EFFECT OF FAT AND SUCROSE REPLACERS ON PHYSICAL, CHEMICAL, AND SENSORY PROPERTIES OF REDUCE CALORIE ICE CREAM.

By

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DECLARATION

The work described in this thesis was carried out by me at the Research and Development Laboratory of Ceylon Cold Stores Ltd., Colombo- 02 and the Faculty of Applied Sciences under the supervision of Mr. D. A. M. Arsecularatne and Mrs. K. M. Somawathie. A report on this has not been submitted to any other University for another Degree.

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ABSTRACT

Concern about the impact of diet on health has led consumers to reduce the consumption of high calorie foods in many countries. Health conscious consumers in Sri Lanka often suffer from lack of suitable low calorie foods, leading to monotonous uninteresting diets.

Ice cream is a highly palatable and energetic (200kCal/100g) food of people of every age. About 75% of its energy is contributed from fat and sugar. Successful development of low calorie ice cream depends to large extent on the imitation of functional and sensory properties produce by sugar and fat with low calorie ingredients. Effect of these ingredients on physical and sensory properties is very important to for successful development of such product

Objective of this study was to determine the effect of fat replacer, Simpleese[R] Dry100 and Maltrin[R]M-40 and sweetner Maltitol, on physical, chemical and sensory properties of reduce calorie ice cream. Vanillin flavour alone and vanillin flavour together with butter flavour on the product acceptability was also determined. Sample with 10% fat and 15% sucrose was used as a controller. The study was carried out at the Research and Development Laboratory of Ceylon Cold Stores Ltd., Colombo.

There were significant differences between control and samples formulated with fat and sucrose substitutes for creaminess, waxiness, vanillin flavour and sweetness. There were no significant differences between control and samples flavoured with both vanillin and butter flavours for aroma. Maltrin[R]M-40 with only vanillin flavour scored the highest for after taste. Freezing points were lower for samples formulated with fat and sucrose substitutes than control and this resulted faster malting than control.

There is a significant effect on properties of ice cream when fat and sucrose are substituted by other ingredients and further studies are needed to bring them more closer to control.

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CHAPTER-1

INTRODUCTION

Foods are need for people to build up their body tissues and to fuel their body functions. The main constituents in our foods are carbohydrate, protein, fat, vitamins and minerals. Carbohydrate and protein contribute 4kCal/g (17kJ/g) and fats contribute 9kCal/g(38kJ/g). A person is over weight or obese (caused by excessive build up of fatty tissues of the body) normally becomes that way because of taking in more energy in the form of food than is expended by the activities of living. There are few people who are seem naturally predispose to put on weight just as there are those fortunate ones who are slim however much they seem to eat. A person who is obese probably more at a risk in terms of health, and if he is wise will do his utmost to the to limit the amount of energy he takes in as food. Because of these reasons health conscious consumers look for ways to improve their nutritional habits without scarifying their physiological satisfaction. This can be achieved by the adaptation of a diet, which avoid excess intake of energy, saturated fats and refined sugars.

In the world marker there a number of fat and sugar free, reduced calorie foods, which are belonging in to different categories. It has been reported that 64% of Australians eats reduced fat food and about 30% eat low calorie sugar free food products.(Vandana et.al,1998). According to the survey conducted in America indicated that 141 million people used low calorie or low fat foods (45%), low fat foods (22%), or low calorie foods (9%). This represented about 76% of adult population (Alexander & Zabel, 1994).

But this is not still common in Sri Lankan market. Certain type of foods such as less sugar jams, drinks, low fat milk and milk powders are available to certain extent. Most of these are imported food products. Therefore health conscious consumers in Sri Lanka often suffer from a lack of suitable foods leading to monotonous uninteresting diet.

Ice cream is a highly palatable and interesting food for people of every age. It is highly energetic food with high amount of fat and sugar. Typical ice cream contains more than 10% fat and 15% sugar. Energy value of this product is around 200kCal/100g and about 90kCal of this comes from fat and about 60kCal comes from sugar. Therefore reducing or replacing of fat or sugar or reducing or replacing of both can reduce the calorie content of the product to a considerable extent.

Apart from functioning as energy source, fat and sugar provide several functional and sensory properties of ice cream. Therefore successful development of good quality fat sugar free ice cream depends to a large extent on the imitation of organoleptic and maintenance of physical properties of the equivalent standard ice cream.

In the early eighties the use of fat replacers was unthinkable. As fat replacement technologies developed, number of carbohydrate based, protein based and synthetic fat substitutes are now available. Developments in sugar technology also have developed low calorie sweetners that also can be tolerated by diabetes. Understanding the effect on sensory and physical properties when fat and sugar are replaced by these ingredients is essential to achieve high quality profitable product

However few research studies were found on effect of removing or replacing both fat and sugar on physical and sensory properties of ice cream. Carbohydrate based fat replacers, tapioca maltodextrin and potato maltodextrin and polydextrose-aspartame system has been used to reduce the fat and sugar in reduce calorie frozen desserts (Specter & Sester, 1994).

Most of the research studies have been conducted on the effect of removing or replacing fat alone by using protein based fat replacers (Ohmes *et. al.*, 1998) or carbohydrate based fat replacers or both (Roland *et.al.*, 1999, Kailasapathy and Songvanich,1998).

