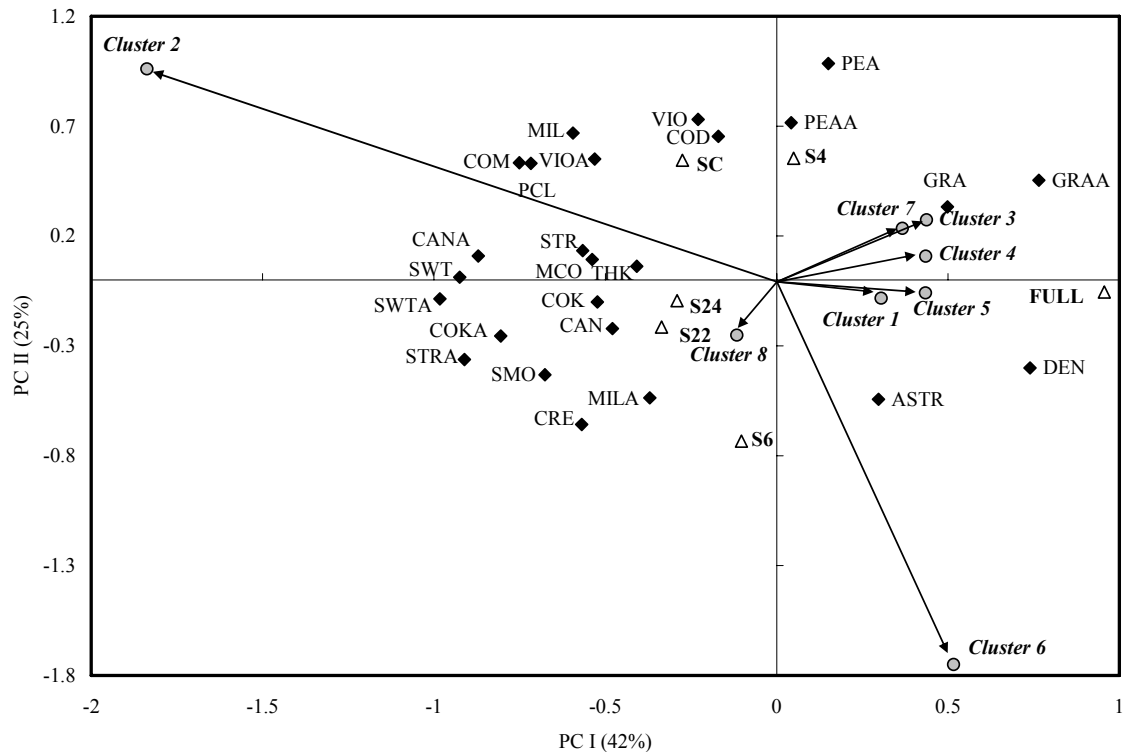


Figure 5-9. External preference mapping of consumer perception of overall liking for 6 ice creams using descriptive data and hedonic data.

Parenthesis denotes the percent explained by the corresponding PC dimension.

PCL	Pink color	DEN	Dense	SWT	Sweetness
STR	Strawberry flavor	CAN	Candy flavor	COK	Cooked sugar flavor
GRA	Grassy flavor	VIO	Violet flavor	PEA	Peach flavor
MIL	Milky flavor	COM	Condensed milk	COD	Coldness
SMO	Smoothness	THK	Thickness	CRE	Creaminess
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

Full: 10% ice cream; SC: Ice cream with Simplese[®] (Control)

S (Numeric Value): Different flavored ice cream with Simplese[®] (See Table 5-1)

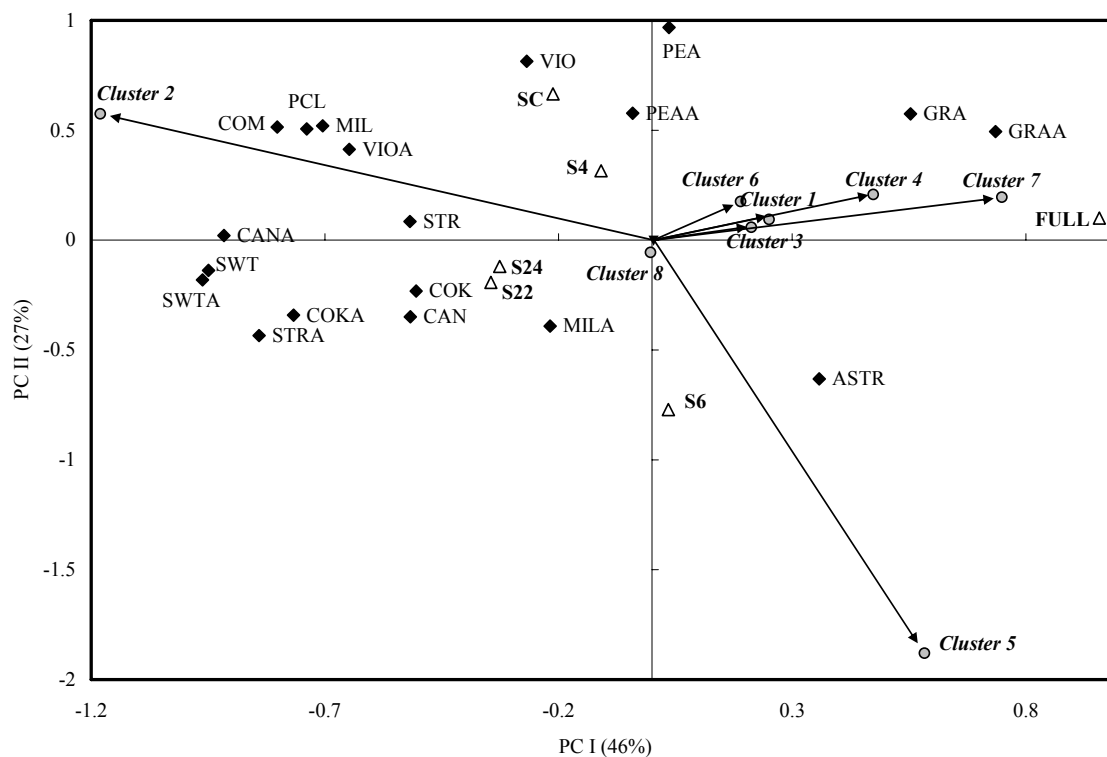


Figure 5-10. External preference mapping of consumer perception of flavor liking for 6 ice creams using descriptive data and hedonic data.

Parenthesis denotes the percent explained by the corresponding PC dimension.

SWT	Sweetness	STR	Strawberry flavor	CAN	Candy flavor
GRA	Grassy flavor	VIO	Violet flavor	COK	Cooked sugar flavor
MIL	Milky flavor	COM	Condensed milk	PEA	Peach flavor
MCO	Mouth coating	SWTA	Sweet aftertaste	STRA	Strawberry aftertaste
CANA	Candy aftertaste	GRAA	Grassy aftertaste	VIOA	Violet aftertaste
PEAA	Peach aftertaste	COKA	Cooked sugar aftertaste	ASTR	Astringency
MILA	Milky aftertaste				

Full: 10% ice cream; SC: Ice cream with Simplese[®] (Control)

S (Numeric Value): Different flavored ice cream with Simplese[®] (See Table 5-1)

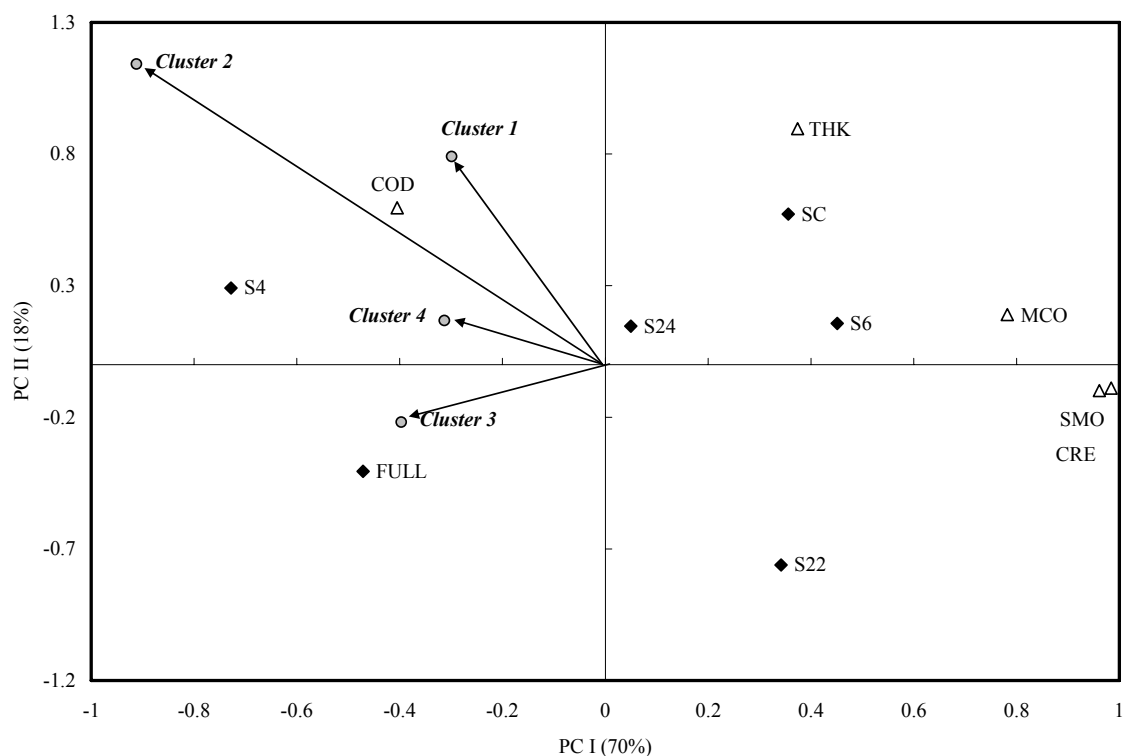


Figure 5-11. External preference mapping of consumer perception of texture liking for 6 ice creams using descriptive data and hedonic data.

Paranthesis denotes the percent explained by the corresponding PC dimension.
 COD Coldness MCO Mouth coating CRE Creaminess
 SMO Smoothness THK Thickness
 Full: 10% ice cream; SC: Ice cream with Simplese® (Control)
 S (Numeric Value): Different flavored ice cream with Simplese® (See Table 5-1)

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CHAPTER 6

SUMMARY AND CONCLUSIONS

The objective of this study was to investigate the release behavior of five strawberry flavor compounds and to determine sensory characteristics in full-fat ice cream and low-fat ice cream with protein- and carbohydrate-based fat mimetics using descriptive analysis. It was anticipated that the sensory data could provide information to help reformulate the flavoring added to a fat mimetic containing low-fat ice cream. This would lead to development of a high quality and “better-for-you” strawberry ice cream, which when tested by consumers, would be close to the desired flavor of the full-fat ice cream.

In the initial experiments, the five flavoring compounds were spiked separately at 200% of base concentration using 5 ice cream formulations (10%, 4% without fat mimetics, 4% with Simplese[®], 4% with Litesse[®] and 4% with both fat mimetics). In that part of the study, it was demonstrated that fat content, fat mimetics and flavor formulation had a significant influence on the perception of furaneol[™] (cooked sugar flavor), α -ionone (violet flavor) and γ -undecalactone (peach flavor) but there was no interaction between ice cream type and flavor formulation for the three flavors according to a mixed model analysis of variance (ANOVA). Overall, *cis*-3-hexen-1-ol (grassy flavor), α -ionone, γ -undecalactone and ethyl-3-methyl-3-phenylglycidate (candy flavor) were perceived with greater intensity in 4% ice cream, while furaneol[™] was perceived more strongly in 10% ice cream and 4% ice creams with Simplese[®]. Spiking of furaneol[™], α -ionone and γ -undecalactone significantly increased the intensity of the corresponding attributes,

cooked sugar, violet and peach flavor, but spiking of *cis*-3-hexen-1-ol increased the intensity of violet flavor, instead of grassy flavor according to the results of canonical variate analysis.

Ice cream with Litesse[®] and low-fat ice creams were similar to each other in flavor profile of the five compounds. Ice creams with Simplese[®] had similar flavor characteristics to those of 10% ice cream, but there were significant differences for milky flavor and condensed milk flavor. In addition, Simplese[®] products were sweeter than other ice cream products. On the other hand, 4% ice creams with Simplese[®] were more similar in mouthfeel to 10% ice cream than were Litesse[®] products. As for ice creams with the L/S mix, they had similar flavor properties to those of ice creams with Litesse[®] but were more similar in textural characteristics to the Simplese[®] ice creams. Based on flavor and textural characteristics, Simplese[®] is a better choice for reformulating the flavoring compounds of ice cream than Litesse[®] because it yields properties more similar to those of 10% ice creams.

In the second step, ice creams with Simplese[®] were manufactured and the concentrations of the individual flavor chemicals were either maintained at original concentrations or decreased individually by 25% in concentration for *cis*-3-hexen-1-ol and furaneol or decreased by 25% and 50% for α -ionone and γ -undecalactone in order to reformulate the artificial strawberry flavor added to match the flavor profile of full-fat ice cream. It was found that high intensity in sweetness, cooked sugar flavor and their aftertaste among 36 Simplese[®] ice creams were determinants for taste similarity with 10% ice cream, instead of violet flavor and peach flavor. Canonical variate analysis and principal component analysis complementarily revealed that the product, in which

γ -undecalactone was decreased by 25% of base concentration, was the closest product to 10% ice cream. Dissimilarity matrix using Euclidean distance also showed similar conclusions. However, cluster analysis indicated products, in which both γ -undecalactone and *cis*-hexen-1-ol were decreased by 25%, had the smallest dissimilarity with 10% ice cream. This result indicated indirectly that cooked sugar flavor could be masked in the presence of other flavors, such as peach flavor and violet flavor. Sweetness also decreased with a lower intensity of cooked sugar flavor in ice creams with Simplese[®].

In the final step of the study, the four reformulated ice creams, which were the closest in sensory characteristics with 10% ice cream, were used to test consumer acceptance and preference. The result showed there were no significant differences in consumer preference compared with 10% ice cream. However, consumer acceptance indicated there were no significant differences between full-fat ice cream and the products that were reformulated by lowering γ -undecalactone by 25% or by lowering γ -undecalactone by 25% and α -ionone by 50% but there were lower hedonic ratings of the products in which γ -undecalactone and *cis*-hexen-1-ol were decreased by 25% with or without a 50% decrease of α -ionone compared with 10% ice cream. Ice cream, in which the flavoring was reformulated by lowering γ -undecalactone by 25% and α -ionone by 50%, had the highest mean hedonic rating of 6.22. It was found that texture and sweetness appear to play a critical role in the overall degree of liking. External preference mapping showed that some consumers would like products having strong milky flavor aftertaste and weak peach flavor. However another consumer group prefers the strawberry ice creams to have more pink color, sweetness, strawberry flavor, milky flavor, violet flavor and violet flavor aftertaste, condensed milk, thickness and mouth coating.

However, it was also found that some consumers were not able to distinguish differences in taste among the products.

The study was successful in formulating artificial strawberry flavored ice creams using Simplese[®] and to understand flavor perception in ice creams with or without fat mimetics.

Appendix A- Sampling plan of quantitative descriptive test for 30 ice creams with or without fat mimetics.

Ice Cream Type	Flavor Formulation					Sample		Sampling Plan						Amount	
	<i>cis</i> 3-Hexeno-1-ol (CH)	Ethyl-3-methyl-3-phenylglycidate (EMP)	Furaneol™ (FUR)	γ -Undecalactone (GU)	α -Ionone (AI)	Sample Code	Product Code	Rep 1		Rep 2		Rep 3		Flavor (ml) 0.1(% (v/v))	Color (ml) 0.4 ml/L
								Code	Order	Code	Order	Code	Order		
10% ice cream	0.375	3.75	1.875	0.5	0.375	A	10COF	526	20	204	9	112	27	3.785	1.514
	0.75	3.75	1.875	0.5	0.375	B	10CHF	359	27	308	14	406	7	3.785	1.514
	0.375	7.5	1.875	0.5	0.375	C	10EMF	774	23	197	1	856	12	3.785	1.514
	0.375	3.75	3.75	0.5	0.375	D	10FUF	751	7	562	19	468	2	3.785	1.514
	0.375	3.75	1.875	1	0.375	E	10GUF	689	14	285	6	133	19	3.785	1.514
	0.375	3.75	1.875	0.5	0.75	F	10AIF	679	13	376	25	167	22	3.785	1.514
4% ice cream	0.375	3.75	1.875	0.5	0.375	G	04COF	149	22	199	3	577	28	3.785	1.514
	0.75	3.75	1.875	0.5	0.375	H	04CHF	811	19	623	10	108	30	3.785	1.514
	0.375	7.5	1.875	0.5	0.375	I	04EMF	537	28	679	2	858	1	3.785	1.514
	0.375	3.75	3.75	0.5	0.375	J	04FUF	450	6	977	26	497	13	3.785	1.514
	0.375	3.75	1.875	1	0.375	K	04GUF	170	18	597	24	354	6	3.785	1.514
	0.375	3.75	1.875	0.5	0.75	L	04AIF	880	16	251	20	298	21	3.785	1.514
4% ice cream with Litesse®	0.375	3.75	1.875	0.5	0.375	M	04COL	637	25	216	15	254	11	3.785	1.514
	0.75	3.75	1.875	0.5	0.375	N	04CHL	580	30	931	13	168	14	3.785	1.514
	0.375	7.5	1.875	0.5	0.375	O	04EML	308	21	965	7	553	5	3.785	1.514
	0.375	3.75	3.75	0.5	0.375	P	04FUL	835	2	306	4	399	29	3.785	1.514
	0.375	3.75	1.875	1	0.375	Q	04GUL	956	10	379	5	579	10	3.785	1.514
	0.375	3.75	1.875	0.5	0.75	R	04AIL	984	1	846	16	333	20	3.785	1.514
4% ice cream with Simplesse®	0.375	3.75	1.875	0.5	0.375	S	04COS	635	24	365	11	933	23	3.785	1.514
	0.75	3.75	1.875	0.5	0.375	T	04CHS	534	15	208	17	394	4	3.785	1.514
	0.375	7.5	1.875	0.5	0.375	U	04EMS	301	12	367	18	314	17	3.785	1.514
	0.375	3.75	3.75	0.5	0.375	V	04FUS	843	9	999	27	421	26	3.785	1.514
	0.375	3.75	1.875	1	0.375	W	04GUS	378	5	741	21	564	9	3.785	1.514
	0.375	3.75	1.875	0.5	0.75	X	04AIS	728	4	708	8	701	3	3.785	1.514
4% ice cream with L / S mix	0.375	3.75	1.875	0.5	0.375	Y	04COLS	441	26	911	23	679	16	3.785	1.514
	0.75	3.75	1.875	0.5	0.375	Z	04CHLS	571	29	201	29	266	24	3.785	1.514
	0.375	7.5	1.875	0.5	0.375	AA	04EMLS	182	11	148	12	116	25	3.785	1.514
	0.375	3.75	3.75	0.5	0.375	AB	04FULS	564	3	111	30	179	18	3.785	1.514
	0.375	3.75	1.875	1	0.375	AC	04GULS	821	17	554	28	376	8	3.785	1.514
	0.375	3.75	1.875	0.5	0.75	AD	04AISLS	217	8	379	22	120	15	3.785	1.514

Appendix B-Complete block design of quantitative descriptive test used on 30 ice creams with or without fat mimetics.