Objectives of this study were to;

1. Determined the effects of fat and sucrose replacers on physical, chemical and sensory properties of reduce calorie ice cream. Carbohydrate based fat replacer, Maltrin^R M-40 and protein based fat replacer, Simpleese^{R}Dry 100A and Maltitol sweetning system were evaluated.

2. Determined the effect of vanillin flavour alone and vanillin flavour together with butter flavour on the product acceptability.

CHAPTER - 2

LITERATURE REVIEW

2.1. History of Ice Cream

Ice cream is thought to have originated in china perhaps as long ago as 1000 BC. Macropola is reported to have brought the idea back from china to Europe in the 13th century which then became popular, in Venice and through out the Europe (Holdsworth. & Haylock, 1995).

The courts of Henry III and Louis XIV served ice cream as frozen dessert in the 17th century but we can't vouch for the consistency of its bacteriological and flavour characteristics (Anonymous, 1996).

By the late 18th century ice cream was in the United States and was apparently served at the inaugural Presidency Ball in the White House, George Washington having developed liking for delicacy (Anonymous, 1996).

Jacob Fussell established the first commercial ice cream plant, in Baltimore in USA and supplying of ice cream to union officers during the civil war has helped to develop the ice cream market in America (Anonymous, 1996)

The developments occurred in the field of power generation, manufacturing and processing techniques and equipment, transport vehicles, refrigeration and in ingredient technology helped too develop the ice cream manufacturing process to a considerable extent.

In Sri Lanka, Ceylon Cold Stores (former Ceylon Ice Company) started manufacturing and distribution of ice cream, after acquiring Ceylon Cremaries in 1925.

2.2. Classification of Ice cream

Ice cream is a frozen dessert and there are several categories of frozen desserts depending on the composition of ingredients in each type of frozen dessert. Although there are differences in composition similar processing method is followed.

Ice cream is highest in milk fat and milk solids among frozen desserts. Fruit, nuts and other bulky flavourings such as candy are added to ice cream. French custard ice cream is distinguished from others because of the addition of egg yolk solids to the mix. Ice milk contains less total solids content than others and normally has more sugar than ice cream.

Soft ice creams are soft and ready to eat when drawn from freezer without hardening. Fruit sherbet is low fat, low milk solids, frozen food and it has more sugar than ice cream. A tart flavour characterizing fruit sherbets and it comes from added fruit and fruit acids. Water ices contain about 70-75% water and considered as non dairy frozen food because they contain no dairy ingredients. They are high in sugar, containing 15- 20% fruit juice and have a tart flavour (Anonymous, 1971).

2.3. Composition and Structure of Ice cream

2.3.1. Composition of Ice Cream

The major essential ingredients such as fat, non-fat Milk solids, sugar and water together with the functional ingredients (emulsifying and stabilizing agents) and optional ingredients (flavours and colours) are included in the mix composition of ice cream.

Requirement of these ingredients in the final product is different from country to country depending on the legal regulations and desired product characteristics. A typical range of mix composition is given in Table 2.1

Table 2. 1. Average composition of ice cream

Ingredient	Average range
Fat	2.5-14.0%
Milk Solids Non Fat (MSNF)	7.0-12.0%
Sugar	10.0-16.0%
Stabilizing agent	0.1-0.5%
Emulsifying agent	0.5-1.0%
Water	60.0-78.0%
Total Solids	23.0-42.0%

Source. Hamilton, 1990

According to the Sri Lanka Standard Institution (SLSI), ice cream must full fill following requirements.

Table 2.2. Compositional Requirements of Ice Cream for the Sri Lankan standard

Characteristic	Requirement
Total Solids, percent by mass, min	32
Fats, percent by mass, min	08
MSNF, percent by mass, min	08
Sucrose, percent by mass, min	10
Acidity as Lactic Acid, percent by mass, max	0.25
Mass in Grams, per Liter, min	475

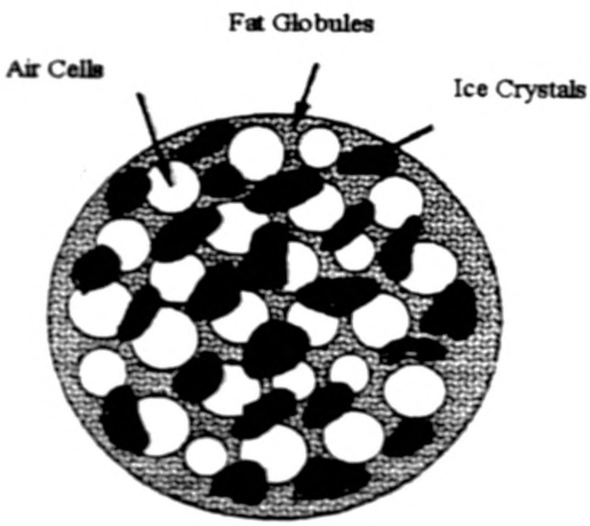
Source. Sri Lanka Standard Institution

2.3.2. Structure of Ice Cream

Ingredients that are mentioned above form very complex structure in ice cream. Gas or air dispersed as small air cells in a partially frozen continuous phase. In this phase fat is dispersed as inner phase in an emulsion. MSNF and stabilizers in colloidal solution and the sugars and salts form genuine solution.