(Replication 1)

Sample	Product Code	Blinding Code	Panelist												
			J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12	
			Section 1												
R	04AIL	984	Serving order	4	5	2	2	4	2	1	1	6	6	5	2
P	04FUL	835		1	1	6	5	5	1	3	5	1	4	3	4
AB	04FULS	564		3	6	1	6	2	4	5	2	2	1	2	6
X	04AIS	728		6	2	3	3	3	6	6	6	3	2	6	3
W	04GUS	378		2	4	5	4	6	3	2	3	5	5	1	1
J	04FU	450		5	3	4	1	1	5	4	4	4	3	4	5
			Section 2												
AC	04GULS	821	Serving order	6	3	6	5	6	3	6	5	1	3	2	1
AD	04AILS	217		3	5	3	1	4	1	5	6	5	4	3	3
V	04FUS	843		2	2	2	2	1	6	1	4	2	2	6	5
Q	04GUL	956		1	6	5	4	2	5	2	2	4	1	1	4
AA	04EMLS	182		4	1	4	3	3	4	4	1	3	6	5	6
U	04EMS	301		5	4	1	6	5	2	3	3	6	5	4	2
			Section 3												
F	10AIF	679	Serving order	1	2	2	4	6	5	1	4	1	4	5	5
E	10GUF	689		4	3	6	6	1	3	6	5	2	6	6	3
T	04CHS	534		6	5	3	3	2	4	4	1	6	3	1	1
L	04AIF	880		2	4	5	2	3	1	5	2	4	5	4	6
D	10FUF	751		5	1	1	1	4	2	2	6	3	1	3	4
K	04GUF	170		3	6	4	5	5	6	3	3	5	2	2	2
			Section 4												
H	04CHF	811	Serving order	1	6	2	3	4	2	5	2	6	3	1	5
A	10COF	526		2	4	5	5	1	4	1	1	3	6	2	1
O	04EML	308		4	3	6	2	5	3	2	6	1	1	3	2
G	04COF	149		3	1	1	1	6	5	3	4	4	2	4	3
C	10EMF	774		6	2	4	6	2	6	6	3	5	4	5	6
S	04COS	635		5	5	3	4	3	1	4	5	2	5	6	4
			Section 5												
B	10CHF	359	Serving order	6	2	6	3	2	5	2	1	2	3	1	1
I	04EMF	537		4	5	3	1	4	3	4	2	5	6	4	5
M	04COL	637		2	3	4	4	1	6	5	6	4	5	2	4
N	04CHL	580		5	1	2	5	5	2	1	3	6	1	6	6
Y	04CLS	441		3	4	5	6	6	1	6	4	1	2	3	3
Z	04CHLS	571		1	6	1	2	3	4	3	5	3	4	5	2

Complete block design of quantitative descriptive test used on 30 ice creams with or without fat mimetics.

(Replication 2)

Sample	Product Code	Blinding Code	Panelist												
			J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12	
			Section 6												
C	10EMF	197	Serving order	1	3	1	5	4	6	1	2	1	2	6	2
E	10GUF	285		2	1	2	1	1	4	2	1	5	5	4	5
G	04COF	199		4	5	5	2	3	1	3	6	4	1	2	4
I	04EMF	679		6	6	6	6	2	3	4	5	2	4	3	3
P	04FUL	306		3	4	3	4	6	2	6	3	6	6	1	1
Q	04GUL	379		5	2	4	3	5	5	5	4	3	3	5	6
			Section 7												
O	04EMPL	965	Serving order	2	6	3	6	2	1	4	6	3	1	2	2
X	04AIS	708		6	4	6	4	5	5	6	4	6	2	1	4
A	10COF	204		1	2	1	2	1	3	1	1	1	4	3	6
H	04CHF	623		3	1	4	3	4	4	2	5	2	3	4	5
S	04COS	365		4	3	5	5	6	2	5	3	4	6	6	3
AA	04EMPLS	148		5	5	2	1	3	6	3	2	5	5	5	1
			Section 8												
N	04CHL	931	Serving order	2	1	3	1	5	1	1	4	5	4	6	3
B	10CHF	308		3	4	4	3	1	4	3	1	1	1	3	1
M	04COL	216		1	6	6	2	2	6	2	2	4	2	2	4
R	04AIL	846		6	5	5	6	4	5	6	3	2	3	1	6
T	04CHS	208		4	3	2	5	3	2	4	5	3	6	4	2
U	04EMPS	367		5	2	1	4	6	3	5	6	6	5	5	5
			Section 9												
D	10FUR	562	Serving order	2	6	3	6	2	1	4	6	3	1	2	2
L	04AI	251		6	4	6	4	5	5	6	4	6	2	1	4
W	04GUS	741		1	2	1	2	1	3	1	1	1	4	3	5
AD	04AILS	379		3	1	4	3	4	4	2	5	2	3	4	6
Y	04COLS	911		4	3	5	5	6	2	5	3	4	6	6	3
K	04GU	597		5	5	2	1	3	6	3	2	5	5	5	1
			Section 10												
F	10AI	376	Serving order	2	1	3	1	5	1	1	4	5	4	6	3
J	04FUR	977		3	4	4	3	1	4	3	1	1	1	3	1
V	04FURS	999		1	6	6	2	2	6	2	2	4	2	2	4
AC	04GULS	554		6	5	5	6	4	5	6	3	2	3	1	6
Z	04CHLS	201		4	3	2	5	3	2	4	5	3	6	4	2
AB	04FURLS	111		5	2	1	4	6	3	5	6	6	5	5	5

Complete block design of quantitative descriptive test used on 30 ice creams with or without fat mimetics.

(Replication 3)

Sample	Product Code	Blinding Code	Panelist												
			J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12	
			Section 11												
I	04EMP	858	Serving order	2	6	3	6	2	1	4	6	3	1	2	2
D	10FUR	468		6	4	6	4	5	5	6	4	6	2	1	4
X	04AIS	701		1	2	1	2	1	3	1	1	1	4	3	5
T	04CHS	394		3	1	4	3	4	4	2	5	2	3	4	6
O	04EMPL	553		4	3	5	5	6	2	5	3	4	6	6	3
K	04GU	354		5	5	2	1	3	6	3	2	5	5	5	1
			Section 12												
B	10CH	406	Serving order	2	1	3	1	5	1	1	4	5	4	6	3
AC	04GULS	376		3	4	4	3	1	4	3	1	1	1	3	1
W	04GUS	564		1	6	6	2	2	6	2	2	4	2	2	4
Q	04GUL	579		6	5	5	6	4	5	6	3	2	3	1	6
M	04COL	254		4	3	2	5	3	2	4	5	3	6	4	2
C	10EMP	856		5	2	1	4	6	3	5	6	6	5	5	5
			Section 13												
J	04FUR	497	Serving order	2	6	3	6	2	1	4	6	3	1	2	2
N	04CHL	168		6	4	6	4	5	5	6	4	6	2	1	4
AD	04AIS	120		1	2	1	2	1	3	1	1	1	4	3	5
Y	04COLS	679		3	1	4	3	4	4	2	5	2	3	4	6
U	04EMPS	314		4	3	5	5	6	2	5	3	4	6	6	3
AB	04FURLS	179		5	5	2	1	3	6	3	2	5	5	5	1
			Section 14												
E	10GU	133	Serving order	2	1	3	1	5	1	1	4	5	4	6	3
R	04AIL	333		3	4	4	3	1	4	3	1	1	1	3	1
L	04AI	298		1	6	6	2	2	6	2	2	4	2	2	4
F	10AI	167		6	5	5	6	4	5	6	3	2	3	1	6
S	04COS	933		4	3	2	5	3	2	4	5	3	6	4	2
Z	04CHLS	266		5	2	1	4	6	3	5	6	6	5	5	5
			Section 15												
A	10CO	112	Serving order	6	2	6	3	2	5	2	1	2	3	1	1
G	4CO	577		4	5	3	1	4	3	4	2	5	6	4	5
P	4FURL	399		2	3	4	4	1	6	5	6	4	5	2	4
H	4CH	266		5	1	2	5	5	2	1	3	6	1	6	6
AA	04EMPLS	116		3	4	5	6	6	1	6	4	1	2	3	3
V	04FURS	421		1		1	2	3	4	3	5	3	4	5	2

Appendix C- Mean intensity value (mixed model ANOVA) for 30 ice creams with or without fat mimetics

(Mean intensity value for pink color and dense)

Effect=Product (ice cream *formulation); Method=LSD(P<.05)

Pink Color					Dense				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	L	7.9361	0.7486	A	1	E	8.4667	0.9164	A
2	K	7.7333	0.7486	AB	2	X	8.3278	0.9164	AB
3	G	7.7194	0.7486	AB	3	V	8.2639	0.9164	ABC
4	AC	7.6625	0.7486	ABC	4	AD	8.1556	0.9164	ABCD
5	H	7.4833	0.7486	ABCD	5	O	8.0111	0.9164	ABCDE
6	X	7.4639	0.7486	ABCD	6	Q	7.9597	0.9164	ABCDE
7	S	7.4250	0.7486	ABCD	7	P	7.9583	0.9164	ABCDE
8	Y	7.3167	0.7486	ABCD	8	AB	7.9306	0.9164	ABCDE
9	F	7.2639	0.7486	ABCD	9	Y	7.9306	0.9164	ABCDE
10	V	7.0667	0.7486	ABCDE	10	Z	7.9250	0.9164	ABCDE
11	Z	7.0472	0.7486	ABCDE	11	K	7.8917	0.9164	ABCDE
12	T	7.0333	0.7486	ABCDE	12	M	7.8847	0.9164	ABCDE
13	W	6.9931	0.7486	ABCDE	13	U	7.8611	0.9164	ABCDE
14	AB	6.9556	0.7486	ABCDE	14	D	7.8583	0.9164	ABCDE
15	J	6.9250	0.7486	ABCDE	15	A	7.8500	0.9164	ABCDE
16	I	6.8667	0.7486	ABCDEF	16	F	7.8444	0.9164	ABCDE
17	B	6.6833	0.7486	ABCDEF	17	L	7.8222	0.9164	ABCDE
18	N	6.6750	0.7486	ABCDEF	18	T	7.8083	0.9164	ABCDE
19	U	6.5528	0.7486	ABCDEF	19	B	7.7708	0.9164	ABCDEF
20	AA	6.4000	0.7486	BCDEF	20	S	7.7667	0.9164	ABCDEF
21	E	6.3972	0.7486	BCDEF	21	AA	7.6028	0.9164	ABCDEF
22	Q	6.2653	0.7486	CDEF	22	G	7.5750	0.9164	ABCDEF
23	D	6.1333	0.7486	DEFG	23	C	7.5528	0.9164	ABCDEF
24	A	5.8139	0.7486	EFG	24	R	7.5444	0.9164	ABCDEF
25	O	5.7861	0.7486	EFG	25	AC	7.5292	0.9164	BCDEF
26	P	5.7750	0.7486	EFG	26	H	7.4250	0.9164	BCDEF
27	R	5.7417	0.7486	EFG	27	W	7.3931	0.9164	CDEF
28	M	5.6542	0.7486	EFG	28	N	7.3278	0.9164	DEF
29	AD	5.4556	0.7486	FG	29	J	7.1722	0.9164	EF
30	C	4.7861	0.7486	G	30	I	6.8611	0.9164	F

Means sharing the same letter do not differ at P<0.05

Sample refer to Appendix A for product information

(Mean intensity value for rate of melt and sweetness)

Effect=Product (ice cream *formulation); Method=LSD(P<.05)

Rate of Melt					Sweetness				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	X	15.7500	1.8690	A	1	P	8.4306	0.7772	A
2	AD	15.4167	1.8690	AB	2	Z	8.3500	0.7772	AB
3	A	14.9722	1.8690	ABC	3	S	8.3306	0.7772	AB
4	Q	14.8611	1.8690	ABC	4	AB	8.2472	0.7772	ABC
5	W	14.7917	1.8690	ABC	5	Y	8.2222	0.7772	ABCD
6	U	14.7500	1.8690	ABC	6	X	8.1611	0.7772	ABCD
7	B	14.7361	1.8690	ABC	7	C	8.0389	0.7772	ABCD
8	AA	14.6944	1.8690	ABC	8	V	7.9917	0.7772	ABCD
9	Y	14.6667	1.8690	ABC	9	Q	7.9514	0.7772	ABCD
10	T	14.5556	1.8690	ABC	10	L	7.9083	0.7772	ABCD
11	V	14.5556	1.8690	ABC	11	AA	7.9000	0.7772	ABCD
12	H	14.5000	1.8690	ABC	12	J	7.8528	0.7772	ABCD
13	J	14.5000	1.8690	ABC	13	T	7.8194	0.7772	ABCD
14	D	14.3889	1.8690	ABC	14	O	7.7444	0.7772	ABCD
15	I	14.2500	1.8690	ABC	15	B	7.7264	0.7772	ABCD
16	S	14.2222	1.8690	ABC	16	U	7.7222	0.7772	ABCD
17	N	14.1667	1.8690	ABC	17	W	7.5125	0.7772	ABCD
18	E	14.1667	1.8690	ABC	18	AD	7.4389	0.7772	ABCD
19	K	14.1667	1.8690	ABC	19	A	7.4333	0.7772	ABCD
20	AB	14.0833	1.8690	BC	20	M	7.4236	0.7772	ABCD
21	R	14.0833	1.8690	BC	21	D	7.4028	0.7772	BCD
22	P	13.9722	1.8690	BC	22	I	7.3917	0.7772	BCD
23	L	13.8611	1.8690	BC	23	R	7.3500	0.7772	BCD
24	Z	13.8056	1.8690	BC	24	G	7.3000	0.7772	CD
25	C	13.8056	1.8690	BC	25	K	7.2917	0.7772	CD
26	O	13.7778	1.8690	BC	26	H	7.2500	0.7772	CD
27	M	13.7222	1.8690	C	27	F	7.2472	0.7772	CD
28	G	13.6111	1.8690	C	28	E	7.2333	0.7772	CD
29	AC	13.5139	1.8690	C	29	N	7.2278	0.7772	CD
30	F	13.4167	1.8690	C	30	AC	7.2111	0.7772	D

Means sharing the same letter do not differ at P<0.05

Sample refer to Appendix A for product information

(Mean intensity value for strawberry flavor and candy flavor)

Effect=Product (ice cream *formulation); Method=LSD(P<.05)

Strawberry flavor					Candy flavor				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	O	5.6028	0.6809	A	1	AC	5.7208	0.7263	A
2	P	5.5417	0.6809	AB	2	X	5.5667	0.7263	AB
3	C	5.5083	0.6809	AB	3	M	5.5056	0.7263	AB
4	V	5.4917	0.6809	AB	4	AA	5.4222	0.7263	ABC
5	E	5.4722	0.6809	AB	5	U	5.3111	0.7263	ABCD
6	X	5.4667	0.6809	AB	6	I	5.2500	0.7263	ABCD
7	AB	5.4361	0.6809	AB	7	L	5.2083	0.7263	ABCD
8	AA	5.3694	0.6809	AB	8	O	5.1694	0.7263	ABCD
9	N	5.3278	0.6809	AB	9	R	5.1361	0.7263	ABCD
10	I	5.3222	0.6809	AB	10	G	5.1278	0.7263	ABCD
11	T	5.2833	0.6809	AB	11	E	5.0611	0.7263	ABCDE
12	AD	5.2722	0.6809	AB	12	B	5.0528	0.7263	ABCDE
13	Q	5.2708	0.6809	AB	13	AB	5.0472	0.7263	ABCDE
14	S	5.2056	0.6809	AB	14	C	4.8986	0.7263	ABCDEF
15	A	5.1806	0.6809	AB	15	T	4.8722	0.7263	ABCDEF
16	Y	5.1667	0.6809	AB	16	Y	4.8611	0.7263	ABCDEF
17	H	5.1556	0.6809	AB	17	AD	4.8611	0.7263	ABCDEF
18	J	5.1417	0.6809	AB	18	N	4.8389	0.7263	ABCDEF
19	AC	5.1153	0.6809	AB	19	W	4.8278	0.7263	ABCDEF
20	U	5.1056	0.6809	AB	20	K	4.8222	0.7263	ABCDEF
21	M	5.0597	0.6809	AB	21	H	4.7972	0.7263	ABCDEF
22	D	5.0472	0.6809	AB	22	A	4.7944	0.7263	ABCDEF
23	B	5.0458	0.6809	AB	23	D	4.7833	0.7263	ABCDEF
24	G	5.0333	0.6809	AB	24	Q	4.7639	0.7263	ABCDEF
25	Z	5.0306	0.6809	AB	25	V	4.7222	0.7263	ABCDEF
26	L	5.0111	0.6809	AB	26	J	4.6583	0.7263	BCDEF
27	W	4.9833	0.6809	AB	27	P	4.4417	0.7263	CDEF
28	F	4.9694	0.6809	AB	28	S	4.4083	0.7263	DEF
29	R	4.9389	0.6809	AB	29	F	4.0611	0.7263	EF
30	K	4.8750	0.6809	B	30	Z	4.0139	0.7263	F

Means sharing the same letter do not different at P<0.05

Sample refer to Appendix A for product information

(Mean intensity value for grassy flavor and cooked sugar flavor)

Effect=Product (ice cream *formulation); Method=LSD(P<.05)

Grassy flavor					Cooked Sugar flavor				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	Q	3.5708	0.6960	A	1	P	5.7083	0.7340	A
2	N	3.5194	0.6960	AB	2	V	5.5389	0.7340	AB
3	AA	3.3528	0.6960	ABC	3	Y	5.3917	0.7340	ABC
4	H	3.2972	0.6960	ABC	4	F	5.2861	0.7340	ABCD
5	AD	3.2833	0.6960	ABC	5	T	5.1139	0.7340	ABCDE
6	R	3.2194	0.6960	ABC	6	U	5.1028	0.7340	ABCDE
7	AC	3.2056	0.6960	ABC	7	S	5.0917	0.7340	ABCDEF
8	X	3.1472	0.6960	ABC	8	D	5.0833	0.7340	ABCDEF
9	W	3.0889	0.6960	ABC	9	AB	5.0806	0.7340	ABCDEF
10	B	3.0556	0.6960	ABC	10	B	5.0306	0.7340	ABCDEF
11	Z	3.0139	0.6960	ABC	11	W	4.9889	0.7340	ABCDEF
12	J	2.9111	0.6960	ABC	12	Z	4.9333	0.7340	ABCDEF
13	A	2.8556	0.6960	ABC	13	AD	4.9306	0.7340	ABCDEF
14	Y	2.8194	0.6960	ABC	14	N	4.9250	0.7340	ABCDEF
15	P	2.7833	0.6960	ABC	15	Q	4.9153	0.7340	ABCDEF
16	U	2.7028	0.6960	ABC	16	A	4.6667	0.7340	BCDEFG
17	AB	2.6889	0.6960	ABC	17	AA	4.6361	0.7340	BCDEFG
18	K	2.6611	0.6960	ABC	18	C	4.5472	0.7340	CDEFGH
19	F	2.6528	0.6960	ABC	19	X	4.5306	0.7340	CDEFGH
20	E	2.6250	0.6960	ABC	20	E	4.5083	0.7340	CDEFGH
21	G	2.6167	0.6960	ABC	21	G	4.4917	0.7340	CDEFGH
22	D	2.6083	0.6960	ABC	22	J	4.3556	0.7340	DEFGH
23	M	2.6042	0.6960	ABC	23	R	4.2556	0.7340	EFGH
24	V	2.5778	0.6960	ABC	24	AC	4.2014	0.7340	EFGH
25	O	2.5778	0.6960	ABC	25	H	4.1750	0.7340	EFGH
26	T	2.5500	0.6960	ABC	26	I	4.1722	0.7340	EFGH
27	L	2.5250	0.6960	ABC	27	K	4.1222	0.7340	FGH
28	C	2.4792	0.6960	BC	28	M	3.9444	0.7340	GH
29	I	2.4750	0.6960	BC	29	O	3.8583	0.7340	GH
30	S	2.3611	0.6960	C	30	L	3.6639	0.7340	H

Means sharing the same letter do not differ at P<0.05

Sample refer to Appendix A for product information

(Mean intensity value for peach flavor and violet flavor)