A thin slice of ice cream under microscope would appear as in Figure2.1. The circular spaces are air cells in the foam and irregular shapes masses are ice crystals. Separating the air pockets and surrounding the ice crystals is a highly viscous unfrozen emulsion (Keeney, 1996).

Figure 2.1. Model Structure of Ice Cream



Source: Keeney, 1982

2.4. Functionality of Ice Cream Ingredients and their sources

2.4.1. Fat

Fat is the most important factor that affects the quality of the ice cream. It contributes to the formation of sub structure of the product, and helps to give richness body and the creaminess of the ice cream (Hamilton, 1990). Fat has major impact on the flavour because fat is a good carrier and synergist for added flavour compounds, and it promotes the desirable tactile qualities. Fat help to increase the caloric content and thereby increase the food value of ice cream. On the other hand if ice cream contain high amount of fat, it limit the amount of ice cream consumed because of its high-energy value (Keeny, 1996).

Milk fat or vegetable fat can be used as the source of fat in ice cream. Choice of this is based on the availability, coast and manufacturing process. Fresh milk is the best basic ingredient and it imparts better flavour than processed milk products. It also supplies milk solids non-fat

Fresh cream is produced by separation of the milk fat from full cream milk, which has been standardized, pasteurized and homogenized. Typical composition includes 40-42% milk fat and 5-6% MSNF. This is the most desirable concentrated source of milk fat for ice cream. The cream must possess a high standard quality with a low microbiological count, low acidity and be free from off flavours and odours (Ford, 1996).

Frozen cream is fresh cream, which has been rapidly frozen. Typical composition include 50-52% fat, 4-5% MSNF. It provides the same benefits as fresh cream yet shelf life is greatly increased (Ford, 1996).

Plastic cream is concentrated cream, typically processing a fat content between 80-85%, 1-2% MSNF and similar consistency to butter (Ford, 1996).

Butter is a good source of milk fat. Specially unsalted sweet cream butter. Salted or lactic butter tends to impart their characteristic pronounced flavours. Unsalted butter typically contains 82-83% fat and 0.4-0.6% MSNF and it imparts excellent flavour and mouth feel (Ford, 1996).

Anhydrous milk fat (AMF) or Butter oil is dark to pale yellow and contains 99.7-99.9% milk fat. The remaining moisture is removed by centrifugation and vacuum drying. The quality of AMF depends on the quality of butter or cream from which it is made. With good quality AMF the flavour and texture of ice cream are excellent (Hamilton, 1990).

Vegetable fats such as palm kernel oil, palm oil and coconut oil or mixture of these can be used in ice cream as source of fat in ice cream. These are normally solids at ambient temperatures. Good vegetable fat source should clear when melted without sediments or foreign matter or moisture. Further these should be bland in taste and free from rancidity and other foreign flavours. During the storage, should store away from heat, preferably under cool conditions.

2.4.2. Milk Solid Non-Fat (MSNF)

The non-fat milk solids are also referred as serum solids. These non-fat milk solids contain lactose, proteins, ash or minerals and salts. These ingredients contribute to body and texture and they are essential to the formation of and maintenance of small stable air cells.

Protein in MSNF denatures during heating and homogenization and provides following properties. Proteins absorb free moisture and hold it as water of hydration. This prevents the growth of large ice crystals, which would give a coarse texture. Milk proteins also emulsify fat since they constitute part of the fat globule membrane. Too much denatured protein cause excess aeration and curdley melt down (Hamilton, 1990).

The lactose component of milk solids non-fat contributes to some sweetness. But lactose level must be balanced. If too low the ice lacks body and its watery, if too high the lactose tends to concentrate and come out of the solution as crystals, imparting a grainy mouth feel. The lactose also contributes to depressing the freezing point of the ice cream (Varman and Sutherland, 1996).

The milk salts also serves to depress the freezing point and contribute a slight saltiness to the ice cream. Milk salts effect on the milk protein stability. Milk solids non-fat also contributes to the acidity, viscosity and melting resistance of the ice cream (Keeny, 1996).

Liquid whole milk was mentioned as a source of milk fat but it also supplies a good proportion of MSNF in the ice cream. Liquid skim milk contains about 9% MSNF and act as an excellent basic ingredient for ice cream. But both not supplies enough in the mix (Hamilton, 1990). Concentrated skim milk is obtained by the vacuum evaporation of some of the water. It contains about 30% MSNF and required refrigerated storage (Hamilton, 1990).

Skim milk powder (SMP) is produced from fresh pasteurized milk, which has been concentrated, and spray dried. It typically contains between 0.8-1.2% milk fat, 33-37% protein, 3-4% moisture and 96-97% MSNF and there for it is a good source of MSNF. Low, medium and high heated SMP are available. Low heat SMP is generally used due to the minimal level of denatured proteins and minimal cocked flavour. Medium and high heat powders are also used for improved whipping properties, texture, reduced melt down and improved shelf life of the product with respect to quality. A 'powdery mouth feel' can be caused by SMP as like other dry ingredients. Because it is a concentrated source of MSNF, SMP is efficiently stored and possess a 12-month shelf life if stored under dry cool conditions (Ford, 1996).