Effect=Product (ice cream *formulation); Method=LSD(P<.05)

Peach flavor					Violet flavor				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	AC	5.1583	0.7757	A	1	Q	5.0000	0.7842	A
2	K	5.0472	0.7757	AB	2	L	4.7833	0.7842	AB
3	AA	4.8694	0.7757	ABC	3	R	4.6444	0.7842	ABC
4	Q	4.7625	0.7757	ABCD	4	Z	4.5000	0.7842	ABC
5	L	4.7167	0.7757	ABCD	5	X	4.4722	0.7842	ABCD
6	O	4.6528	0.7757	ABCD	6	AD	4.2778	0.7842	ABCDE
7	P	4.6194	0.7757	ABCD	7	P	4.1583	0.7842	ABCDE
8	AB	4.6000	0.7757	ABCD	8	H	4.1056	0.7842	ABCDEF
9	X	4.5583	0.7757	ABCDE	9	AA	4.0750	0.7842	ABCDEF
10	AD	4.4722	0.7757	ABCDE	10	K	4.0694	0.7842	ABCDEF
11	J	4.4250	0.7757	ABCDE	11	N	4.0194	0.7842	ABCDEFG
12	M	4.3639	0.7757	ABCDEF	12	O	3.9833	0.7842	ABCDEFG
13	H	4.3472	0.7757	ABCDEF	13	T	3.9417	0.7842	BCDEFG
14	W	4.1417	0.7757	ABCDEF	14	J	3.8472	0.7842	BCDEFG
15	I	4.1250	0.7757	ABCDEF	15	W	3.7792	0.7842	BCDEFG
16	Z	4.1139	0.7757	ABCDEF	16	AC	3.7722	0.7842	BCDEFG
17	R	4.0528	0.7757	ABCDEF	17	V	3.7722	0.7842	BCDEFG
18	U	4.0417	0.7757	ABCDEF	18	Y	3.7667	0.7842	BCDEFG
19	Y	4.0306	0.7757	ABCDEF	19	U	3.7333	0.7842	CDEFG
20	V	4.0167	0.7757	ABCDEF	20	F	3.6806	0.7842	CDEFG
21	N	3.9417	0.7757	BCDEF	21	AB	3.6694	0.7842	CDEFG
22	G	3.9417	0.7757	BCDEF	22	B	3.6639	0.7842	CDEFG
23	A	3.9194	0.7757	BCDEF	23	I	3.6528	0.7842	CDEFG
24	E	3.8167	0.7757	CDEF	24	E	3.6056	0.7842	CDEFG
25	D	3.7417	0.7757	CDEF	25	S	3.4556	0.7842	DEFG
26	B	3.7208	0.7757	DEF	26	M	3.4167	0.7842	EFG
27	C	3.6847	0.7757	DEF	27	C	3.3389	0.7842	EFG
28	S	3.6306	0.7757	DEF	28	A	3.1083	0.7842	FG
29	T	3.4528	0.7757	EF	29	G	3.0722	0.7842	FG
30	F	3.2250	0.7757	F	30	D	2.9917	0.7842	G

Means sharing the same letter do not differ at P<0.05

Sample refer to Appendix A for product information

(Mean intensity value for milky flavor and condensed milk flavor)

Effect=Product (ice cream *formulation); Method=LSD(P<.05)

Milky flavor					Condensed milk flavor				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	B	5.9514	0.7126	A	1	S	4.2667	0.7118	A
2	A	5.7833	0.7126	AB	2	V	4.1417	0.7118	AB
3	F	5.7778	0.7126	AB	3	U	4.0028	0.7118	ABC
4	E	5.6528	0.7126	ABC	4	W	3.9111	0.7118	ABCD
5	C	5.6486	0.7126	ABC	5	X	3.8444	0.7118	ABCDE
6	D	5.5556	0.7126	ABCD	6	AD	3.7639	0.7118	ABCDEF
7	P	5.4833	0.7126	ABCD	7	T	3.7611	0.7118	ABCDEF
8	W	5.4236	0.7126	ABCD	8	Z	3.7472	0.7118	ABCDEF
9	R	5.4056	0.7126	ABCDE	9	E	3.7333	0.7118	ABCDEF
10	U	5.3639	0.7126	ABCDE	10	AB	3.6806	0.7118	ABCDEF
11	AB	5.3222	0.7126	ABCDE	11	Y	3.6667	0.7118	ABCDEF
12	V	5.3111	0.7126	ABCDE	12	AA	3.5139	0.7118	ABCDEFG
13	J	5.3056	0.7126	ABCDE	13	R	3.3556	0.7118	BCDEFG
14	Z	5.2972	0.7126	ABCDE	14	I	3.3500	0.7118	BCDEFG
15	M	5.2931	0.7126	ABCDE	15	G	3.3472	0.7118	BCDEFG
16	G	5.2917	0.7126	ABCDE	16	F	3.3056	0.7118	BCDEFG
17	X	5.2750	0.7126	ABCDE	17	C	3.2819	0.7118	BCDEFG
18	AA	5.2028	0.7126	ABCDE	18	B	3.2778	0.7118	BCDEFG
19	O	5.1167	0.7126	BCDE	19	A	3.2722	0.7118	BCDEFG
20	I	5.0167	0.7126	BCDE	20	P	3.2500	0.7118	CDEFG
21	T	4.9917	0.7126	BCDE	21	Q	3.2028	0.7118	CDEFG
22	AC	4.9833	0.7126	BCDE	22	H	3.1722	0.7118	CDEFG
23	AD	4.9778	0.7126	BCDE	23	AC	3.1125	0.7118	DEFG
24	L	4.9556	0.7126	BCDE	24	N	3.0667	0.7118	DEFG
25	K	4.9167	0.7126	CDE	25	J	3.0444	0.7118	DEFG
26	H	4.9111	0.7126	CDE	26	L	3.0250	0.7118	EFG
27	S	4.8944	0.7126	CDE	27	K	2.9889	0.7118	EFG
28	N	4.7861	0.7126	DE	28	O	2.9611	0.7118	FG
29	Y	4.7528	0.7126	DE	29	D	2.9028	0.7118	FG
30	Q	4.5806	0.7126	E	30	M	2.6472	0.7118	G

Means sharing the same letter do not differ at P<0.05

Sample refer to Appendix A for product information

(Mean intensity value for coldness and smoothness)

Effect=Product (ice cream *formulation); Method=LSD(P<.05)

Coldness					Smoothness				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	L	10.0889	0.5230	A	1	AC	7.4000	0.7175	A
2	Q	9.8597	0.5230	AB	2	M	7.3903	0.7175	A
3	G	9.8528	0.5230	AB	3	T	7.3472	0.7175	AB
4	W	9.7722	0.5230	AB	4	C	7.2333	0.7175	AB
5	K	9.7500	0.5230	AB	5	Y	7.1917	0.7175	AB
6	AA	9.6917	0.5230	ABC	6	S	7.1833	0.7175	AB
7	H	9.6694	0.5230	ABCD	7	B	7.1653	0.7175	AB
8	X	9.6194	0.5230	ABCD	8	R	7.1500	0.7175	ABC
9	V	9.5667	0.5230	ABCD	9	D	7.1472	0.7175	ABC
10	Y	9.5028	0.5230	ABCDE	10	O	7.0917	0.7175	ABCD
11	J	9.4056	0.5230	ABCDE	11	E	7.0306	0.7175	ABCD
12	AB	9.3889	0.5230	ABCDE	12	A	6.9306	0.7175	ABCD
13	AD	9.3861	0.5230	ABCDE	13	W	6.8750	0.7175	ABCDE
14	Z	9.3694	0.5230	ABCDE	14	AA	6.8389	0.7175	ABCDE
15	S	9.3222	0.5230	ABCDEF	15	AB	6.8333	0.7175	ABCDEF
16	I	9.2278	0.5230	ABCDEF	16	F	6.7667	0.7175	ABCDEF
17	P	9.1556	0.5230	ABCDEF	17	AD	6.5528	0.7175	ABCDEFG
18	E	9.1250	0.5230	ABCDEF	18	U	6.5361	0.7175	ABCDEFG
19	T	9.0861	0.5230	ABCDEF	19	Z	6.5139	0.7175	ABCDEFG
20	A	9.0528	0.5230	ABCDEF	20	V	6.4833	0.7175	ABCDEFG
21	AC	9.0167	0.5230	ABCDEF	21	N	6.4611	0.7175	ABCDEFG
22	U	8.9528	0.5230	ABCDEF	22	G	6.3167	0.7175	BCDEFG
23	C	8.8014	0.5230	BCDEF	23	Q	6.0944	0.7175	CDEFG
24	N	8.7667	0.5230	BCDEF	24	P	6.0806	0.7175	DEFG
25	F	8.7444	0.5230	BCDEF	25	K	5.8694	0.7175	EFG
26	R	8.7111	0.5230	BCDEF	26	X	5.8389	0.7175	EFG
27	D	8.5194	0.5230	CDEF	27	H	5.8167	0.7175	EFG
28	O	8.4750	0.5230	DEF	28	J	5.7778	0.7175	FG
29	B	8.3306	0.5230	EF	29	I	5.6889	0.7175	G
30	M	8.1514	0.5230	F	30	L	5.6361	0.7175	G

Means sharing the same letter do not differ at P<0.05

Sample refer to Appendix A for product information

(Mean intensity value for thickness and creaminess)

Effect=Product (ice cream *formulation); Method=LSD(P<.05)

Thickness					Creaminess				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	V	7.1361	0.6191	A	1	C	7.3194	0.7415	A
2	U	7.0417	0.6191	AB	2	B	7.1778	0.7415	AB
3	AD	6.8889	0.6191	ABC	3	AB	7.1694	0.7415	AB
4	A	6.7583	0.6191	ABCD	4	D	7.1611	0.7415	AB
5	F	6.7556	0.6191	ABCD	5	AC	7.1125	0.7415	AB
6	Q	6.7208	0.6191	ABCD	6	Z	7.1111	0.7415	AB
7	X	6.7111	0.6191	ABCD	7	A	7.0222	0.7415	AB
8	W	6.6931	0.6191	ABCD	8	M	6.9667	0.7415	ABC
9	D	6.6250	0.6191	ABCDE	9	E	6.9611	0.7415	ABC
10	N	6.5750	0.6191	ABCDE	10	W	6.9431	0.7415	ABC
11	Y	6.5694	0.6191	ABCDE	11	Y	6.9056	0.7415	ABCD
12	AB	6.5472	0.6191	ABCDEF	12	N	6.8417	0.7415	ABCD
13	AA	6.5417	0.6191	ABCDEF	13	AD	6.8389	0.7415	ABCD
14	T	6.5194	0.6191	ABCDEF	14	S	6.8222	0.7415	ABCD
15	M	6.5042	0.6191	ABCDEF	15	R	6.7806	0.7415	ABCDE
16	C	6.4986	0.6191	ABCDEF	16	Q	6.7639	0.7415	ABCDEF
17	E	6.4528	0.6191	ABCDEF	17	F	6.7444	0.7415	ABCDEF
18	H	6.2722	0.6191	ABCDEF	18	V	6.7222	0.7415	ABCDEFG
19	S	6.1583	0.6191	BCDEF	19	U	6.6778	0.7415	ABCDEFG
20	Z	6.1472	0.6191	BCDEF	20	O	6.6639	0.7415	ABCDEFG
21	AC	6.1389	0.6191	BCDEF	21	T	6.4722	0.7415	ABCDEFGH
22	O	6.0361	0.6191	CDEF	22	P	6.2972	0.7415	BCDEFGH
23	B	5.9569	0.6191	CDEF	23	AA	6.0778	0.7415	CDEFGHI
24	J	5.9472	0.6191	CDEF	24	X	6.0306	0.7415	DEFGHI
25	K	5.8917	0.6191	DEF	25	G	5.9167	0.7415	EFGHI
26	G	5.8861	0.6191	DEF	26	J	5.8639	0.7415	FGHI
27	I	5.8444	0.6191	DEF	27	H	5.8361	0.7415	GHI
28	P	5.8389	0.6191	DEF	28	I	5.7250	0.7415	HI
29	R	5.7333	0.6191	EF	29	L	5.6750	0.7415	HI
30	L	5.6028	0.6191	F	30	K	5.3472	0.7415	I

Means sharing the same letter do not differ at P<0.05

Sample refer to Appendix A for product information

(Mean intensity value for mouth coating and sweet aftertaste)

Effect=Product (ice cream *formulation); Method=LSD(P<.05)

Mouth Coating					Sweet Aftertaste				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	C	5.5542	0.6300	A	1	P	5.1083	0.7130	A
2	V	5.5000	0.6300	A	2	X	4.9556	0.7130	AB
3	B	5.4542	0.6300	A	3	T	4.9528	0.7130	AB
4	E	5.4306	0.6300	A	4	AB	4.9500	0.7130	AB
5	Y	5.4167	0.6300	A	5	Z	4.8889	0.7130	ABC
6	D	5.4056	0.6300	A	6	AC	4.8458	0.7130	ABCD
7	AC	5.3694	0.6300	AB	7	S	4.8361	0.7130	ABCD
8	T	5.3583	0.6300	AB	8	R	4.8306	0.7130	ABCD
9	AB	5.2917	0.6300	AB	9	U	4.7889	0.7130	ABCDE
10	F	5.2111	0.6300	ABC	10	V	4.7028	0.7130	ABCDEF
11	R	5.2111	0.6300	ABC	11	Q	4.6875	0.7130	ABCDEFG
12	A	5.2056	0.6300	ABC	12	AA	4.5750	0.7130	ABCDEFG
13	W	5.0750	0.6300	ABCD	13	AD	4.5667	0.7130	ABCDEFG
14	O	5.0611	0.6300	ABCD	14	C	4.4542	0.7130	ABCDEFG
15	AD	5.0444	0.6300	ABCD	15	Y	4.4333	0.7130	ABCDEFG
16	U	4.9972	0.6300	ABCD	16	O	4.4222	0.7130	ABCDEFG
17	P	4.9000	0.6300	ABCDE	17	J	4.3917	0.7130	ABCDEFG
18	X	4.8722	0.6300	ABCDE	18	B	4.3792	0.7130	ABCDEFG
19	N	4.8639	0.6300	ABCDE	19	L	4.3361	0.7130	BCDEFG
20	AA	4.8528	0.6300	ABCDE	20	G	4.3361	0.7130	BCDEFG
21	Q	4.7431	0.6300	ABCDE	21	W	4.2639	0.7130	BCDEFG
22	S	4.7389	0.6300	ABCDE	22	D	4.2583	0.7130	BCDEFG
23	Z	4.6750	0.6300	ABCDE	23	K	4.1556	0.7130	CDEFG
24	M	4.3986	0.6300	BCDE	24	M	4.1278	0.7130	CDEFG
25	L	4.2306	0.6300	CDE	25	I	4.1000	0.7130	DEFG
26	J	4.2028	0.6300	DE	26	N	4.0667	0.7130	EFG
27	H	4.1694	0.6300	DE	27	H	4.0389	0.7130	EFG
28	I	4.0861	0.6300	DE	28	F	4.0250	0.7130	FG
29	G	3.9972	0.6300	E	29	A	3.9667	0.7130	FG
30	K	3.9444	0.6300	E	30	E	3.9389	0.7130	G

Means sharing the same letter do not differ at P<0.05

Sample refer to Appendix A for product information

**(Mean intensity value for strawberry flavor aftertaste and candy flavor aftertaste)
Effect=Product (ice cream *formulation); Method=LSD(P<.05)**

Strawberry flavor Aftertaste					Candy flavor Aftertaste				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	X	4.5444	0.7120	A	1	AA	4.4250	0.7399	A
2	AD	4.4361	0.7120	AB	2	AC	4.1653	0.7399	AB
3	C	4.4333	0.7120	AB	3	C	4.0472	0.7399	AB
4	AC	4.4208	0.7120	AB	4	U	3.9333	0.7399	AB
5	E	4.3528	0.7120	AB	5	L	3.8806	0.7399	ABC
6	Z	4.3389	0.7120	AB	6	AB	3.8167	0.7399	ABC
7	Y	4.3389	0.7120	AB	7	R	3.7778	0.7399	ABC
8	Q	4.3375	0.7120	AB	8	P	3.7667	0.7399	ABC
9	J	4.3083	0.7120	AB	9	O	3.7389	0.7399	ABC
10	L	4.2833	0.7120	AB	10	W	3.7222	0.7399	ABC
11	U	4.2194	0.7120	AB	11	X	3.7083	0.7399	ABC
12	G	4.1889	0.7120	AB	12	G	3.6972	0.7399	ABC
13	S	4.1667	0.7120	AB	13	H	3.6833	0.7399	ABC
14	W	4.1611	0.7120	AB	14	M	3.6722	0.7399	ABC
15	O	4.1528	0.7120	AB	15	J	3.6639	0.7399	ABC
16	I	4.0861	0.7120	AB	16	I	3.6472	0.7399	ABC
17	P	4.0444	0.7120	AB	17	AD	3.6389	0.7399	ABC
18	AB	4.0389	0.7120	AB	18	D	3.6361	0.7399	ABC
19	V	3.9889	0.7120	AB	19	V	3.5806	0.7399	ABC
20	T	3.9722	0.7120	AB	20	Q	3.5639	0.7399	ABC
21	N	3.9306	0.7120	AB	21	K	3.5611	0.7399	ABC
22	B	3.9194	0.7120	AB	22	S	3.5583	0.7399	ABC
23	AA	3.9167	0.7120	AB	23	N	3.4361	0.7399	BC
24	M	3.9097	0.7120	AB	24	B	3.3583	0.7399	BC
25	H	3.8972	0.7120	AB	25	A	3.3528	0.7399	BC
26	A	3.8917	0.7120	AB	26	T	3.3444	0.7399	BC
27	D	3.8472	0.7120	AB	27	E	3.3361	0.7399	BC
28	K	3.8139	0.7120	B	28	Z	3.3139	0.7399	BC
29	R	3.7639	0.7120	B	29	Y	3.3056	0.7399	BC
30	F	3.7333	0.7120	B	30	F	3.0194	0.7399	C

Means sharing the same letter do not differ at P<0.05

Sample refer to Appendix A for product information

(Mean intensity value for cooked sugar flavor aftertaste and peach flavor aftertaste)
 Effect=Product (ice cream *formulation); Method=LSD(P<.05)

Cooked Sugar flavor Aftertaste					Peach flavor Aftertaste				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	P	4.2972	0.7258	A	1	AC	4.0736	0.7609	A
2	Y	4.0778	0.7258	AB	2	AA	3.9944	0.7609	A
3	B	4.0667	0.7258	AB	3	K	3.7167	0.7609	AB
4	F	3.9306	0.7258	ABC	4	J	3.6472	0.7609	ABC
5	S	3.9222	0.7258	ABC	5	Q	3.5903	0.7609	ABCD
6	E	3.8861	0.7258	ABC	6	W	3.5278	0.7609	ABCDE
7	AB	3.8778	0.7258	ABC	7	O	3.4972	0.7609	ABCDE
8	D	3.7750	0.7258	ABCD	8	L	3.4722	0.7609	ABCDE
9	W	3.7694	0.7258	ABCD	9	G	3.4083	0.7609	ABCDE
10	Z	3.7222	0.7258	ABCD	10	U	3.3167	0.7609	ABCDE
11	AD	3.7222	0.7258	ABCD	11	H	3.3111	0.7609	ABCDE
12	T	3.7056	0.7258	ABCD	12	AD	3.2389	0.7609	ABCDEF
13	V	3.7000	0.7258	ABCD	13	R	3.2083	0.7609	ABCDEF
14	U	3.6861	0.7258	ABCD	14	AB	3.1806	0.7609	ABCDEF
15	C	3.6792	0.7258	ABCD	15	X	3.0083	0.7609	BCDEF
16	AA	3.6417	0.7258	ABCDE	16	M	2.9778	0.7609	BCDEF
17	A	3.5583	0.7258	ABCDEF	17	A	2.9444	0.7609	BCDEF
18	Q	3.5306	0.7258	ABCDEF	18	C	2.9375	0.7609	BCDEF
19	O	3.4333	0.7258	BCDEF	19	V	2.9194	0.7609	BCDEF
20	X	3.4222	0.7258	BCDEF	20	Y	2.9083	0.7609	BCDEF
21	R	3.4139	0.7258	BCDEF	21	P	2.8833	0.7609	BCDEF
22	AC	3.3792	0.7258	BCDEF	22	D	2.8000	0.7609	CDEF
23	G	3.3361	0.7258	BCDEF	23	S	2.8000	0.7609	CDEF
24	L	3.2694	0.7258	BCDEF	24	N	2.7917	0.7609	CDEF
25	N	3.2444	0.7258	CDEF	25	E	2.7778	0.7609	CDEF
26	I	3.2056	0.7258	CDEF	26	I	2.7583	0.7609	CDEF
27	J	3.1583	0.7258	CDEF	27	Z	2.7139	0.7609	DEF
28	H	3.0333	0.7258	DEF	28	F	2.6833	0.7609	DEF
29	M	2.8403	0.7258	EF	29	T	2.6694	0.7609	EF
30	K	2.7639	0.7258	F	30	B	2.3639	0.7609	F

Means sharing the same letter do not differ at P<0.05
 Sample refer to Appendix A for product information

(Mean intensity value for violet flavor aftertaste and grassy flavor aftertaste)

Effect=Product (ice cream *formulation); Method=LSD(P<.05)

Violet flavor Aftertaste					Grassy flavor Aftertaste				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	Q	3.8778	0.7508	A	1	AD	2.8472	0.7212	A
2	R	3.6639	0.7508	AB	2	H	2.7028	0.7212	AB
3	T	3.5722	0.7508	ABC	3	N	2.6500	0.7212	AB
4	X	3.5250	0.7508	ABCD	4	R	2.6417	0.7212	AB
5	AD	3.4639	0.7508	ABCDE	5	F	2.6361	0.7212	AB
6	L	3.3361	0.7508	ABCDE	6	X	2.6222	0.7212	AB
7	J	3.2833	0.7508	ABCDEF	7	W	2.6083	0.7212	AB
8	Z	3.2778	0.7508	ABCDEF	8	Q	2.5667	0.7212	AB
9	O	3.0611	0.7508	ABCDEFG	9	C	2.5333	0.7212	ABC
10	S	3.0472	0.7508	ABCDEFG	10	M	2.5194	0.7212	ABC
11	H	3.0083	0.7508	ABCDEFG	11	AC	2.5181	0.7212	ABC
12	W	2.9917	0.7508	ABCDEFG	12	I	2.4500	0.7212	ABC
13	Y	2.9778	0.7508	ABCDEFGH	13	AB	2.4389	0.7212	ABC
14	AA	2.9500	0.7508	BCDEFGH	14	J	2.3917	0.7212	ABC
15	F	2.9472	0.7508	BCDEFGH	15	AA	2.3611	0.7212	ABC
16	P	2.9083	0.7508	BCDEFGHI	16	T	2.3278	0.7212	ABC
17	I	2.8528	0.7508	BCDEFGHI	17	D	2.3222	0.7212	ABC
18	K	2.8194	0.7508	BCDEFGHI	18	V	2.2694	0.7212	ABC
19	AB	2.7667	0.7508	BCDEFGHI	19	U	2.2194	0.7212	ABC
20	V	2.7389	0.7508	CDEFGHI	20	Y	2.2111	0.7212	ABC
21	AC	2.7153	0.7508	CDEFGHI	21	K	2.1667	0.7212	ABC
22	U	2.6694	0.7508	CDEFGHI	22	O	2.1667	0.7212	ABC
23	N	2.6306	0.7508	DEFGHI	23	P	2.1611	0.7212	ABC
24	E	2.5611	0.7508	EFGHI	24	B	2.1486	0.7212	ABC
25	B	2.4111	0.7508	FGHI	25	E	2.1444	0.7212	ABC
26	G	2.3361	0.7508	GHI	26	S	2.1028	0.7212	ABC
27	D	2.2528	0.7508	GHI	27	Z	2.0944	0.7212	ABC
28	C	2.2306	0.7508	GHI	28	A	1.9361	0.7212	BC
29	A	2.0750	0.7508	HI	29	L	1.8889	0.7212	BC
30	M	2.0278	0.7508	I	30	G	1.7361	0.7212	C

Means sharing the same letter do not differ at P<0.05

Sample refer to Appendix A for product information

(Mean intensity value for astringency and milky flavor aftertaste)

Effect=Product (ice cream *formulation); Method=LSD(P<.05)

Astringency					Milky flavor Aftertaste				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	C	3.7347	0.5905	A	1	C	5.4056	0.7625	A
2	G	3.6500	0.5905	AB	2	E	5.2361	0.7625	AB
3	Z	3.6056	0.5905	ABC	3	U	5.1861	0.7625	AB
4	S	3.5806	0.5905	ABC	4	W	5.1042	0.7625	ABC
5	V	3.4889	0.5905	ABCD	5	AB	5.0806	0.7625	ABCD
6	T	3.4778	0.5905	ABCD	6	B	5.0736	0.7625	ABCDE
7	P	3.4667	0.5905	ABCD	7	A	5.0611	0.7625	ABCDE
8	B	3.3986	0.5905	ABCD	8	T	4.9722	0.7625	ABCDEF
9	X	3.3028	0.5905	ABCD	9	V	4.9333	0.7625	ABCDEF
10	U	3.2667	0.5905	ABCD	10	S	4.9083	0.7625	ABCDEF
11	AB	3.2111	0.5905	ABCDE	11	D	4.8556	0.7625	ABCDEF
12	E	3.2111	0.5905	ABCDE	12	AD	4.7000	0.7625	ABCDEFG
13	W	3.1958	0.5905	ABCDE	13	Q	4.6486	0.7625	BCDEFGH
14	Q	3.1944	0.5905	ABCDE	14	F	4.6417	0.7625	BCDEFGH
15	AC	3.1597	0.5905	ABCDE	15	P	4.6167	0.7625	BCDEFGHI
16	AD	3.1083	0.5905	ABCDE	16	X	4.6028	0.7625	BCDEFGHI
17	F	3.0611	0.5905	ABCDE	17	J	4.5750	0.7625	BCDEFGHI
18	O	3.0417	0.5905	ABCDE	18	M	4.5486	0.7625	BCDEFGHI
19	A	3.0333	0.5905	ABCDE	19	AC	4.4139	0.7625	CDEFGHI
20	R	2.9889	0.5905	ABCDE	20	Y	4.4083	0.7625	CDEFGHI
21	Y	2.9639	0.5905	ABCDE	21	N	4.4056	0.7625	CDEFGHI
22	I	2.9444	0.5905	ABCDE	22	AA	4.4000	0.7625	CDEFGHI
23	AA	2.9167	0.5905	ABCDE	23	O	4.3750	0.7625	DEFGHI
24	L	2.7889	0.5905	ABCDE	24	L	4.3472	0.7625	EFGHI
25	J	2.7750	0.5905	ABCDE	25	R	4.3139	0.7625	FGHI
26	H	2.6833	0.5905	BCDE	26	G	4.2694	0.7625	FGHI
27	D	2.6583	0.5905	CDE	27	I	4.1222	0.7625	GHI
28	M	2.6417	0.5905	CDE	28	H	4.0778	0.7625	GHI
29	K	2.5667	0.5905	DE	29	K	3.9583	0.7625	HI
30	N	2.2833	0.5905	E	30	Z	3.8972	0.7625	I

Means sharing the same letter do not differ at P<0.05

Sample refer to Appendix A for product information

Appendix D - Sampling plan of quantitative descriptive test for reformulated ice creams

Sample	Design	Flavor formulation					Sampling Plan						Amount		
		<i>cis</i> 3-Hexeno-1-ol (CH)	Ethyl-3-methyl-3-phenylglycidate (EMP)	Furaneol™ (FUR)	γ -Undecalactone (GU)	α -Ionone (AI)	Rep 1		Rep 2		Rep 3		Total Weight	Flavor (ml) 0.1% (v/v)	color (ml) (0.4ml/L)
							Code	Order	Code	Order	Code	Order			
Control		0.375	3.75	1.875	0.5	0.375	403	19	097	12	023	37	1	3.785	1.514
4% ice cream with Simplese®	S1	0.375	3.75	1.875	0.5	0.375	888	14	542	25	586	6	0.5	1.893	0.757
	S2	0.375	3.75	1.875	0.5	0.28	843	1	823	32	759	26	0.5	1.893	0.757
	S3	0.375	3.75	1.875	0.5	0.188	475	23	013	6	795	4	0.5	1.893	0.757
	S4	0.375	3.75	1.875	0.375	0.375	451	18	473	33	345	11	0.5	1.893	0.757
	S5	0.375	3.75	1.875	0.375	0.28	134	7	512	17	253	18	0.5	1.893	0.757
	S6	0.375	3.75	1.875	0.375	0.188	235	24	353	10	677	2	0.5	1.893	0.757
	S7	0.375	3.75	1.875	0.25	0.375	768	13	333	1	109	29	0.5	1.893	0.757
	S8	0.375	3.75	1.875	0.25	0.28	346	10	619	8	100	16	0.5	1.893	0.757
	S9	0.375	3.75	1.875	0.25	0.188	256	22	583	24	302	5	0.5	1.893	0.757
	S10	0.375	3.75	1.4	0.5	0.375	423	8	889	3	205	12	0.5	1.893	0.757
	S11	0.375	3.75	1.4	0.5	0.28	987	2	196	11	352	33	0.5	1.893	0.757
	S12	0.375	3.75	1.4	0.5	0.188	567	9	463	16	783	24	0.5	1.893	0.757
	S13	0.375	3.75	1.4	0.375	0.375	734	15	753	23	167	14	0.5	1.893	0.757
	S14	0.375	3.75	1.4	0.375	0.28	527	16	233	26	591	28	0.5	1.893	0.757
	S15	0.375	3.75	1.4	0.375	0.188	590	3	442	31	222	10	0.5	1.893	0.757
	S16	0.375	3.75	1.4	0.25	0.375	432	25	111	7	095	25	0.5	1.893	0.757
	S17	0.375	3.75	1.4	0.25	0.28	887	31	674	27	502	17	0.5	1.893	0.757
	S18	0.375	3.75	1.4	0.25	0.188	122	32	001	21	195	35	0.5	1.893	0.757
	S19	0.28	3.75	1.875	0.5	0.375	673	30	445	37	362	19	0.5	1.893	0.757
	S20	0.28	3.75	1.875	0.5	0.28	234	33	968	30	326	23	0.5	1.893	0.757
	S21	0.28	3.75	1.875	0.5	0.188	187	37	364	14	276	34	0.5	1.893	0.757
	S22	0.28	3.75	1.875	0.375	0.375	653	34	264	15	299	27	0.5	1.893	0.757
	S23	0.28	3.75	1.875	0.375	0.28	385	27	005	28	476	15	0.5	1.893	0.757
	S24	0.28	3.75	1.875	0.375	0.188	275	35	074	35	367	20	0.5	1.893	0.757
	S25	0.28	3.75	1.875	0.25	0.375	354	28	067	22	434	31	0.5	1.893	0.757
	S26	0.28	3.75	1.875	0.25	0.28	989	11	375	36	212	30	0.5	1.893	0.757
	S27	0.28	3.75	1.875	0.25	0.188	901	17	219	5	357	13	0.5	1.893	0.757
	S28	0.28	3.75	1.4	0.5	0.375	631	29	413	29	745	22	0.5	1.893	0.757
	S29	0.28	3.75	1.4	0.5	0.28	555	4	606	34	616	8	0.5	1.893	0.757
	S30	0.28	3.75	1.4	0.5	0.188	666	20	817	19	230	3	0.5	1.893	0.757
	S31	0.28	3.75	1.4	0.375	0.375	034	26	075	13	252	32	0.5	1.893	0.757
	S32	0.28	3.75	1.4	0.375	0.28	728	36	639	20	272	21	0.5	1.893	0.757
	S33	0.28	3.75	1.4	0.375	0.188	618	6	613	2	579	9	0.5	1.893	0.757
	S34	0.28	3.75	1.4	0.25	0.375	183	21	319	9	107	1	0.5	1.893	0.757
	S35	0.28	3.75	1.4	0.25	0.28	520	12	517	4	810	7	0.5	1.893	0.757
	S36	0.28	3.75	1.4	0.25	0.188	815	5	629	18	571	36	0.5	1.893	0.757

Appendix E- Complete block design of quantitative descriptive test for reformulated ice creams

(Replication 1)

Sample	Blinding Code	Panelist											
		J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	
Section 1													
S2	843	Serving order	1	3	4	6	2	3	5	1	3	4	4
S11	987		4	2	1	4	4	1	6	5	2	6	6
S15	590		2	4	2	5	1	4	2	2	4	3	5
S29	555		6	6	3	2	6	2	4	3	5	2	2
S36	815		3	1	6	1	3	6	3	4	6	5	1
S33	618		5	5	5	3	5	5	1	6	1	1	3
Section 2													
S5	134	Serving order	1	5	2	5	3	2	5	2	6	5	5
S10	423		2	2	6	3	1	4	2	3	1	3	1
S12	567		5	3	4	4	5	3	6	1	3	6	6
S8	346		4	6	5	1	2	5	4	5	4	4	4
S26	989		3	4	1	2	4	6	1	6	5	1	3
S35	520		6	1	3	6	6	1	3	4	2	2	2
Section 3													
S7	768	Serving order	4	5	6	6	6	3	6	4	4	6	3
S1	888		6	2	1	3	1	4	4	2	5	4	5
S13	734		1	1	2	2	2	6	5	3	3	2	6
S14	527		2	6	4	4	4	1	3	5	6	1	1
S27	901		3	4	3	5	5	5	2	1	1	5	2
S4	451		5	3	5	1	3	2	1	6	2	3	4
Section 4													
S0	403	Serving order	5	2	6	4	1	1	3	1	4	1	5
S30	666		4	6	2	5	3	3	5	3	1	6	2
S34	183		3	5	1	1	5	4	4	4	5	4	4
S9	256		6	4	5	2	6	2	2	6	6	3	6
S3	475		1	1	4	3	4	6	6	2	2	2	1
S6	235		2	3	3	6	2	5	1	5	3	5	3
Section 5													
S16	432	Serving order	5	6	5	1	5	6	1	1	3	2	3
S31	034		1	3	2	6	1	2	4	6	4	5	5
S23	385		3	5	1	2	6	1	3	4	2	1	2
S25	354		2	1	6	4	4	4	2	2	6	3	1
S28	631		6	2	3	3	2	5	5	5	1	4	4
S19	673		4	4	4	5	3	3	6	3	5	6	6
Section 6													
S17	887	Serving order	4	1	2	3	5	6	2	6	1	4	4
S18	122		5	4	1	7	1	5	6	2	2	5	2
S20	234		2	6	6	6	3	3	7	4	6	1	5
S22	653		6	2	4	5	6	4	1	3	7	7	7
S24	275		1	7	5	4	7	1	4	5	5	6	1
S32	728		3	5	3	1	2	2	3	7	4	3	3
S21	187		7	3	7	2	4	7	5	1	3	2	6

Reformulated ice cream (Replication 2)

Sample	Blinding Code	Panelist											
		J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	
Section 7													
S7	333	Serving order	2	2	4	2	4	4	4	6	3	3	3
S33	613		1	3	2	3	3	5	1	3	4	4	5
S10	889		6	4	6	5	1	1	2	4	6	6	2
S35	517		5	6	3	1	6	3	3	1	5	2	6
S27	219		3	5	1	4	2	6	6	2	1	1	1
S3	013		4	1	5	6	5	2	5	5	2	5	4
Section 8													
S16	111	Serving order	5	6	5	1	5	6	1	1	3	2	3
S8	619		1	3	2	6	1	2	4	6	4	5	5
S34	319		3	5	1	2	6	1	3	4	2	1	2
S6	353		2	1	6	4	4	4	2	2	6	3	1
S11	196		6	2	3	3	2	5	5	5	1	4	4
S2	759		4	4	4	5	3	3	6	4	5	6	6
Section 9													
S31	075	Serving order	5	6	5	1	5	6	1	1	3	2	3
S21	364		1	3	2	6	1	2	4	6	4	5	5
S22	264		3	5	1	2	6	1	3	4	2	1	2
S12	463		2	1	6	4	4	4	2	2	6	3	1
S5	512		6	2	3	3	2	5	5	5	1	4	4
S36	629		4	4	4	5	3	3	6	3	5	6	6
Section 10													
S30	817	Serving order	2	2	4	2	4	4	4	6	3	3	3
S32	639		1	3	2	3	3	5	1	3	4	4	5
S18	001		6	4	6	5	1	1	2	4	6	6	2
S25	067		5	6	3	1	6	3	3	1	5	2	6
S13	753		3	5	1	4	2	6	6	2	1	1	1
S9	583		4	1	5	6	5	2	5	5	2	5	4
Section 11													
S1	542	Serving order	5	6	7	4	1	3	1	3	7	1	2
S14	233		7	2	4	5	3	5	6	5	5	4	6
S17	674		4	5	1	2	7	6	7	4	3	6	4
S23	005		3	3	6	6	6	4	3	1	2	7	5
S28	413		6	4	2	3	2	2	5	2	1	5	3
S20	968		2	7	3	1	4	7	4	6	4	2	7
S15	442		1	1	5	7	5	1	2	7	6	3	1
Section 12													
S2	823	Serving order	2	2	4	2	4	4	4	6	3	3	3
S4	473		1	3	2	3	3	5	1	3	4	4	5
S29	606		6	4	6	5	1	1	2	4	6	6	2
S24	074		5	6	3	1	6	3	3	1	5	2	6
S26	375		3	5	1	4	2	6	6	2	1	1	1
S19	445		4	1	5	6	5	2	5	5	2	5	4
S2	823		2	2	4	2	4	4	4	6	3	3	3

Reformulated ice cream (Replication 3)

Sample	Blinding Code	Panelist											
		J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	
Section 13													
S34	107	Serving order	2	2	4	2	4	4	4	6	3	3	3
S6	677		1	3	2	3	3	5	1	3	4	4	5
S30	230		6	4	6	5	1	1	2	4	6	6	2
S3	795		5	6	3	1	6	3	3	1	5	2	6
S9	302		3	5	1	4	2	6	6	2	1	1	1
S1	586		4	1	5	6	5	2	5	5	2	5	4
Section 14													
S35	810	Serving order	5	6	5	1	5	6	1	1	3	2	3
S29	616		1	3	2	6	1	2	4	6	4	5	5
S33	579		3	5	1	2	6	1	3	4	2	1	2
S15	222		2	1	6	4	4	4	2	2	6	3	1
S4	345		6	2	3	3	2	5	5	5	1	4	4
S10	205		4	4	4	5	3	3	6	3	5	6	6
Section 15													
S27	357	Serving order	2	2	4	2	4	4	4	6	3	3	3
S13	167		1	3	2	3	3	5	1	3	4	4	5
S23	476		6	4	6	5	1	1	2	4	6	6	2
S8	100		5	6	3	1	6	3	3	1	5	2	6
S17	502		3	5	1	4	2	6	6	2	1	1	1
S5	253		4	1	5	6	5	2	5	5	2	5	4
Section 16													
S19	362	Serving order	2	2	4	2	4	4	4	6	3	3	3
S24	367		1	3	2	3	3	5	1	3	4	4	5
S32	272		6	4	6	5	1	1	2	4	6	6	2
S28	745		5	6	3	1	6	3	3	1	5	2	6
S20	326		3	5	1	4	2	6	6	2	1	1	1
S12	783		4	1	5	6	5	2	5	5	2	5	4
Section 17													
S16	095	Serving order	5	6	5	1	5	6	1	1	3	2	3
S0	097		1	3	2	6	1	2	4	6	4	5	5
S22	299		3	5	1	2	6	1	3	4	2	1	2
S14	591		2	1	6	4	4	4	2	2	6	3	1
S7	109		6	2	3	3	2	5	5	5	1	4	4
S26	212		4	4	4	5	3	3	6	3	5	6	6
Section 18													
S25	434	Serving order	5	6	7	4	1	3	1	3	7	1	2
S31	252		7	2	4	5	3	5	6	5	5	4	6
S11	352		4	5	1	2	7	6	7	4	3	6	4
S21	276		3	3	6	6	6	4	3	1	2	7	5
S18	195		6	4	2	3	2	2	5	2	1	5	3
S36	571		2	7	3	1	4	7	4	6	4	2	7
S0	103		1	1	5	7	5	1	2	7	6	3	1