Whey powder (WP) is produced from fresh, sweet whey, which has been concentrated, slowly crystallized and then spray dried. It typically contains 3-4% moisture, 0.5-1.5% milk fat, 95-97% MSNF< 68-75% lactose and 3-10% minerals.

This is an excellent source of concentrated MSNF and an extremely cheap, is commonly used as a cheap replacer of SMP. Non-hydroscopic and demineralised WP are also available which minimize lumping and saltiness respectively. Levels of WP in ice cream has to be balanced due to high lactose content which cause sandiness and "whey flavour " in ice cream. WP has shelf life 6-8 months if stored in a cool dry environment (Ford, 1996).

2.4.3. Sugar

Sugar sweetens the product and also it is the cheapest source of solids. Sugar helps t improve the body and texture of the ice cream. The flavour of the fat and true fruit flavours are enhanced by sugars (Hamilton, 1990).

Caloric sweetners profoundly affect the freezing point of ice cream. Different sugars depress the freezing point of water to different extent. Generally the property is related to the concentration of each of individual sugars and their molecular weight (Appendix A). The more molecules added the greater the depression of freezing point. Heat shock may become a problem in ice cream with too low freezing point and the product become too soft when stored in a conventional home freezer. Conversely ice cream become too hard if the freezing point is too high. Therefore careful attention must be given to the type and amount of sweetning or bulking added to mix formulation (Mitten, 1986).

Sugars that may be present in frozen dessert include sucrose, lactose, maltose, fructose and conventional corn sweetners. Sucrose is the standard sweetner in ice cream and levels of approximately 15% are considered optimal in ice cream. However this varies depending on the regional preference and characterizing flavour ingredients. Chocolates and fruit flavours require higher concentrations. Sucrose provides sweet taste without secondary or after flavours. It is very soluble in cold or hot water and exhibits reversibility of crystallization (Kilara, 1996).

Lactose is a reducing sugar composed of glucose and galactose. Lactose may enhance fruity flavours; however its low solubility results in crystallization on prolonged storage at high concentrations. Crystallization of lactose may cause sandy or gritty ice cream (Kilara, 1996).

Maltose is a reducing disaccharide composed of two glucose units. In frozen desserts maltose derived from cornstarch. Being reducing sugar, it participates in browning on heating, thus influencing flavour and colour. Level of maltose in frozen desserts range from 1-5% (Kilara, 1996).

Fructose is a reducing monosaccharide with a keto structure and is a natural constituent of many foods such as honey. On weight basis, fructose sweetned ice creams are not significantly different in appearance, texture or taste compared to sucrose. However melting characteristics of fructose based ice cream are superior under prolonged frozen storage. In frozen desserts the level of fructose range from 0-4% (Kilara, 1996).

High fructose corn syrup is produced from glucose syrups using the enzyme glucose isomerase. In ice cream and frozen desserts levels of 25-100% are used. Formula adjustment may be needed specially at higher levels of substitution the effect of HFCS on freezing point reduction are compensated for by lower DE corn syrup, stabilizer or retaining some of sucrose in the formulation (Kilara, 1996).

Conventional corn sweetnersare derived from cornstarch, by the hydrolysis of glucose polymer by acid or enzymes. Types of corn sweetners are glucose syrups, corn syrup solids, maltodextrins (10-120 DE) and dextrose (glucose). In ice cream and frozen desserts corn syrups from the sweetest to the very low (20 DE) are used. These syrups provides better melt down characteristics, inhibit crystallization of sucrose, lactose and other sugars. It also contributes to the body, mouth feel and chew ness of the product (Kilara, 1996).

2.4.4. Stabilizers

Stabilizers or hydrocolloids are polymer substances. The primary function of stabilizers in ice cream is there ability to influence rheological conditions of water phase. When dispersed in water, gradually hydrated, there by a large number of water molecules are bound primarily by means of hydrogen bonds.

A three dimensional network is formed due to intra and inter molecular links between single stabilizer molecules and /or between several stabilizer molecules in combination with protein, so that the mobility of the residual aqueous phase is restricted.

This helps to produce ice crystals less than 20 microns and also prevent the growth of large ice crystals when there are fluctuations in the temperature during the storage and thereby improve the body and texture (Julin, 1978).

Properly stabilized ice cream will have a heavier body, will not taste cold, melt more slowly and give creamier consistency on melting. In addition to this stabilizer improve mix viscosity and air incorporation. The factors that important in choosing a stabilizer are, ease of incorporation and effect on viscosity and whipping properties in the mix., type of body produce in ice cream, effects on melt down characteristics, ability to retard ice crystal growth, amount required to produce the stabilization and coast (Ramzan,1972).

Locust bean gum is widely used as a primary stabilizer in ice cream mixes because of its excellent water binding and swelling qualities and the smoother melt down and excellent heat shock resistance. Wheing off tendencies of locust bean gum are prevented, by using it in conjunction with carrageen. Maximum use level of locust bean in frozen desserts is 0.5%. (Kilara, 1996).

Guar gum is the natural flour of the guar seed and is obtained by grinding the seed endosperm. A maximum usage level permitted in frozen desserts is 0.5%. This imparts properties similar in Locust bean gum.

In addition Guar hydrated rapidly in cold water making it more suitable than Locust bean gum for HTST processing. Use of Guar has been suggested in combination with calcium sulphate as emulsifier, with carrageen to prevent wheezing off (Kilara, 1996).