Appendix F- Mean intensity value (mixed model ANOVA) for reformulated ice creams

(Mean intensity value for pink color and dense)

Effect=Product; Method=LSD(P<.05)

Pink Color					Dense				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	S2	9.0697	0.7405	A	1	S34	8.5121	0.6822	A
2	S15	8.9879	0.7405	AB	2	S13	8.4303	0.6822	AB
3	S34	8.9242	0.7405	ABC	3	S29	8.3242	0.6822	ABC
4	S11	8.7515	0.7405	ABCD	4	S2	8.1909	0.6822	ABCD
5	S35	8.703	0.7405	ABCDE	5	S33	8.1752	0.7311	ABCD
6	S10	8.697	0.7405	ABCDE	6	S11	8.1303	0.6822	ABCD
7	S36	8.497	0.7405	ABCDEF	7	S25	8.0879	0.6822	ABCDE
8	S12	8.4667	0.7405	ABCDEF	8	S8	8.0818	0.6822	ABCDE
9	S13	8.4455	0.7405	ABCDEF	9	S23	8.0667	0.6822	ABCDE
10	S8	8.397	0.7405	ABCDEFG	10	S30	7.9758	0.6822	ABCDE
11	S29	8.3758	0.7405	ABCDEFG	11	Control	7.9394	0.6822	ABCDE
12	S27	8.3152	0.7405	ABCDEFG	12	S36	7.9242	0.6822	ABCDE
13	S30	8.2333	0.7405	BCDEFGH	13	S12	7.9121	0.6822	ABCDE
14	S23	8.1939	0.7405	BCDEFGHI	14	S18	7.8455	0.6822	ABCDE
15	S7	8.1606	0.7405	BCDEFGHIJ	15	S10	7.8182	0.6822	ABCDE
16	S9	8.1606	0.7405	BCDEFGHIJ	16	S27	7.8061	0.6822	ABCDE
17	S16	8.1545	0.7405	CDEFGHIJ	17	S35	7.7364	0.6822	ABCDE
18	S14	8.1424	0.7405	CDEFGHIJ	18	S31	7.7152	0.6822	ABCDE
19	S26	7.9879	0.7405	DEFGHIJK	19	S15	7.7061	0.6822	ABCDE
20	S5	7.9697	0.7405	DEFGHIJK	20	S28	7.6848	0.6822	ABCDE
21	S3	7.9485	0.7405	DEFGHIJK	21	S16	7.6212	0.6822	ABCDE
22	S31	7.9242	0.7405	DEFGHIJK	22	S22	7.5909	0.6822	ABCDE
23	S1	7.9061	0.7405	EFGHIJK	23	S24	7.5879	0.6822	ABCDE
24	S18	7.903	0.7405	EFGHIJK	24	S14	7.5394	0.6822	ABCDE
25	S17	7.8333	0.7405	FGHIJK	25	S17	7.5152	0.6822	ABCDE
26	S24	7.7788	0.7405	FGHIJKL	26	S6	7.4697	0.6822	ABCDE
27	S25	7.7758	0.7405	FGHIJKL	27	S32	7.4485	0.6822	ABCDE
28	S28	7.7485	0.7405	FGHIJKL	28	S26	7.4212	0.6822	ABCDE
29	S33	7.7152	0.7405	FGHIJKL	29	S4	7.3636	0.6822	ABCDE
30	S32	7.6909	0.7405	FGHIJKL	30	S20	7.2909	0.6822	ABCDE
31	S19	7.5939	0.7405	GHIJKL	31	S1	7.2818	0.6822	ABCDE
32	S20	7.5727	0.7405	GHIJKL	32	S21	7.2576	0.6822	ABCDE
33	S4	7.4455	0.7405	HIJKL	33	S7	7.2394	0.6822	BCDE
34	S21	7.3636	0.7405	IJKL	34	S19	7.1424	0.6822	CDE
35	S22	7.3485	0.7405	JKL	35	S5	7.0727	0.6822	CDE
36	S6	7.1788	0.7405	KL	36	S9	6.9848	0.6822	DE
37	Control	6.9576	0.7405	L	37	S3	6.8424	0.6822	E

Means sharing the same letter do not differ at P<0.05

Sample refer to Appendix D for product information

(Mean intensity value for sweetness and strawberry flavor)

Effect=Product; Method=LSD(P<.05)

Sweetness					Strawberry				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	S36	9.1394	0.8370	A	1	S15	6.9273	0.6855	A
2	S9	9.1091	0.8370	AB	2	S27	6.7818	0.6855	AB
3	S28	9.0970	0.8370	AB	3	S16	6.7576	0.6855	AB
4	S16	9.0697	0.8370	AB	4	S19	6.7242	0.6855	AB
5	S19	9.0606	0.8370	AB	5	S18	6.6788	0.6855	AB
6	S31	9.0485	0.8370	AB	6	S26	6.6758	0.6855	AB
7	S24	9.0485	0.8370	AB	7	S2	6.6636	0.6855	AB
8	S17	9.0030	0.8370	AB	8	S34	6.6545	0.6855	ABC
9	S35	8.9848	0.8370	AB	9	S32	6.6515	0.6855	ABC
10	S13	8.9697	0.8370	AB	10	S28	6.6182	0.6855	ABC
11	S18	8.9636	0.8370	AB	11	S11	6.6152	0.6855	ABC
12	S32	8.9545	0.8370	AB	12	S29	6.6091	0.6855	ABC
13	S26	8.9485	0.8370	AB	13	S5	6.6091	0.6855	ABC
14	S25	8.9394	0.8370	AB	14	S17	6.5788	0.6855	ABC
15	S15	8.9242	0.8370	AB	15	S14	6.5727	0.6855	ABC
16	S23	8.9182	0.8370	AB	16	S36	6.5636	0.6855	ABC
17	S7	8.9121	0.8370	AB	17	S24	6.5606	0.6855	ABC
18	S12	8.8818	0.8370	AB	18	S8	6.5606	0.6855	ABC
19	S34	8.8788	0.8370	AB	19	S1	6.5545	0.6855	ABC
20	S2	8.8273	0.8370	AB	20	S13	6.5364	0.6855	ABC
21	S11	8.8242	0.8370	AB	21	S3	6.4818	0.6855	ABC
22	S14	8.8091	0.8370	AB	22	S23	6.4818	0.6855	ABC
23	S27	8.8061	0.8370	AB	23	S6	6.4697	0.6855	ABC
24	S22	8.7909	0.8370	AB	24	S33	6.4606	0.6855	ABC
25	S5	8.7879	0.8370	AB	25	S12	6.4545	0.6855	ABC
26	S8	8.7818	0.8370	AB	26	S35	6.4182	0.6855	ABC
27	S4	8.7667	0.8370	AB	27	S10	6.4152	0.6855	ABC
28	S3	8.7606	0.8370	AB	28	S25	6.4061	0.6855	ABC
29	S20	8.7576	0.8370	AB	29	S31	6.4061	0.6855	ABC
30	S29	8.7576	0.8370	AB	30	S20	6.4000	0.6855	ABC
31	S30	8.7394	0.8370	AB	31	S21	6.3818	0.6855	ABC
32	S6	8.7303	0.8370	AB	32	S4	6.3667	0.6855	ABC
33	S1	8.7242	0.8370	AB	33	S9	6.2606	0.6855	BC
34	S33	8.7061	0.8370	AB	34	S7	6.2333	0.6855	BC
35	S10	8.6758	0.8370	AB	35	S22	6.1909	0.6855	BC
36	S21	8.5970	0.8370	BC	36	Control	6.1758	0.6855	BC
37	Control	8.0667	0.8370	C	37	S30	6.0212	0.6855	C

Means sharing the same letter do not differ at P<0.05
Sample refer to Appendix D for product information

(Mean intensity value for candy flavor and cooked sugar flavor)

Effect=Product; Method=LSD(P<.05)

Candy flavor					Cooked sugar flavor				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	S18	6.7455	0.6738	A	1	S33	5.9606	0.6177	A
2	S36	6.7303	0.6738	AB	2	S9	5.9000	0.6177	AB
3	S34	6.7212	0.6738	AB	3	S36	5.8545	0.6177	ABC
4	S21	6.6667	0.6738	AB	4	S7	5.8242	0.6177	ABCD
5	S5	6.6606	0.6738	AB	5	S34	5.7273	0.6177	ABCDE
6	S26	6.5848	0.6738	AB	6	S8	5.7242	0.6177	ABCDE
7	S11	6.5636	0.6738	AB	7	S15	5.7061	0.6177	ABCDE
8	S29	6.5152	0.6738	AB	8	S10	5.6727	0.6177	ABCDE
9	S7	6.4667	0.6738	AB	9	S26	5.6667	0.6177	ABCDE
10	S35	6.4394	0.6738	AB	10	S5	5.6545	0.6177	ABCDEF
11	S16	6.4182	0.6738	AB	11	S13	5.6485	0.6177	ABCDEF
12	S15	6.3939	0.6738	AB	12	S18	5.6091	0.6177	ABCDEF
13	S23	6.3788	0.6738	AB	13	S16	5.6030	0.6177	ABCDEF
14	S3	6.3636	0.6738	AB	14	S22	5.5970	0.6177	ABCDEF
15	S14	6.3545	0.6738	AB	15	S27	5.5848	0.6177	ABCDEF
16	S13	6.3515	0.6738	AB	16	S6	5.5485	0.6177	ABCDEF
17	S31	6.3485	0.6738	AB	17	S14	5.5394	0.6177	ABCDEF
18	S27	6.3303	0.6738	AB	18	S2	5.5303	0.6177	ABCDEF
19	S24	6.3273	0.6738	AB	19	S20	5.5242	0.6177	ABCDEF
20	S28	6.3242	0.6738	AB	20	S35	5.5121	0.6177	ABCDEF
21	S8	6.3061	0.6738	AB	21	S4	5.4879	0.6177	ABCDEF
22	S2	6.3030	0.6738	AB	22	S11	5.4394	0.6177	ABCDEF
23	S25	6.2879	0.6738	AB	23	S3	5.4364	0.6177	ABCDEF
24	S33	6.2515	0.6738	AB	24	S12	5.4182	0.6177	ABCDEF
25	S6	6.1970	0.6738	AB	25	S25	5.3727	0.6177	ABCDEF
26	S9	6.1939	0.6738	AB	26	S30	5.3576	0.6177	ABCDEF
27	S4	6.1909	0.6738	AB	27	S1	5.3030	0.6177	ABCDEF
28	S19	6.1909	0.6738	AB	28	S29	5.2788	0.6177	ABCDEF
29	S30	6.1788	0.6738	AB	29	S19	5.2667	0.6177	ABCDEF
30	S22	6.1636	0.6738	AB	30	S28	5.2000	0.6177	BCDEF
31	S12	6.1485	0.6738	AB	31	S31	5.1545	0.6177	CDEF
32	S1	6.1273	0.6738	AB	32	S32	5.1364	0.6177	DEF
33	S20	6.1091	0.6738	AB	33	S23	5.0576	0.6177	EFG
34	Control	6.1091	0.6738	AB	34	S21	4.9424	0.6177	FG
35	S10	6.0970	0.6738	AB	35	S24	4.8970	0.6177	GH
36	S17	6.0394	0.6738	B	36	Control	4.8636	0.6177	H
37	S32	6.0333	0.6738	B	37	S17	4.8424	0.6177	H

Means sharing the same letter do not differ at P<0.05
Sample refer to Appendix D for product information

(Mean intensity value for grassy flavor and peach flavor)

Effect=Product; Method=LSD(P<.05)

Grassy flavor					Peach flavor				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	S11	4.5636	0.7253	A	1	S5	5.2394	0.6942	A
2	S3	4.4121	0.7253	AB	2	S29	5.0242	0.6942	AB
3	S12	4.3758	0.7253	ABC	3	S11	5.0212	0.6942	AB
4	Control	4.3485	0.7253	ABC	4	S10	5.0202	0.6962	AB
5	S14	4.3303	0.7253	ABCD	5	S1	5.0182	0.6942	AB
6	S1	4.3273	0.7253	ABCD	6	S4	5.0182	0.6942	AB
7	S17	4.1939	0.7253	ABCDE	7	S2	5.0121	0.6942	AB
8	S7	4.1818	0.7253	ABCDE	8	S3	4.9909	0.6942	ABC
9	S2	4.1788	0.7253	ABCDE	9	S19	4.9667	0.6942	ABCD
10	S10	4.1182	0.7253	ABCDEF	10	S33	4.9667	0.6942	ABCD
11	S26	4.1061	0.7253	ABCDEF	11	S36	4.7636	0.6942	ABCDE
12	S5	4.0485	0.7253	ABCDEF	12	S12	4.7485	0.6942	ABCDE
13	S13	4.0364	0.7253	ABCDEF	13	S16	4.7424	0.6942	ABCDE
14	S9	4.0273	0.7253	ABCDEF	14	S21	4.7182	0.6942	ABCDE
15	S29	4.0061	0.7253	ABCDEF	15	S27	4.7152	0.6942	ABCDE
16	S8	3.9576	0.7253	ABCDEF	16	S20	4.703	0.6942	ABCDE
17	S15	3.9364	0.7253	BCDEF	17	S17	4.6939	0.6942	ABCDE
18	S19	3.9242	0.7253	BCDEF	18	Control	4.6818	0.6942	ABCDE
19	S24	3.9000	0.7253	BCDEF	19	S30	4.6788	0.6942	ABCDE
20	S36	3.8970	0.7253	BCDEF	20	S15	4.6273	0.6942	ABCDE
21	S30	3.8848	0.7253	BCDEF	21	S7	4.6121	0.6942	ABCDE
22	S27	3.8818	0.7253	BCDEF	22	S14	4.6061	0.6942	ABCDE
23	S22	3.8788	0.7253	BCDEF	23	S18	4.5515	0.6942	ABCDE
24	S16	3.8545	0.7253	BCDEF	24	S31	4.5455	0.6942	ABCDE
25	S25	3.8091	0.7253	BCDEF	25	S32	4.5303	0.6942	BCDE
26	S6	3.8030	0.7253	BCDEF	26	S13	4.5273	0.6942	BCDE
27	S34	3.8000	0.7253	BCDEF	27	S26	4.5121	0.6942	BCDE
28	S33	3.7758	0.7253	CDEF	28	S34	4.5121	0.6942	BCDE
29	S4	3.7697	0.7253	CDEF	29	S28	4.5091	0.6942	BCDE
30	S21	3.7636	0.7253	CDEF	30	S35	4.497	0.6942	BCDE
31	S28	3.7273	0.7253	DEF	31	S24	4.4606	0.6942	BCDE
32	S23	3.7000	0.7253	EF	32	S22	4.4182	0.6942	BCDE
33	S35	3.6879	0.7253	EF	33	S9	4.3818	0.6942	BCDE
34	S18	3.6727	0.7253	EF	34	S23	4.3667	0.6942	BCDE
35	S31	3.6576	0.7253	EF	35	S25	4.3	0.6942	CDE
36	S32	3.5545	0.7253	F	36	S8	4.2879	0.6942	DE
37	S20	3.5394	0.7253	F	37	S6	4.0848	0.6942	E

Means sharing the same letter do not differ at P<0.05
Sample refer to Appendix D for product information

(Mean intensity value for violet flavor and milky flavor)

Effect=Product; Method=LSD(P<.05)

Violet flavor					Milky flavor				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	S11	5.5667	0.7568	A	1	S12	7.2242	0.7033	A
2	S3	5.4818	0.7568	AB	2	S26	7.1394	0.7033	AB
3	S1	5.4242	0.7568	ABC	3	S36	7.097	0.7033	ABC
4	S29	5.4152	0.7568	ABCD	4	S33	7.0758	0.7033	ABCD
5	S7	5.3	0.7568	ABCDE	5	S19	7.0545	0.7033	ABCDE
6	S22	5.2121	0.7568	ABCDEF	6	S25	7.0455	0.7033	ABCDE
7	S34	5.203	0.7568	ABCDEF	7	S27	7.003	0.7033	ABCDE
8	S5	5.1576	0.7568	ABCDEF	8	S32	6.9303	0.7033	ABCDEF
9	S23	5.1576	0.7568	ABCDEF	9	S11	6.8909	0.7033	ABCDEF
10	S10	5.1182	0.7568	ABCDEF	10	S5	6.8848	0.7033	ABCDEF
11	S2	5.1002	0.7575	ABCDEF	11	S17	6.8697	0.7033	ABCDEF
12	S4	5.0545	0.7568	ABCDEF	12	S31	6.8515	0.7033	ABCDEF
13	S31	5.0394	0.7568	ABCDEF	13	S21	6.8515	0.7033	ABCDEF
14	S20	5.0303	0.7568	ABCDEF	14	S18	6.8485	0.7033	ABCDEF
15	S30	5	0.7568	ABCDEF	15	S4	6.7848	0.7033	ABCDEF
16	S15	4.9818	0.7568	ABCDEF	16	S13	6.7758	0.7033	ABCDEF
17	S14	4.9606	0.7568	ABCDEF	17	S16	6.7545	0.7033	ABCDEF
18	S16	4.9606	0.7568	ABCDEF	18	S29	6.7424	0.7033	ABCDEF
19	Control	4.9576	0.7568	ABCDEF	19	S28	6.7303	0.7033	ABCDEF
20	S26	4.9424	0.7568	ABCDEF	20	S3	6.7152	0.7033	ABCDEF
21	S21	4.9273	0.7568	ABCDEF	21	S7	6.6758	0.7033	ABCDEF
22	S36	4.9061	0.7568	ABCDEF	22	S1	6.6727	0.7033	ABCDEF
23	S19	4.8939	0.7568	ABCDEF	23	S22	6.6727	0.7033	ABCDEF
24	S24	4.8697	0.7568	BCDEF	24	S15	6.6485	0.7033	ABCDEF
25	S35	4.803	0.7568	BCDEF	25	S20	6.6485	0.7033	ABCDEF
26	S28	4.7939	0.7568	CDEF	26	S35	6.6091	0.7033	BCDEF
27	S17	4.7727	0.7568	CDEF	27	S10	6.5706	0.7039	BCDEF
28	S25	4.7606	0.7568	CDEF	28	S34	6.5667	0.7033	BCDEF
29	S8	4.7364	0.7568	DEF	29	S24	6.5455	0.7033	BCDEF
30	S33	4.7333	0.7568	DEF	30	S2	6.4939	0.7033	CDEF
31	S18	4.6667	0.7568	EFG	31	S14	6.4636	0.7033	DEF
32	S6	4.6636	0.7568	EFG	32	S23	6.4545	0.7033	EFG
33	S32	4.6424	0.7568	EFG	33	S30	6.3879	0.7033	FG
34	S12	4.5333	0.7568	FG	34	S6	6.3697	0.7033	FG
35	S27	4.5091	0.7568	GH	35	S8	6.3485	0.7033	FG
36	S13	4.5061	0.7568	GH	36	S9	6.303	0.7033	G
37	S9	4.4212	0.7568	H	37	Control	6.2818	0.7033	G