Gum arabic was reported to produce a fine texture by inhibiting the formation of ice crystals by its water binding properties. However, ice cream stabilize with this has inferior melt down characteristics (Kilara, 1996).

Tragacanth also has been used in the levels of 0.2-0.3% particularly in combinations with other gums and imparts good body and texture. Alginates are extracted from the giant kelp, *Macrosystis pyrifera*. The usage limit in frozen desserts not exceeds 0.5% (Kilara, 1996).

Carboxymethyl cellulose (CMC) was found to be effective at 0.15-0.2% levels in ice cream mix imparting good body, chewy texture and enhancing the whipping properties of the mix. This also causes whey separation and is there for used in conjunction with Locust bean gum or carrageenan (Kilara, 1996).

Carrageenan is extracted from the seaweed *Chondus crispus* or other seaweeds in the same family. Carrageenan alone is not a satisfactory stabilizer for ice cream since it greatly increases mix viscosity making it difficult to incorporate sufficient quantity for proper stabilization. However it is extremely useful as a secondary stabilizer at approximately 0.03% in preventing the' wheying off ' caused by primary stabilizers such as CMC, Locust bean gum or Guar (Kilara, 1996).

Microcrystalline cellulose (MCC) is derived from alpha cellulose or wood pulp and it should not exceed 1.5% by weight in a finished frozen desserts.

Xanthan gum is a biopolysaccharide manufactured through *Xanthamonas campestris* fermentation of glucose, a nitrogen source, dipotassium hydrogen phosphate plus other trace elements (Kilara, 1996).

2.4.5. Emulsifiers

Any substance that is capable of aiding the formation of a stable mixture of two, otherwise immiscible substances (Eg. Fat and water) is called an emulsifier. Most emulsifiers are called surfaceactants or surface-active agents. These are amphipilic compounds whose chemical structure has both hydrophilic and hydrophobic functions.

Surfactants perform in two different ways in frozen desserts. In the mix before freezing, they help to stabilize the fat emulsion keeping the fat dispersed in the suspension; in the freezer produce one effect of dryness by aiding the controlled destabilization of the fat emulsion thus promoting agglomeration of fat globules. It was believed by reducing the interfacial tension they aided the dispersion of fats and thereby associated in the production of fine air cell structure and improved whipping properties.

Among the emulsifiers available mono-diglycerides and polysorbates are widely used for ice cream manufacture. Mono-diglycerides can be produced from fatty acids of e. g. various chain lengths, various degree of hydrogenation and there are many possibilities for choosing exactly the combination which in the best possible way to satisfy the specific demands in ice cream industry (Julin, 1978).

Commercial mono-diglycerides used in ice cream usually have a monoester content between 40-60%. The general use level of mono-diglycerides in frozen desserts is 0.1-0.3%(Kilara, 1996).

Polysorbates are polyethylene derivatives of sorbitan tristearate and sorbitan monoleate. These are more hydrophilic than monoglycerides and are used at much lower levels, since they are especially effective in imparting stiffness of ice cream as it leaves the freezer. The general use level of polysorbate is 0.1-0.26% in frozen desserts (Kilara, 1996).

2.4.6. Ice Cream Flavours and colours.

The flavour is a one of the most important attributes in Ice Cream. Flavour is a sensory response that includes olfaction (odor, smell) gustation (taste), and tactural (mouth feel) compounds. Perfection of aroma compounds is affected by the composition, physical structure and temperature of the food.Colours can be used in ice cream that matches with flavour to enhance the appealing of ice cream (Kilara, 1996).

2.5. Manufacturing process

The basic steps in the manufacture of ice cream are summarized in Figure 2.2. Process should fulfill the legal requirements and also it depends on the quality of the final product that manufacture wish to obtain.

Figure 2.2. Schematic diagram of ice cream manufacture

Mix formulation
↓
Preparation of the mix
↓
Heat treatment / Pasteurization (83°C for 25 Sec)
↓
Homogenization (1500 psi)
↓
Cooling (4°C within 1.5 Hours)
↓
Aging (4°C, 4 to 24 hours)
↓
Addition of flavours and colours
↓
Air injection and scraped surface cooling / freezing (-4°C)
↓
Packaging
↓
Hardening (below -19°C)
↓
Storage (below -18°C)
↓
Distribution

2.5.1 Mix formulation

A number of factors must be considered when determining mix formulations. Legal standards must be obviously met Economic considerations however interact with market considerations and it is common practice to use cheapest possible ingredient comparable with quality standards. The quantities of the ingredients are calculated, then weighed or metered out as appropriate (Varman and Sutherland, 1996).

2.5.2 Preparation of the mix

Ingredients are blended in a processing vessel (vat) or in special blender. First heat the liquid ingredients to about 37 °C (100 °F) and add sweetners and other dry ingredients. Certain stabilizers (and/or emulsifiers) may not be added until the temperature reaches to 67 °C (150 °F). At the end all ingredients are in solution or suspension (Varman and Sutherland, 1996).