Means sharing the same letter do not differ at P<0.05
Sample refer to Appendix D for product information

(Mean intensity value for condensed milk flavor and coldness)

Effect=Product; Method=LSD(P<.05)

Condensed milk flavor					Coldness				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	S19	6.2606	0.7522	A	1	S2	8.7559	0.8321	A
2	S28	6.1909	0.7522	AB	2	S35	8.7273	0.8317	AB
3	S16	6.1515	0.7522	ABC	3	S13	8.7182	0.8317	ABC
4	S36	6.1515	0.7522	ABC	4	S25	8.7091	0.8317	ABC
5	S29	6.1121	0.7522	ABC	5	S34	8.6515	0.8317	ABCD
6	S25	6.0636	0.7522	ABCD	6	S23	8.6424	0.8317	ABCD
7	S13	6.0364	0.7522	ABCD	7	S20	8.597	0.8317	ABCD
8	S17	6.0212	0.7522	ABCD	8	S11	8.5758	0.8317	ABCD
9	S33	6.0182	0.7522	ABCD	9	S27	8.5576	0.8317	ABCD
10	S27	5.9636	0.7522	ABCDE	10	S15	8.5394	0.8317	ABCD
11	S18	5.9576	0.7522	ABCDE	11	S18	8.5273	0.8317	ABCD
12	S14	5.9485	0.7522	ABCDEF	12	S24	8.5212	0.8317	ABCD
13	S31	5.9424	0.7522	ABCDEF	13	S10	8.4727	0.8317	ABCD
14	S15	5.9364	0.7522	ABCDEF	14	S36	8.4636	0.8317	ABCD
15	S26	5.9333	0.7522	ABCDEF	15	S16	8.4576	0.8317	ABCD
16	S12	5.9121	0.7522	ABCDEF	16	S4	8.4364	0.8317	ABCD
17	S8	5.9061	0.7522	ABCDEF	17	S29	8.4152	0.8317	ABCD
18	S30	5.8788	0.7522	ABCDEF	18	S12	8.4091	0.8317	ABCD
19	S20	5.7818	0.7522	ABCDEF	19	S28	8.4091	0.8317	ABCD
20	S32	5.7576	0.7522	ABCDEF	20	S7	8.4061	0.8317	ABCD
21	S1	5.7242	0.7522	ABCDEF	21	S31	8.4061	0.8317	ABCD
22	S9	5.7182	0.7522	ABCDEF	22	S14	8.3909	0.8317	ABCD
23	S11	5.6727	0.7522	ABCDEF	23	S30	8.3909	0.8317	ABCD
24	S22	5.6636	0.7522	ABCDEF	24	S1	8.3879	0.8317	ABCD
25	S10	5.6606	0.7522	ABCDEF	25	S17	8.3848	0.8317	ABCD
26	S7	5.6424	0.7522	ABCDEF	26	S32	8.3606	0.8317	ABCD
27	S24	5.6364	0.7522	ABCDEF	27	S19	8.3242	0.8317	ABCD
28	S21	5.6273	0.7522	ABCDEF	28	S8	8.3152	0.8317	ABCD
29	S3	5.5848	0.7522	BCDEF	29	S5	8.3	0.8317	ABCD
30	S34	5.5758	0.7522	BCDEF	30	S9	8.3	0.8317	ABCD
31	S4	5.5586	0.7528	BCDEF	31	S26	8.2909	0.8317	ABCD
32	S5	5.5455	0.7522	CDEF	32	Control	8.2636	0.8317	ABCD
33	S23	5.5212	0.7522	CDEF	33	S3	8.2606	0.8317	ABCD
34	S2	5.4727	0.7522	DEF	34	S33	8.2485	0.8317	ABCD
35	S35	5.4394	0.7522	DEF	35	S22	8.1667	0.8317	BCD
36	S6	5.3515	0.7522	EF	36	S6	8.1606	0.8317	CD
37	Control	5.3152	0.7522	F	37	S21	8.097	0.8317	D

Means sharing the same letter do not different at P<0.05

Sample refer to Appendix D for product information

(Mean intensity value for thickness and smoothness)

Effect=Product; Method=LSD(P<.05)

Thickness					Smoothness				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	S10	7.603	0.5001	A	1	S10	6.8242	0.8704	A
2	S26	7.4667	0.5001	AB	2	S36	6.8	0.8704	A
3	S12	7.3915	0.5143	AB	3	S12	6.7697	0.8704	AB
4	S2	7.3333	0.5001	AB	4	S27	6.7364	0.8704	ABC
5	S27	7.3091	0.5001	AB	5	S33	6.6364	0.8704	ABCD
6	S5	7.2939	0.5001	AB	6	S35	6.5697	0.8704	ABCDE
7	S19	7.2697	0.5001	ABC	7	S26	6.5424	0.8704	ABCDEF
8	S35	7.2606	0.5001	ABC	8	S13	6.5152	0.8704	ABCDEF
9	S36	7.2515	0.5001	ABC	9	S29	6.5121	0.8704	ABCDEF
10	S16	7.2394	0.5001	ABC	10	S3	6.4727	0.8704	ABCDEFG
11	S33	7.2152	0.5001	ABC	11	S16	6.4576	0.8704	ABCDEFG
12	S14	7.2091	0.5001	ABC	12	S8	6.4303	0.8704	ABCDEFG
13	S30	7.1909	0.5001	ABC	13	S7	6.4061	0.8704	ABCDEFG
14	S9	7.1879	0.5001	ABCD	14	S34	6.3697	0.8704	ABCDEFG
15	S18	7.1818	0.5001	ABCD	15	S2	6.3333	0.8704	ABCDEFG
16	S29	7.1364	0.5001	ABCD	16	S1	6.3323	0.8764	ABCDEFG
17	S3	7.1091	0.5001	ABCD	17	S6	6.3242	0.8704	ABCDEFG
18	S32	7.0939	0.5001	ABCD	18	S31	6.3152	0.8704	ABCDEFG
19	S13	7.0788	0.5001	ABCD	19	S5	6.2939	0.8704	ABCDEFG
20	S7	7.0758	0.5001	ABCD	20	S20	6.2909	0.8704	ABCDEFG
21	S11	7.0758	0.5001	ABCD	21	S23	6.2485	0.8704	ABCDEFG
22	S22	7.0667	0.5001	ABCD	22	S9	6.1909	0.8704	ABCDEFG
23	S8	7.0364	0.5001	ABCD	23	S21	6.1667	0.8704	ABCDEFG
24	S6	7.003	0.5001	ABCD	24	S19	6.1364	0.8704	ABCDEFG
25	S1	7	0.5001	ABCD	25	S30	6.1242	0.8704	ABCDEFG
26	S15	6.997	0.5001	ABCD	26	S24	6.1242	0.8704	ABCDEFG
27	S28	6.9879	0.5001	ABCD	27	S4	6.103	0.8704	ABCDEFG
28	S25	6.9788	0.5001	ABCD	28	S17	6.0576	0.8704	BCDEFG
29	S20	6.9394	0.5001	ABCD	29	S18	6.0364	0.8704	CDEFG
30	S31	6.9242	0.5001	ABCD	30	S28	6.0212	0.8704	CDEFG
31	S17	6.9212	0.5001	ABCD	31	S25	5.9242	0.8704	DEFG
32	S21	6.9121	0.5001	ABCD	32	S32	5.8939	0.8704	EFG
33	S34	6.9061	0.5001	ABCD	33	Control	5.8848	0.8704	EFG
34	S23	6.8788	0.5001	ABCD	34	S22	5.8333	0.8704	FG
35	S24	6.8061	0.5001	BCD	35	S11	5.8182	0.8704	FG
36	Control	6.5545	0.5001	CD	36	S15	5.7667	0.8704	G
37	S4	6.4606	0.5001	D	37	S14	5.7636	0.8704	G

Means sharing the same letter do not differ at P<0.05
Sample refer to Appendix D for product information

(Mean intensity value for creaminess and mouth coating)

Effect=Product; Method=LSD(P<.05)

Creaminess					Mouth Coating				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	S26	7.8636	0.6678	A	1	S26	6.497	0.6121	A
2	S10	7.7818	0.6678	AB	2	S10	6.4939	0.6121	A
3	S19	7.5606	0.6678	ABC	3	S12	6.4455	0.6121	A
4	S33	7.5455	0.6678	ABCD	4	S27	6.3697	0.6121	AB
5	S27	7.5455	0.6678	ABCD	5	S19	6.303	0.6121	ABC
6	S13	7.4273	0.6678	ABCDE	6	S29	6.2909	0.6121	ABC
7	S5	7.4242	0.6678	ABCDE	7	S36	6.2636	0.6121	ABCD
8	S29	7.3636	0.6678	ABCDE	8	S33	6.2273	0.6121	ABCDE
9	S20	7.3394	0.6678	ABCDE	9	S11	6.1818	0.6121	ABCDEF
10	S17	7.3394	0.6678	ABCDE	10	S8	6.1697	0.6121	ABCDEF
11	S35	7.2939	0.6678	ABCDE	11	S16	6.1576	0.6121	ABCDEF
12	S6	7.2939	0.6678	ABCDE	12	S15	6.1455	0.6121	ABCDEF
13	S36	7.2848	0.6678	ABCDE	13	S3	6.1242	0.6121	ABCDEF
14	S18	7.2758	0.6678	ABCDE	14	S35	6.1182	0.6121	ABCDEF
15	S8	7.2606	0.6678	ABCDE	15	S17	6.1061	0.6121	ABCDEF
16	S23	7.2515	0.6678	ABCDE	16	S14	6.103	0.6121	ABCDEF
17	S12	7.2424	0.6678	ABCDE	17	S2	6.048	0.6197	ABCDEF
18	S16	7.2242	0.6678	ABCDE	18	S1	6.0394	0.6121	ABCDEF
19	S31	7.2212	0.6678	ABCDE	19	S9	6.0333	0.6121	ABCDEF
20	S34	7.2121	0.6678	ABCDE	20	S13	6.0121	0.6121	ABCDEF
21	S22	7.1818	0.6678	ABCDE	21	S20	6.0121	0.6121	ABCDEF
22	S21	7.1788	0.6678	ABCDE	22	S7	5.997	0.6121	ABCDEF
23	S3	7.1485	0.6678	BCDEF	23	S34	5.9788	0.6121	ABCDEF
24	S7	7.1424	0.6678	BCDEF	24	S5	5.9697	0.6121	ABCDEF
25	S24	7.1303	0.6678	BCDEF	25	S18	5.9636	0.6121	ABCDEF
26	S32	7.1303	0.6678	BCDEF	26	S23	5.9394	0.6121	ABCDEF
27	S30	7.1273	0.6678	BCDEF	27	S21	5.9242	0.6121	ABCDEF
28	S1	7.0852	0.6745	BCDEF	28	S31	5.9212	0.6121	ABCDEF
29	S14	7.0727	0.6678	CDEF	29	S28	5.903	0.6121	ABCDEF
30	S9	7.0576	0.6678	CDEF	30	S32	5.897	0.6121	ABCDEF
31	S2	7.0576	0.6678	CDEF	31	S22	5.8394	0.6121	ABCDEF
32	S28	7.0091	0.6678	CDEF	32	S6	5.7455	0.6121	BCDEF
33	S15	6.9364	0.6678	CDEF	33	S25	5.6515	0.6121	CDEF
34	S25	6.9303	0.6678	CDEF	34	S30	5.6515	0.6121	CDEF
35	S11	6.8515	0.6678	DEF	35	S24	5.6273	0.6121	DEF
36	Control	6.7303	0.6678	EF	36	Control	5.5758	0.6121	EF
37	S4	6.4788	0.6678	F	37	S4	5.5394	0.6121	F

Means sharing the same letter do not differ at P<0.05
Sample refer to Appendix D for product information

(Mean intensity value for sweet aftertaste and strawberry flavor aftertaste)

Effect=Product; Method=LSD(P<.05)

Sweet Aftertaste					Strawberry flavor Aftertaste				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	S19	7.2303	0.9918	A	1	S26	5.5242	0.8164	A
2	S27	7.2091	0.9918	A	2	S28	5.397	0.8164	AB
3	S28	7.1758	0.9918	AB	3	S15	5.3848	0.8164	AB
4	S26	7.1455	0.9918	AB	4	S16	5.3636	0.8164	AB
5	S29	7.1061	0.9918	ABC	5	S14	5.3545	0.8164	AB
6	S14	7.0636	0.9918	ABC	6	S33	5.3515	0.8164	AB
7	S36	7.0606	0.9918	ABC	7	S36	5.3455	0.8164	AB
8	S33	7.0455	0.9918	ABC	8	S19	5.2939	0.8164	AB
9	S15	7.0424	0.9918	ABC	9	S27	5.2939	0.8164	AB
10	S16	7.0091	0.9918	ABC	10	S23	5.2697	0.8164	AB
11	S7	7.003	0.9918	ABC	11	S9	5.2636	0.8164	AB
12	S17	6.9576	0.9918	ABC	12	S29	5.2424	0.8164	AB
13	S20	6.9424	0.9918	ABC	13	S21	5.2182	0.8164	ABC
14	S31	6.9333	0.9918	ABC	14	S31	5.2091	0.8164	ABC
15	S23	6.9333	0.9918	ABC	15	S17	5.1758	0.8164	ABC
16	S18	6.9121	0.9918	ABC	16	S32	5.1667	0.8164	ABC
17	S25	6.8576	0.9918	ABC	17	S6	5.1576	0.8164	ABC
18	S3	6.8476	0.9957	ABC	18	S24	5.1576	0.8164	ABC
19	S24	6.8424	0.9918	ABC	19	S3	5.1485	0.8164	ABC
20	S2	6.8273	0.9918	ABC	20	S20	5.1212	0.8164	ABC
21	S5	6.803	0.9918	ABC	21	S25	5.1152	0.8164	ABC
22	S13	6.7909	0.9918	ABC	22	S18	5.0939	0.8164	ABC
23	S9	6.7485	0.9918	ABC	23	S22	5.0848	0.8164	ABC
24	S30	6.7485	0.9918	ABC	24	S8	5.0848	0.8164	ABC
25	S12	6.7424	0.9918	ABC	25	S12	5.0818	0.8164	ABC
26	S22	6.7333	0.9918	ABC	26	S13	5.0758	0.8164	ABC
27	S35	6.7333	0.9918	ABC	27	S11	5.0394	0.8164	ABC
28	S1	6.6848	0.9918	ABC	28	S1	5.0333	0.8164	ABC
29	S8	6.6667	0.9918	ABC	29	S5	5.0273	0.8164	ABC
30	S34	6.6636	0.9918	ABC	30	S35	5.003	0.8164	ABC
31	S6	6.6636	0.9918	ABC	31	S2	4.996	0.8169	ABC
32	S10	6.6333	0.9918	ABCD	32	S10	4.9576	0.8164	ABC
33	S32	6.6303	0.9918	ABCD	33	S30	4.9485	0.8164	ABC
34	S21	6.6242	0.9918	ABCD	34	S34	4.9485	0.8164	ABC
35	S11	6.5939	0.9918	BCD	35	S4	4.903	0.8164	BC
36	S4	6.5303	0.9918	CD	36	S7	4.8758	0.8164	BC
37	Control	6.0485	0.9918	D	37	Control	4.6576	0.8164	C

Means sharing the same letter do not differ at P<0.05

Sample refer to Appendix D for product information

(Mean intensity value for candy flavor aftertaste and grassy flavor aftertaste)

Effect=Product; Method=LSD(P<.05)

Candy flavor Aftertaste					Grassy flavor Aftertaste				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	S29	5.7212	0.8741	A	1	Control	3.6	0.7569	A
2	S36	5.4455	0.8741	AB	2	S17	3.5758	0.7569	A
3	S31	5.4152	0.8741	AB	3	S14	3.5697	0.7569	A
4	S7	5.4121	0.8741	AB	4	S4	3.503	0.7569	AB
5	S25	5.403	0.8741	AB	5	S1	3.4753	0.7591	AB
6	S17	5.4	0.8741	AB	6	S2	3.4727	0.7569	AB
7	S24	5.3909	0.8741	AB	7	S11	3.4152	0.7569	ABC
8	S5	5.3515	0.8741	AB	8	S12	3.4	0.7569	ABC
9	S21	5.3364	0.8741	AB	9	S6	3.3636	0.7569	ABC
10	S26	5.3304	0.8788	AB	10	S7	3.3576	0.7569	ABCD
11	S2	5.3303	0.8741	AB	11	S33	3.3273	0.7569	ABCD
12	S8	5.3152	0.8741	AB	12	S31	3.3242	0.7569	ABCD
13	S33	5.2848	0.8741	AB	13	S3	3.3152	0.7569	ABCD
14	S18	5.2848	0.8741	AB	14	S10	3.303	0.7569	ABCD
15	S14	5.2818	0.8741	AB	15	S24	3.3	0.7569	ABCD
16	S3	5.2727	0.8741	AB	16	S13	3.297	0.7569	ABCD
17	S12	5.2727	0.8741	AB	17	S29	3.2879	0.7569	ABCD
18	S35	5.2545	0.8741	AB	18	S5	3.2848	0.7569	ABCD
19	S15	5.2364	0.8741	AB	19	S23	3.2848	0.7569	ABCD
20	S22	5.2273	0.8741	AB	20	S34	3.2758	0.7569	ABCD
21	S13	5.1909	0.8741	AB	21	S19	3.2727	0.7569	ABCD
22	S19	5.1879	0.8741	AB	22	S28	3.2697	0.7569	ABCD
23	S27	5.1788	0.8741	AB	23	S36	3.2697	0.7569	ABCD
24	S9	5.1758	0.8741	AB	24	S9	3.2485	0.7569	ABCD
25	S16	5.1667	0.8741	ABC	25	S16	3.2485	0.7569	ABCD
26	S23	5.1515	0.8741	ABC	26	S8	3.2485	0.7569	ABCD
27	S34	5.1515	0.8741	ABC	27	S27	3.2394	0.7569	ABCD
28	S20	5.1182	0.8741	ABC	28	S30	3.2273	0.7569	ABCD
29	S28	5.1121	0.8741	BC	29	S22	3.1818	0.7569	ABCD
30	S32	5.0727	0.8741	BC	30	S26	3.1667	0.7569	ABCD
31	S1	5.0727	0.8741	BC	31	S25	3.1424	0.7569	ABCD
32	S10	5.0545	0.8741	BC	32	S15	3.1121	0.7569	ABCD
33	S30	5.0394	0.8741	BC	33	S32	3.1	0.7569	ABCD
34	S11	5.0364	0.8741	BC	34	S21	3.0727	0.7569	ABCD
35	S4	5.0061	0.8741	BC	35	S18	3.0091	0.7569	BCD
36	S6	4.8667	0.8741	BC	36	S20	2.8939	0.7569	CD
37	Control	4.5606	0.8741	C	37	S35	2.803	0.7569	D

Means sharing the same letter do not differ at P<0.05

Sample refer to Appendix D for product information

(Mean intensity value for peach flavor aftertaste and violet flavor aftertaste)

Effect=Product; Method=LSD(P<.05)

Peach flavor Aftertaste					Violet flavor Aftertaste				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	S29	4.4606	0.7992	A	1	S14	4.6061	0.7303	A
2	S19	4.403	0.7992	AB	2	S4	4.4424	0.7303	AB
3	S10	4.3788	0.7992	AB	3	S22	4.4364	0.7303	AB
4	S3	4.3727	0.7992	AB	4	S23	4.4121	0.7303	AB
5	S33	4.3636	0.7992	AB	5	S7	4.3818	0.7303	AB
6	S4	4.3303	0.7992	AB	6	S10	4.3182	0.7303	ABC
7	S5	4.2788	0.7992	AB	7	S26	4.3121	0.7303	ABC
8	S11	4.2364	0.7992	AB	8	S15	4.3030	0.7303	ABC
9	S27	4.2212	0.7992	AB	9	S2	4.2970	0.7303	ABC
10	S14	4.2	0.7992	AB	10	S34	4.2970	0.7303	ABC
11	S1	4.1697	0.7992	ABC	11	S29	4.2879	0.7303	ABC
12	S21	4.1636	0.7992	ABC	12	S20	4.2818	0.7303	ABC
13	S30	4.1182	0.7992	ABC	13	S1	4.2455	0.7303	ABC
14	S36	4.1152	0.7992	ABC	14	S5	4.1909	0.7303	ABCD
15	S35	4.103	0.7992	ABC	15	S3	4.1182	0.7303	ABCD
16	S18	4.0818	0.7992	ABC	16	S16	4.1121	0.7303	ABCD
17	S8	4.0636	0.7992	ABC	17	S8	4.0939	0.7303	ABCD
18	S15	4.0455	0.7992	ABC	18	S21	4.0909	0.7303	ABCD
19	S9	4.0394	0.7992	ABC	19	S36	4.0848	0.7303	ABCD
20	S28	4.0273	0.7992	ABC	20	S24	4.0788	0.7303	ABCD
21	S34	4.0152	0.7992	ABC	21	S19	4.0697	0.7303	ABCD
22	S16	4.0061	0.7992	ABC	22	S27	4.0545	0.7303	ABCD
23	S6	4	0.7992	ABC	23	S11	4.0545	0.7303	ABCD
24	Control	3.9788	0.7992	ABC	24	S31	4.0333	0.7303	ABCD
25	S23	3.9758	0.7992	ABC	25	S25	4.0152	0.7303	ABCD
26	S17	3.9364	0.7992	ABC	26	S33	4.0091	0.7303	ABCD
27	S31	3.9364	0.7992	ABC	27	S28	3.9970	0.7303	BCD
28	S20	3.9242	0.7992	ABC	28	S6	3.9455	0.7303	BCD
29	S12	3.9212	0.7992	ABC	29	S35	3.9455	0.7303	BCD
30	S22	3.9182	0.7992	ABC	30	S13	3.9091	0.7303	BCD
31	S7	3.8848	0.7992	BC	31	Control	3.9030	0.7303	BCD
32	S13	3.8758	0.7992	BC	32	S30	3.8697	0.7303	BCD
33	S26	3.8667	0.7992	BC	33	S17	3.8515	0.7303	BCD
34	S24	3.8576	0.7992	BC	34	S32	3.8424	0.7303	BCD
35	S25	3.8517	0.8007	BC	35	S9	3.7606	0.7303	CD
36	S2	3.8455	0.7992	BC	36	S12	3.7455	0.7303	CD
37	S32	3.6091	0.7992	C	37	S18	3.6242	0.7303	D

Means sharing the same letter do not differ at P<0.05
 Sample refer to Appendix D for product information

(Mean intensity value for cooked sugar flavor aftertaste and astringency)

Effect=Product; Method=LSD(P<.05)

Cooked sugar flavor Aftertaste					Astringency				
Obs	Sample	Estimate	Standard Error	Letter Group	Obs	Sample	Estimate	Standard Error	Letter Group
1	S16	4.697	0.7449	A	1	S34	4.1121	0.6809	A
2	S33	4.697	0.7449	A	2	S29	3.9515	0.6809	AB
3	S10	4.6636	0.7449	AB	3	S26	3.903	0.6809	AB
4	S35	4.6424	0.7449	ABC	4	S3	3.8909	0.6809	AB
5	S36	4.5909	0.7449	ABCD	5	S27	3.8788	0.6809	AB
6	S22	4.5545	0.7449	ABCDE	6	S2	3.8667	0.6809	AB
7	S9	4.4818	0.7449	ABCDEF	7	S35	3.8545	0.6809	AB
8	S34	4.4606	0.7449	ABCDEFG	8	S5	3.8364	0.6809	AB
9	S27	4.4424	0.7449	ABCDEFG	9	S7	3.8273	0.6809	AB
10	S5	4.4182	0.7449	ABCDEFGH	10	S10	3.7957	0.6873	AB
11	S14	4.4182	0.7449	ABCDEFGH	11	S6	3.7606	0.6809	AB
12	S18	4.403	0.7449	ABCDEFGH	12	S12	3.7515	0.6809	AB
13	S13	4.3758	0.7449	ABCDEFGH	13	S9	3.7515	0.6809	AB
14	S11	4.3667	0.7449	ABCDEFGH	14	S14	3.7273	0.6809	AB
15	S8	4.3606	0.7449	ABCDEFGH	15	S33	3.7061	0.6809	AB
16	S3	4.3333	0.7449	ABCDEFGH	16	S13	3.703	0.6809	AB
17	S6	4.3303	0.7449	ABCDEFGH	17	S19	3.6727	0.6809	AB
18	S12	4.3212	0.7449	ABCDEFGH	18	S11	3.6727	0.6809	AB
19	S30	4.3	0.7449	ABCDEFGH	19	S8	3.6636	0.6809	AB
20	S29	4.2697	0.7449	ABCDEFGHI	20	S15	3.6394	0.6809	AB
21	S26	4.2515	0.7449	ABCDEFGHI	21	S36	3.6333	0.6809	AB
22	S28	4.2394	0.7449	ABCDEFGHI	22	S4	3.6242	0.6809	AB
23	S2	4.2121	0.7449	ABCDEFGHI	23	Control	3.597	0.6809	AB
24	S15	4.1788	0.7449	ABCDEFGHI	24	S16	3.5939	0.6809	AB
25	S1	4.1515	0.7449	BCDEFGHI	25	S30	3.5758	0.6809	AB
26	S4	4.1455	0.7449	BCDEFGHI	26	S31	3.5697	0.6809	AB
27	S7	4.1382	0.7454	BCDEFGHI	27	S22	3.5273	0.6809	AB
28	S20	4.1242	0.7449	BCDEFGHI	28	S25	3.5091	0.6809	B
29	S19	4.1121	0.7449	CDEFGHI	29	S18	3.5	0.6809	B
30	S25	4.1121	0.7449	CDEFGHI	30	S23	3.4939	0.6809	B
31	S24	4.0667	0.7449	DEFGHI	31	S1	3.4788	0.6809	B
32	S31	4.0152	0.7449	EFGHI	32	S17	3.4727	0.6809	B
33	S17	3.9485	0.7449	FGHI	33	S24	3.4727	0.6809	B
34	S23	3.9303	0.7449	GHI	34	S28	3.4424	0.6809	B
35	S21	3.9273	0.7449	GHI	35	S21	3.3879	0.6809	B
36	S32	3.897	0.7449	HI	36	S32	3.3788	0.6809	B
37	Control	3.7303	0.7449	I	37	S20	3.3667	0.6809	B

Means sharing the same letter do not differ at P<0.05
Sample refer to Appendix D for product information

(Mean intensity value for milky flavor aftertaste)

Effect=Product; Method=LSD(P<.05)

Milky flavor Aftertaste				
Obs	Sample	Estimate	Standard Error	Letter Group
1	S35	6.2182	0.8177	A
2	S17	6.0818	0.8177	AB
3	S19	6.0788	0.8177	AB
4	S26	6.0697	0.8177	AB
5	S28	6.0485	0.8177	AB
6	S14	6.0212	0.8177	AB
7	S27	6.0091	0.8177	ABC
8	S10	5.9879	0.8177	ABCD
9	S33	5.9606	0.8177	ABCD
10	S18	5.9303	0.8177	ABCD
11	S29	5.8364	0.8177	ABCD
12	S25	5.8212	0.8177	ABCD
13	S16	5.8212	0.8177	ABCD
14	S34	5.7667	0.8177	ABCD
15	S13	5.7545	0.8177	ABCD
16	S5	5.7485	0.8177	ABCD
17	S36	5.7455	0.8177	ABCD
18	S9	5.7424	0.8177	ABCD
19	S12	5.7424	0.8177	ABCD
20	S8	5.7383	0.8181	ABCD
21	S3	5.7333	0.8177	ABCD
22	S24	5.7061	0.8177	ABCD
23	S20	5.6788	0.8177	ABCD
24	S2	5.6727	0.8177	ABCD
25	S6	5.6485	0.8177	ABCD
26	S31	5.6394	0.8177	ABCD
27	S1	5.6152	0.8177	ABCD
28	S15	5.597	0.8177	BCD
29	S22	5.5606	0.8177	BCD
30	S11	5.5576	0.8177	BCD
31	S21	5.5515	0.8177	BCD
32	S7	5.5394	0.8177	BCD
33	Control	5.5303	0.8177	BCD
34	S32	5.4848	0.8177	BCD
35	S23	5.4121	0.8177	CD
36	S30	5.3939	0.8177	D
37	S4	5.3848	0.8177	D

Means sharing the same letter do not differ at P<0.05
Sample refer to Appendix D for product information

Appendix G- SAS code for statistical analysis

The SAS Code of Principle Component Analysis

Title1 'Covariance-Primary Component Analysis for Artificial Strawberry Ice Creams';
Filename in 'd:\my files\NewData\meansdata.csv';

Data icecream;
Infile in dlm=',' dsd truncover LRECL=800;
Input Ice\$ formu\$ Produc\$ PCL DEN RMT SWT STRA CAN COK GRA VIO PEA
MIL COM COD THK SMO CRE MCO SWTA STRA CANA GRAA VIOA PEAA
COKA ASTR MILA;

Proc factor data=icecream scree score cov outstat=stuff rotate=none method=prin
mineigen=0.01;
var PCL DEN RMT SWT STRA CAN COK GRA VIO PEA MIL COM COD THK
SMO CRE MCO SWTA STRA CANA GRAA VIOA PEAA COKA ASTR MILA;

Proc score data=icecream scores=stuff out=scores;
var PCL DEN RMT SWT STRA CAN COK GRA VIO PEA MIL COM COD THK
SMO CRE MCO SWTA STRA CANA GRAA VIOA PEAA COKA ASTR MILA;

Proc print data=scores;
run;

The SAS Code of Analysis of Variance for mixed model (mixed-ANOVA)

```
title1 'ANOVA for Ice Creams with fat replacers';
filename in 'd:\newdataexpl.csv';
data icecream;
infile in dlm=';' dsd trunccover LRECL=800;
input judge$ Rep$ ice$ formu$ PCL DEN RMT SWT STR CAN COK GRA VIO PEA
MIL COM COD THK SMO CRE MCO SWTA STRA CANA GRAA VIOA PEAA
COKA ASTR MILA;
proc means n mean std;
class formu; run;
proc means n mean std;
class ice; run;
proc mixed data=icecream;
class judge Rep formu ice;;
model PCL=formu ice formu*ice /ddfm=satterth;
random judge rep judge*formu*ice judge*rep rep*formu*ice;
lsmeans formu ice formu*ice /pdiff;
ods output diffs=ppp lsmeans=mmm;
ods listing exclude diffs lsmeans;
%include 'd:pdmix800.sas';
%pdmix800(ppp,mmm,alpha=.05,sort=yes); run;
```

The SAS Code of mixed-MANOVA

```
title1 'MANOVA for Ice Creams with fat replacers';
filename in 'd:\my files\NewData\rawdata.csv';
data icecream;
infile in dlm=';' dsd trunccover LRECL=800;
input judge$ Rep$ ice$ formu$ PCL DEN RMT SWT STRA CAN COK GRA VIO
PEA MIL COM COD THK SMO CRE MCO SWTA STRA CANA GRAA VIOA PEAA
COKA ASTR MILA;
proc glm data=icecream outstat=stat;
class judge Rep formu ice;
model PCL DEN RMT SWT STRA CAN COK GRA VIO PEA MIL COM COD THK
SMO CRE MCO SWTA STRA CANA GRAA VIOA PEAA COKA ASTR MILA
```

```
= judge Rep formu ice formu*ice formu*judge ice*judge formu*ice*judge/nouni;
manova h=formu*ice e=judge*formu*ice;
manova h=formu e=judge*formu;
manova h=ice e=judge*ice; run;
```

The SAS Code of Canonical Variate Analysis (CVA)

```
Title1 'Canonical Variate Analysis for Ice Creams';
filename in 'd:\rawdata2.csv';
data icecream;
infile in dlm=',' dsd truncover LRECL=800;
input judge$ Rep$ Product$ PCL DEN RMT SWT STRA CAN COKGRA VIO PEA
MIL COM COD THK SMO CRE MCO SWTA STRA CANA GRAA VIOA PEAA
COKA ASTR MILA;
proc glm data=icecream outstat=stat;
class judge Product Rep;
model PCL DEN RMT SWT STRA CAN COK GRA VIO PEA MIL COM COD THK
SMO CRE MCO SWTA STRA CANA GRAA VIOA PEAA COKA ASTR MILA =
judge Product Rep Product*rep judge*Product judge*rep/nouni;
means Product/lsd e=judge*Product;
manova h=Product e=judge*Product/canonical; run;
```

```
data scorepi;
set stat (where=( _type_='SCORE' and _source_='Product') drop = df ss f prob); run;
proc standard data=icecream out=icecreamcva mean=0;
var PCL DEN RMT SWT STRA CAN COKGRA VIO PEA MIL COM COD THK SMO
CRE MCO SWTA STRA CANA GRAA VIOA PEAA COKA ASTR MILA; run;
proc score data=icecreamcva score=scorepi out=coordp;
var PCL DEN RMT SWT STRA CAN COKGRA VIO PEA MIL COM COD THK SMO
CRE MCO SWTA STRA CANA GRAA VIOA PEAA COKA ASTR MILA;
proc sort; by Product;
proc means; by Product;
var can1 can2 can3; run;
```

The SAS Code of Stepwise Discriminant Analysis

```
title1 'Stepwise Discriminant analysis';
data disc;
input ice$ formu$ SWT STR CAN COK GRA VIO PEA MIL COM COD THK SMO
CRE MCO SWTA STRA CANA GRAS VIOA PEAA COKA ASTR MILA;
datalines; inserted data;
proc stepdisc stepwise simple stdmean tcorr wcorr data=disc;
var SWT STR CAN COK GRA VIO PEA MIL COM COD THK SMO CRE MCO
SWTA STRA CANA GRAS VIOA PEAA COKA ASTR MILA;
class ice; run;
proc candisc data=disc out=cand;
var CRE COM MIL PEA THK SWTA MILA COKA COD VIO SMO;
class ice; run;
proc stepdisc stepwise simple stdmean tcorr wcorr data=disc;
var SWT STR CAN COK GRA VIO PEA MIL COM COD THK SMO CRE MCO
SWTA STRA CANA GRAS VIOA PEAA COKA ASTR MILA;
class formu; run;
proc candisc data=disc out=cand;
var VIO PEAA SWT COK;
class formu; run;
```

The SAS Code of Ranking Test

Friedman's test

```
data icecream;  
input judge$ product$ ranking;  
datalines; inserted data;  
proc freq data=icecream;  
  tables judge*product*ranking / cmh2 scores=rank noprint; run;
```

Wilcoxon-Mann-Whitney test

```
data icecream;  
input judge$ sampleid ranking;  
datalines; inserted data;  
proc sort; by sampleid ranking;  
proc freq; by sampleid; tables ranking; run;  
proc means; by sampleid;  
proc npar1way wilcoxon;  
  class sampleid;  
  output out=datat wilcoxon; var ranking;  
proc rank out=rankdata data=icecream; var ranking; ranks r;  
proc sort data=rankdata; by sampleid;  
proc means mean stderr; var r; by sampleid; run;
```

Appendix H- Example of consent form for descriptive test

INFORMED CONSENT TO PARTICIPATE IN THIS RESEARCH PROJECT

I, (Name _____), (Date _____) consent to participate in this research project and understand the following:

PROJECT BACKGROUND: This project involves gathering data on ice cream. The data will be collected for analysis and may be published. You must be at least 18 years of age to participate.

PURPOSE: The purpose of this study is to determine sensory properties of ice creams.

VOLUNTARY: The survey is entirely voluntary. You may refuse to answer any question or choose to withdraw from participation at any time without any penalty or loss of benefits to which you are otherwise entitled.

WHAT DO YOU DO? All participants of the sensory panel will attend 5-6 training sessions to become familiar with the methodology. The training sessions will take approximately 1 hour. The panelist will then attend at least 10 sessions in each of which the panelist will score the ice cream products using the selected attributes.

BENEFITS: Your participation in this research project will enrich the information base. U.S. consumers enjoy the safest and most varied food supply in the world, in large part because of the great achievements of the food science research. Ice cream is the most favorite desserts of the American consumer, but many consumers crave lower fat ice creams, however, without compromising the taste of the product. The development of good tasting ice creams that are lower in fat requires extensive knowledge of what sensory attributes consumers like. Your participation will help in gathering this important information.

RISKS: The expected risks are none other than those encountered in normal daily food consumption.

CONFIDENTIALITY: Your confidentiality will be maintained in that a participant's name will not appear on the ballot or in the published study itself. The data will only be reported in aggregate form. Score sheets will be stored for a period of three years in a locked file cabinet in the principal investigators office and then destroyed.

INJURY: It is not the policy of the University of Missouri to compensate human subjects in the event the research results in injury. The University of Missouri does have medical, professional and general liability self-insurance coverage for any injury caused by the negligence of its faculty and staff. Within the limitations of the laws of the State of Missouri, the University of Missouri will also provide facilities and medical attention to subjects who suffer injuries while participating in the research projects of the University of Missouri. In the event you have suffered injury as the result of participating in this research project, you are to immediately contact the Campus Institutional Review Board Compliance Officer at (573) 882-9585 and the Risk Management Officer at (573) 882-3735 to review the matter and provide you further information. This statement is not to be construed as an admission of liability.

Thank you for your assistance in developing these new ice cream products. Although great strides have been made in the instrumental analysis of foods, the development of new foods still requires the human sensory response and feedback. Your efforts are greatly appreciated. If you have any questions regarding the study, please contact Dr. Ingolf Gruen at (572) 882-6746. If you have questions regarding your rights as a participant in research, please feel free to contact the Campus Institutional Review Board at (573) 882-9585.

Dr. Ingolf Gruen

Date _____ Printed Name _____ Signature _____

Appendix I- Example of score sheet for descriptive test

SCORE SHEET IN COMPUSENSE FIVE

This is a descriptive test of strawberry ice creams. Before you begin this test, please make sure you have a cup of water, a dish of references, a spit-out cup, some spoons and papers. If you lack something or want more, please turn on the switch once or inform me.

Direction:

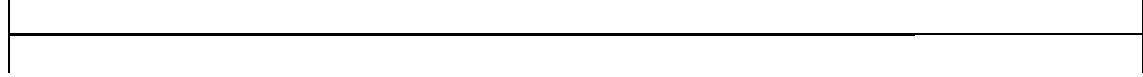
- (1) Please masticate a piece of carrot or cracker and then rinse your mouth with water before you start the test.
- (2) Open the deli cup of references and taste them to make sure you figure out the intensity of each reference provided for each attribute. Rinse your mouth with water between you taste each reference.
- (3) Open the deli cup containing the ice cream sample, scrape three times of the central part of ice cream sample and evaluate "APPEARANCE".
- (4) Place the ice cream sample in your mouth and evaluate "THE RATE OF MELT" by using a timer. Then key into the seconds which you got.
- (5) Place the ice cream sample in your mouth and evaluate "FLAVOR" and "TEXTURE".
- (6) Expectorate or swallow the sample and evaluate the "AFTERTASTE".
- (7) Please masticate a piece of carrot or cracker and then rinse your mouth with water in between samples.
- (8) Mark a vertical line on the horizontal line that is presented the perceived intensity of the attribute by comparing to the reference.
- (9) If you are unclear about any attribute, please go back to taste and check the reference.