2.5.3. Heat treatment / Pasteurization

The mix is heat treated to the selected temperature and for the appropriate time to comply with the legislation. It is mandatory to heat treat the mix to a level sufficient to destroy the vegetative pathogens. Four minimum temperature / time treatments are permitted, 65.6 °C/ 30 min, 71.1 °C / 10 min, 79.4 °C / 15 s and 148.8 / 2 s (SLS, 223). More severe heat treatments have been suggested to ensure destruction of *Listeria monocytogenes* but may result burnt or cocked milk flavours (Varman and Sutherland, 1996).

Batch high temperature short time (HTST) or ultra high temperature (UHT) plants are used for pasteurization. In addition to microbiological safety heat treatment affects the physiochemical structure of the mix. It allows mixing and blending of ingredients, dissolve sugars and milk powders, and activates stabilizers and emulsifiers. Availability of binding sites of protein increase due to denaturation and partially denatured whey protein begin to act as emulsifiers. It also prepares the mix for homogenization (Holdsworth and Haylock, 1995).

2.5.4. Homogenization

Homogenization of ice cream mix reduces the size of fat globules and prevents churning in the ice cream freezer. This helps to improve the smoothness of the ice cream, and allow more milk protein to absorb on the fat globules. This increases the viscosity of the mix and produces a smoother body and texture in the frozen ice cream. Homogenization occurs only when the fat is liquid. This means the ice cream mix must be at 50 ^{0}C or higher, and higher the temperature, the better the efficiency of homogenization (Varman & Sutherland, 1996).

Fat globules in the ice cream mix can be over homogenized to the extent that amount of natural phospholipids available to the globule membrane insufficient to cover the increased surface. In this case globules can coalesces to form larger globules or clumps. Another factor effecting homogenization is the fat content of the mix. In general, the greater the fat content lowers the homogenization pressure needed (Holdsworth and Haylock, 1995).

2.5.5. Cooling

After pasteurization and homogenization, mix must be cooled as rapidly as possible to 4 °C. This helps to begin the crystallization of fat. Plate heat exchangers are used extensively for this operation (Varman & Sutherland, 1996).

2.5.6. Aging

After cooled to 4 °C, mix is held at that temperature until they are required at the freezer. This prevents the growth of microorganisms and promotes crystallization of fat and other changes. Fat crystallization plays an important part in achieving a stable foam. Following pasteurization, all the fat is in a liquid form. By cooling the mix to 4 °C (39 °F) and holding for a minimum of 4 hours, crystallisation of triglycerides occurs within the fat globules. This prevent the spreading of free fat on the surface of air vacuole that caucus collapse of air vacuole by reducing the thickness of the stabilizing protein film. This improves freezing, air incorporation, smoothness, body, texture and resistance to melting (Holsworth and Hoylock, 1995).

Holding time combined with a low mix temperature is called aging. Improvements in ice cream and freezing performances are more pronounced as the aging time increases from 4 to 12 hours or longer. Many progressive ice cream makers have observed that cooling the mix to 0 to 2 °C can shorten aging time. This probably increases the crystallization of fat and improves the absorption of milk protein to the fat surface (Mitten, 1996).

2.5.7 Addition of flavours and colours

Many of the flavouring and colouring are not heat stable. Therefore flavour and colour are generally added just prior to freezing. Because they are adding after the heat treatment care should be taken not to contaminate the mix (Varman & Sutherland, 1996).

2.5.8 Air injection and scraped surface cooling / Freezing

This process is carried out in an ice cream freezer and it is important in developing the correct structure and texture of the product. This is achieved by generating air vacuoles ranging between 10-60 micrometers. These vacuoles are initially stabilized by hydrophilic proteins, which are adhering to the vacuole wall.

Destabilized fat globules also adhere to the vacuole wall and provide additional stability to the foam. Air cells larger than above range can cause snowy, flaky texture. Incorporation of air help to increase the volume that means to give desired over run to the final ice cream (Holsworth and Hoylock, 1995).

Typical ice cream mix, frozen at draw temperature between –5 °C to –6 °C, has about half of the initial water frozen in to ice, leaving viscous, yet pumpable product for packaging and further processing. Refrigerant temperature maintain at –22 °C to –32 °C to give a draw temperature between –5 °C to –6 °C (Mitten, 1996).

Freezers may be vertical, horizontal, batch or continuous. Each will give a different product and require the composition of the mix to be suitably balanced. Vertical or horizontal batch freezers are suitable for small scale while continuous and horizontal freezers suitable for large scale (Varman & Sutherland, 1996)

2.5.9. Packaging

A wide range of packaging materials, such as, waxed, aluminum foil laminate or plastic coated cardboard and plastic containers are used for packaging ice cream. These are available in many sizes and shapes that are suitable for retail or bulk packaging. The package must protect the product and also make it interesting to consumer (Mitten, 1996).

2.5.10. Hardening

After packaging, hardening ice carried out in hardening rooms or hardening tunnels. Rapid reduction in temperature is needed to limit the size of ice crystal growth to eliminate the coarse texture in the final product. During hardening about another 1/3 of water become to frozen stage and remaining water form the continuous phase of ice cream and contains air cells, fat globules, ice crystals, MSNF, sugar and stabilizers (Mitten, 1996).

2.5.11. Storage and distribution

Where the ice cream is not being sold straight away, it is normally hardened to a temperature of –20 °C to –30 °C and stored at this low temperature. It is very important to maintain the constant storage temperature since fluctuations lead to migration and accumulation of water and results formation of large crystals on refreezing. For short-term display and transport, temperature of –13 to –18 °C are acceptable (Mitten, 1996).

2.6. Food value of ice cream

The food value of ice cream depends to a large extent on its composition. It is a good source of energy and nutrients. Typical ice cream contains at least 50% of its volume as air. The energy value of ice cream is mainly come from fat, sucrose and other added sugar, milk protein and lactose and it is about 200 Kcal/100 g for typical ice cream. It also contain appreciable amount of calcium and phosphorous.

Because it contains high amount of fat, ice cream is an excellent source of fat-soluble vitamins. It contain higher amount of vitamin A and fair amount of vitamin D and E. Fat insoluble vitamins, such as vitamin B1 and C are present in considerable amounts.

Ice cream is very palatable and highly digestible. It is only an ideal and notorious food for people in good health (Varman & Sutherland, 1996).

2.7. Resent Trends in ice cream

Concern about the impact of diet on health have led consumers to reduce the consumption of high calorie foods and 'light' food products have entered to the life style of most developed countries. As mentioned before ice cream is a high energetic food with high amount of fat and sugar Therefore to reduce the calorie content of ice cream reduction or removal of fat or sugar or reduction or removal of both using low calorie ingredients is needed. Because the product is characterized by unique physical properties that are influenced by above ingredients, it is difficult to produce ice cream that is exactly similar to normal ice cream, by replacing fat and sugar and it is often required to obtain consumer acceptability of the low calorie version. As the ingredient technology developed several low calorie ingredients are available to replace fat and sugar in ice cream to achieve above target up to certain extent

2.8. Ingredients for reduce calorie ice cream

2.8.1. Fat replacers

Fat replacers are ingredients used to replace fat in food systems. Basically fat replacers have been categorized as those, which include fat substitutes, fat mimetics and bulking agents (Schaefer *et.al.*, 1996).

Fat substitutes are similar to fat and can be defined as compounds that replace triglicerides in foods. Eg. Olestra®, Salatrim®. Fat mimetics are carbohydrates or proteins and are used to replace fat in foods because of their textural and organoleptic properties. Bulking agents can be used to give oily mouth feel, but in most food systems, bulking agent alone is not sufficient to replace fat (Vandana *et. al.* 1998)

2.8.1.1 Maltodextrins

The early fat replacer technology has originated with the starch hydrolysis products (Richter *et. al.* 1976). Maltodextrins are obtained by partial enzyme hydrolysis of nutritional saccharides and subsequent spray drying of the native starch. During enzyme hydrolysis, amylose and amylopectin chains are cleaved. The degree of polymerization of the maltodextrn produce is significantly associated with its functionality. However mltodextrins with low dextrose equivalent (DE) value are considered to be more suitable as fat substitutes As these are carbohydrate based ingredients provide 4kCal/g.(Inglett & Grisamore, 1991).

Number of maltodextrins have been produced commercially from corn, tapioca and potato starches.

Cornstarch maltodextrins are non-sweet saccharine polymers produced by limited hydrolysis of cornstarch and there are several products depending on the dextrose equivalent (DE) value. These products are completely soluble in hot water and forms thermoreversible gels when cooled. These gels are characterized by a bland flavour smooth mouth feel and texture, and can partially or totally replace fat in a verity of food formulations such as ice cream. E.g. Maltrin –M-40, and Maltrin-M-100 (Anon, 1991).

Potato starch maltodextrins are manufactured by enzymatic hydrolysis of potato starch. Paselli SA2 and 'C' pur 01906 are two commercial products mainly differ in terms of their DE values. The dextrose equivalent value of Paselli SA2 is 2 and C PUR 01906 is 5 (Alexander & Zabel, 1994).

It has been described that, boiling of 15% aqueous solution of C PUR 01906 produce solid gels and gel with 20% C PUR 01096 has the consistency of butter when stored at 4°C. These gels are thermoreversible and formed at room temperature and UHT conditions. The optimal hydration temperature is 85°C and at this temperature the proportionally hardest gels in comparison to the above conditions are formed. The gel consistency is not greatly affected by the addition of sucrose, sugar substitutes, modified starches and other saccharification products and the pH value of the product manufactured.

Its excellent suitability for mixing with butterfat and other vegetable oils and fats such as palm kernel fat or soy oil further expands its potential use. The caloric value of this product is 16KJ/g and the limit for use is 3.5% in ice cream and dairy sector in general. Above this limit, it impaired a taste due to the characteristics of the product (Dorp, 1994).

Tapioca maltodextrin is obtained from tapioca starch. It is prepared by heating tapioca starch in the presence of hydrochloric acid. This treatment caucus reduction in the viscosity of cooked starch dispersion, which give rise to gel formation. It is thermally reversible and has fat like properties (Vandana *et.al.*, 1998).Its instant form is marketed as N-oil II .In replacing fat in high fat foods, it provides the texture, creamy mouth feel, body and some times gel character of high fat products (Alexander & Zabel, 1998).

The replacement of milk fat with these ingredients increases coarseness and wateriness and decrease creaminess relative to full fat product The perception of chalkiness increased more with increased tapioca dextrin than with increased potato maltodextrin(Specter & Sestser, 1994).