APPEARANCE

Pink Color

Low

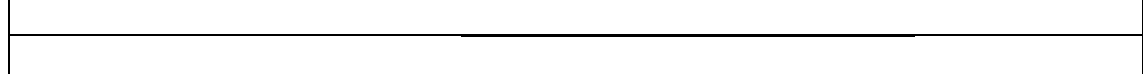
High



Dense

Low

High



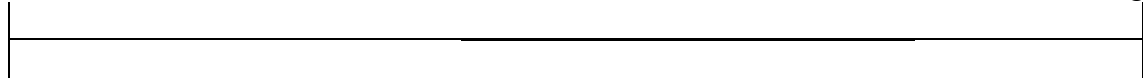
RATE of MELT _____ sec.

FLAVOR

Sweetness

Low

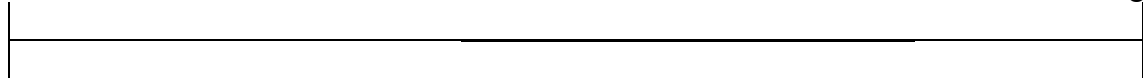
High



Strawberry flavor

Low

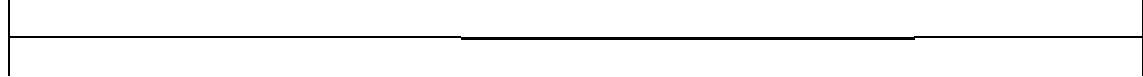
High



Candy flavor

Low

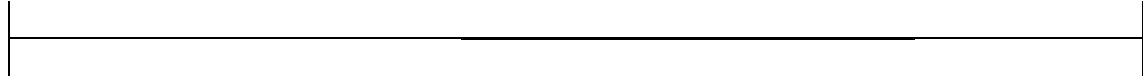
High



Cooked sugar flavor

Low

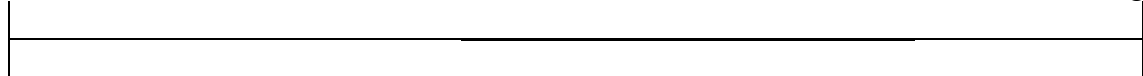
High



Grassy flavor

Low

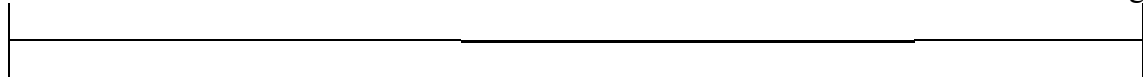
High

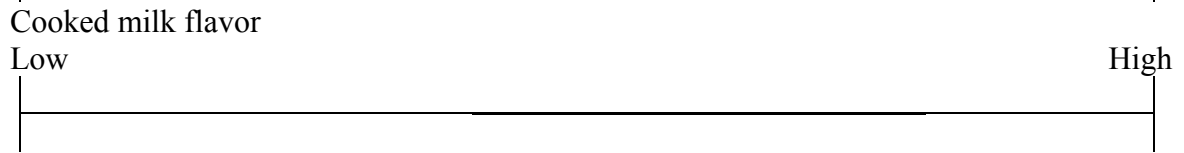
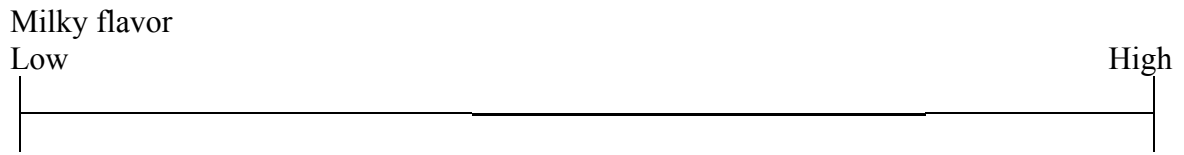
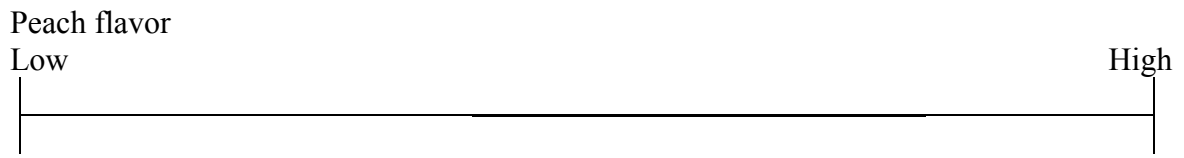


Violet flavor

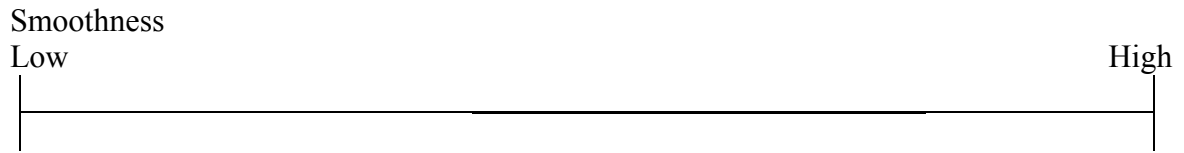
Low

High



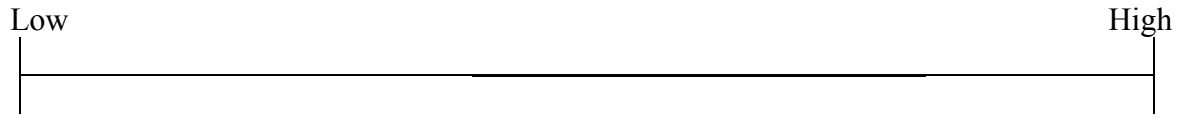


TEXTURE

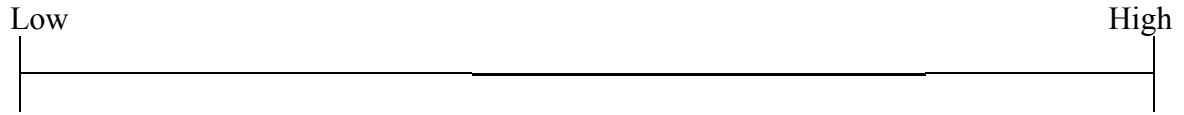


AFTERTASTE

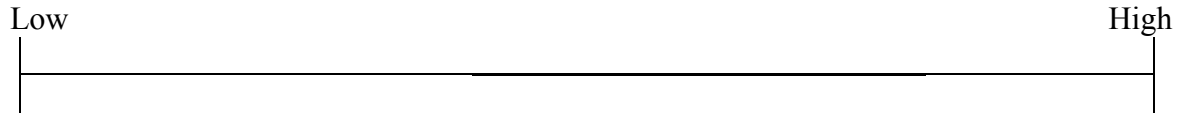
Sweetness aftertaste



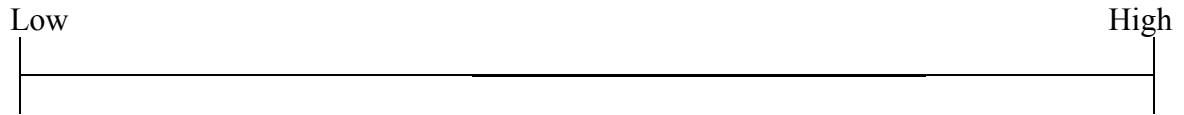
Strawberry flavor aftertaste



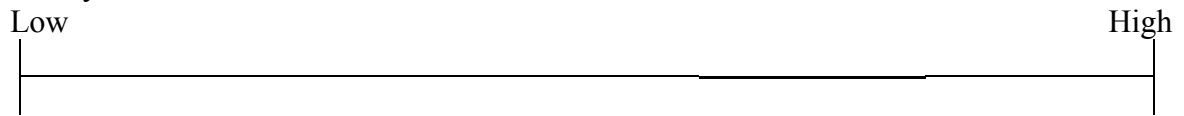
Candy flavor aftertaste



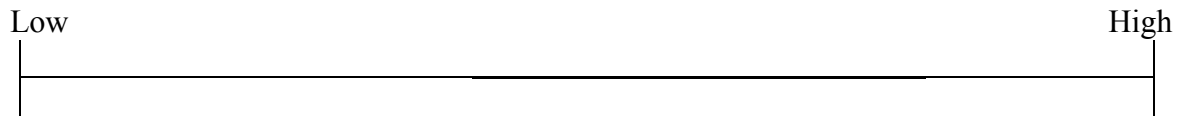
Cooked sugar flavor aftertaste



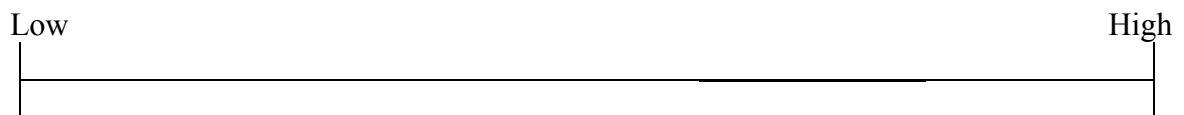
Grassy flavor aftertaste



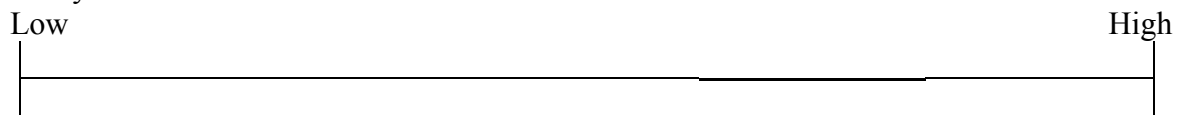
Violet flavor aftertaste



Peach flavor aftertaste



Milky flavor aftertaste



Astringent



Appendix J- Example of consent form for consumer test

INFORMED CONSENT TO PARTICIPATE IN THIS RESEARCH PROJECT

I, (Name _____), (Date _____) consent to participate in this research project and understand the following:

PROJECT BACKGROUND: This project involves gathering data on ice cream. The data will be collected for analysis and may be published. You must be at least 18 years of age to participate.

PURPOSE: The purpose of this study is to determine sensory properties of ice creams.

VOLUNTARY: The survey is entirely voluntary. You may refuse to answer any question or choose to withdraw from participation at any time without any penalty or loss of benefits to which you are otherwise entitled.

WHAT DO YOU DO? All participants of the consumer sensory panel will attend one session in which they taste 6 different strawberry-flavored ice creams twice, once to determine the degree of liking for the various ice creams and a second time in which the ice creams will be ranked for preference. The entire participation will take only about 10 – 15 minutes.

BENEFITS: Your participation in this research project will enrich the information base. U.S. consumers enjoy the safest and most varied food supply in the world, in large part because of the great achievements of the food science research. Ice cream is the most favorite desserts of the American consumer, but many consumers crave lower fat ice creams, however, without compromising the taste of the product. The development of good tasting ice creams that are lower in fat requires extensive knowledge of what sensory attributes consumers like. Your participation will help in gathering this important information.

RISKS: The expected risks are none other than those encountered in normal daily food consumption. Please do NOT participate in this study if you have a known allergic reaction to milk products, such as being lactose intolerant.

CONFIDENTIALITY: Your confidentiality will be maintained in that a participant's name will not appear on the ballot or in the published study itself. The data will only be reported in aggregate form. Score sheets will be stored for a period of three years in a locked file cabinet in the principal investigators office and then destroyed.

INJURY: It is not the policy of the University of Missouri to compensate human subjects in the event the research results in injury. The University of Missouri does have medical, professional and general liability self-insurance coverage for any injury caused by the negligence of its faculty and staff. Within the limitations of the laws of the State of Missouri, the University of Missouri will also provide facilities and medical attention to subjects who suffer injuries while participating in the research projects of the University of Missouri. In the event you have suffered injury as the result of participating in this research project, you are to immediately contact the Campus Institutional Review Board Compliance Officer at (573) 882-9585 and the Risk Management Officer at (573) 882-3735 to review the matter and provide you further information. This statement is not to be construed as an admission of liability.

Thank you for your assistance in developing these new ice cream products. Although great strides have been made in the instrumental analysis of foods, the development of new foods still requires the human sensory response and feedback. Your efforts are greatly appreciated. If you have any questions regarding the study, please contact Dr. Ingolf Gruen at (572) 882-6746. If you have questions regarding your rights as a participant in research, please feel free to contact the Campus Institutional Review Board at (573) 882-9585.

Dr. Ingolf Gruen

Date _____ Name Printed _____ Signature _____

Appendix K- Example of ballot sheet for consumer test

WELCOME to our ICE CREAM RESEARCH

Instruction:

The test contains two parts. You will be tasting six ice creams and evaluating each of them one after the other. Then, you will rank the six ice cream samples together.

Please masticate a piece of carrot or cracker and then rinse your mouth with water before you start the test.

Place the ice cream sample in your mouth and then rate how much you like or dislike the sample by placing a mark on the scale that best describes your opinion.

If at any time you have a question about the test or directions, please ask the lab assistant.

Question # 1 - Sample _____

How would you rate the **"OVERALL LIKING"** of this product?

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Question # 2 - Sample _____

How would your rate the **"OVERALL FLAVOR"** of this product ?

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Question # 3 - Sample _____

How would your rate the **"OVERALL TEXTURE"** of this product?

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Question # 4 - Sample _____

How would you rate the **OVERALL APPEARANCE** of this product?

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

When you are done with your evaluation, please flip the light switch letting lab assistant know you are ready for your next sample

Rinse thoroughly with water and as often as necessary between samples.

If at any time you have a question about the test or directions, please ask the lab assistant.

Question # 5

Please rank the six ice cream samples in the order of preference. TIES ARE NOT ALLOWED

<u>Rank</u>	<u>Sample #</u>
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Appendix L- Sampling plan of consumer test for 6 ice creams

Panelist	Sample Order					
1	4-195	6-618	1-103	3-001	2-542	5-479
2	3-001	2-542	4-195	1-103	6-618	5-479
3	1-103	2-542	3-001	4-195	5-479	6-618
4	2-542	4-195	6-618	3-001	1-103	5-479
5	1-103	2-542	6-618	3-001	5-479	4-195
6	6-618	4-195	5-479	3-001	2-542	1-103
7	4-195	2-542	5-479	3-001	6-618	1-103
8	6-618	1-103	5-479	3-001	4-195	2-542
9	3-001	5-479	4-195	1-103	2-542	6-618
10	5-479	4-195	3-001	6-618	1-103	2-542
11	1-103	4-195	6-618	5-479	2-542	3-001
12	6-618	2-542	4-195	5-479	1-103	3-001
13	3-001	1-103	2-542	5-479	6-618	4-195
14	3-001	6-618	5-479	2-542	4-195	1-103
15	5-479	2-542	3-001	4-195	1-103	6-618
16	6-618	3-001	1-103	4-195	2-542	5-479
17	4-195	6-618	3-001	2-542	1-103	5-479
18	4-195	5-479	3-001	2-542	1-103	6-618
19	4-195	3-001	5-479	1-103	2-542	6-618
20	3-001	5-479	6-618	4-195	1-103	2-542
21	1-103	6-618	5-479	3-001	2-542	4-195
22	3-001	6-618	2-542	1-103	5-479	4-195
23	3-001	6-618	4-195	1-103	5-479	2-542
24	1-103	4-195	5-479	6-618	2-542	3-001
25	4-195	3-001	5-479	2-542	1-103	6-618
26	5-479	6-618	1-103	4-195	2-542	3-001
27	4-195	2-542	3-001	1-103	6-618	5-479
28	2-542	1-103	4-195	5-479	6-618	3-001
29	1-103	2-542	4-195	3-001	6-618	5-479
30	6-618	2-542	5-479	3-001	1-103	4-195
31	2-542	5-479	6-618	3-001	4-195	1-103
32	6-618	4-195	2-542	3-001	5-479	1-103
33	3-001	2-542	4-195	6-618	1-103	5-479
34	5-479	6-618	1-103	2-542	3-001	4-195
35	4-195	3-001	1-103	5-479	2-542	6-618
36	5-479	3-001	4-195	1-103	6-618	2-542
37	6-618	2-542	5-479	4-195	3-001	1-103
38	2-542	4-195	5-479	1-103	3-001	6-618

103: 10% ice cream (Control); 542: 4% ice cream with Simplese[®] (Control)
001: 4% ice cream with Simplese[®] (S4); 195: 4% ice cream with Simplese[®] (S6)
479: 4% ice cream with Simplese[®] (S22); 618: 4% ice cream with Simplese[®] (S24)

Panelist	Sample Order					
39	6-618	5-479	4-195	2-542	1-103	3-001
40	6-618	4-195	5-479	1-103	2-542	3-001
41	5-479	6-618	3-001	2-542	1-103	4-195
42	5-479	3-001	4-195	1-103	6-618	2-542
43	6-618	1-103	3-001	2-542	5-479	4-195
44	4-195	6-618	1-103	5-479	2-542	3-001
45	1-103	4-195	2-542	6-618	3-001	5-479
46	4-195	5-479	1-103	6-618	2-542	3-001
47	5-479	6-618	1-103	4-195	2-542	3-001
48	4-195	1-103	5-479	2-542	6-618	3-001
49	1-103	4-195	5-479	6-618	3-001	2-542
50	1-103	3-001	6-618	2-542	5-479	4-195
51	1-103	2-542	6-618	5-479	3-001	4-195
52	1-103	4-195	2-542	5-479	3-001	6-618
53	3-001	1-103	5-479	4-195	2-542	6-618
54	4-195	5-479	6-618	2-542	3-001	1-103
55	2-542	1-103	5-479	6-618	4-195	3-001
56	6-618	1-103	2-542	5-479	3-001	4-195
57	1-103	6-618	5-479	3-001	2-542	4-195
58	4-195	1-103	5-479	6-618	3-001	2-542
59	1-103	5-479	4-195	3-001	6-618	2-542
60	2-542	3-001	6-618	5-479	1-103	4-195
61	5-479	2-542	4-195	3-001	6-618	1-103
62	5-479	3-001	1-103	4-195	2-542	6-618
63	1-103	5-479	6-618	2-542	4-195	3-001
64	5-479	1-103	2-542	4-195	6-618	3-001
65	6-618	5-479	4-195	3-001	2-542	1-103
66	4-195	5-479	3-001	6-618	1-103	2-542
67	4-195	2-542	5-479	3-001	1-103	6-618
68	2-542	3-001	4-195	1-103	5-479	6-618
69	3-001	4-195	2-542	5-479	1-103	6-618
70	3-001	2-542	5-479	4-195	1-103	6-618
71	6-618	2-542	3-001	1-103	5-479	4-195
72	6-618	5-479	2-542	3-001	1-103	4-195
73	3-001	1-103	4-195	6-618	5-479	2-542
74	1-103	4-195	5-479	6-618	3-001	2-542
103/097: 10% ice cream (Control); 542: 4% ice cream with Simplesse [®] (Control) 001: 4% ice cream with Simplesse [®] (S4); 195: 4% ice cream with Simplesse [®] (S6) 479: 4% ice cream with Simplesse [®] (S22); 618: 4% ice cream with Simplesse [®] (S24)						

VITA

Bo-Kang Liou was born January 7, 1973, in Taichung, Taiwan. After attending public schools in Taiwan, he pursued a Bachelor of Science degree, which was awarded in May 1995, and a Master of Science degree, awarded in July 1997, in the Food Science Department at Chung-Hsing University in Taichung, Taiwan. While completing his army service, he worked in Food Industry Research & Development Institute (FIRDI), Taiwan. In 2001, he entered the graduate program at the University of Missouri Columbia under the direction of Dr. Ingolf Gruen. He completed his Doctor of Philosophy degree in December 2006 and also awarded a Master of Business Administration degree in July 2006 at the William Woods University, Fulton, Missouri. After graduation, he became a young food scientist in the field of food chemistry and sensory science and devoted himself to contributing as much as he can to this field in the future.