Out of maltodextrin, milk protein concentrate, polydextrose, and lactose reduce freeze concentrated skim milk, as fat replacers, the sample containing maltodextrin had the greatest creamy flavour and the best textural characteristics and in the sensory analysis. Maltodextrin had scored as the best overall as a single fat replacer in ice cream (Roland *et. al.*, 1998).

2.8.1.2. Polydextrose

This is produced by the thermal polymerization of glucose in the presence of an acid that function as catalyst (citric acid) and sorbitol which acts in the polymerization process to help to control the upper molecular weight limit and prevent the formation of water insoluble material. It was found that when utilized by man, about 60% are execrated unchanged and the laxative threshold dosage for adults is 90g/day. It has an energy value of about 1Kcal/g (Rothwell, 1985).

Polydextrose help to provide a fat or oily mouth feel in certain fat reduced foods, but it apparently cannot function alone as a fat replacer in most systems. (Alexander &Zabel, 1994).

2.8.1.3. Cellulose based products / Microcrystalline cellulose.

Cellulose is the main constituent of the plant cell wall. This is hard to digest as the human intestine lacks the cellulose-digesting enzyme, cellulase. Microcrystalline form of cellulose is used to substitute the fat in food systems and it is produced by partial depolymerization of cellulose (Vandana *et. al.*, 1998).

The colloidal RC or CL grades of Avicel[R] are used in fat replacement systems. These grades are mixtures of microcrystalline cellulose with small amount of carboxymethylcellulose as stabilizer. When dispersed in water with shear, the colloidal particles form an insoluble network of cellulose crystals. The average size of these particles in dispersion is 0.2 microns, and they simulate the sensation of fat in an oil-in-water emulsion and hence gives the sensation of creamy mouth feel similar to product with a high fat content and contribute zero calories (Alexander & Zabel, 1994).

2.8.1.4 Pectin based products

Slendid[TM] is a proprietary form of pectin that has application in frozen desserts. When replacing fat it provides a creamy fat-like texture and mouth feel that is needed in low fat applications. Pectin is a hydrocolloid consisting mainly of the partial methyl esters of polygalactourinic acid. The acids groups are partially neutralized by ammonium, calcium, potassium and sodium ions. Pectin is obtained by aqueous extraction of appropriate plant materials such as citrus peel and apples (Vandana *et, al.*, 1998).

Slendid[TM] contribute to highest viscosity of reduce fat ice cream as a result of its hydrophobic and hydrophilic interactions. It also resulted batter foam stability due to above groups that are able to interact with the air phase and water phase respectively. Further it has found that melting resistance of the Slendid sample was similar to that of full fat product (Kailasapathy & Songvanich, 1998).

2.8.1.5 Whey protein based products

The denaturation of ultrafiltered whey proteins by controlled heat treatment gives dried whey products that marketed as Dairy Lo™ (Vandana *et. al.* 1998) and Prolo II™(R.L. Ohmes *et. al.*). They have improved functionality such as controlled degree of viscosity and improved water binding. Desirable mouth feel can obtain by using 2-5% of this in dairy products. As these are proteins based ingredients provide 4kal/g or lower than that (Vandana *et. al.*, 1998)..

Simpleese® is a multifunctional food ingredient made by heating whey protein concentrate under high shear conditions to form microparticles. The resulting dairy ingredient also can be labeled as 'whey protein concentrate' or 'milk protein' depending on local regulations (Anonymous A).

Simpleese® is a white to creamy coloured free-flowing powder that readily disperses in liquid and dry items. From the types of Simpleese® Dry 550 and Simpleese® 100 Grade A are recommended to use in ice cream.

Because the microparticles are comprised of protein, isoelectric point is in the pH 4.5-5.5 ranges. They tend to contract slightly and display lower viscosity in this range while maintaining their fat substitution properties. The large numbers of small size microparticles in Simpleese® allow scattering light. This characteristic enables Simpleese® to contribute opacity to reduce fat products such as cheese, ice cream, etc. The particle size of Simpleese® is ranging from 0.1-3.0 microns. Particles belong to this range help to perceive creamy mouth feel (Anonymous A).

When these whey-based ingredients were used to replace fat in ice cream, they increased the intensities of whey and cocked milk flavours (Ohmes *et. al.*, 1998).

2.8.2. Sweetners

2.8.2.1. Polyols

Polyols are chemically defined as saccharide derivatives in which a hydroxyl group replaces the ketone group. These are also referred to as sugar alcohol, polyalcohols or polyhydric alcohols. (Dias, 1999).

Some polyols have same energy value, as those with sucrose and some are low caloric sweeteners. This reduced caloric value results from the different metabolic pathway in the human body. These are not hydrolyzed or absorbed in the small intestine. In the large intestine, these are fermented in to biomass and short chain fatty acids. This fermentation results in an energy loss of 2 Kcal/g. As sugars usually have 4 Kcal/g, the net energy contribution is there for 50% or 2Kcal/g. (Blankers, 1995). For calculating energy value of foods, the official EU calorific value of these polyols is 2.4 Kcal/g. (Dias, 1999).

Hydrogenated glucose syrups, maltitol, sorbitol, mannitol, isomalt galactitol, lactitol and xylitol are examples for polyols. The interest shown recently in these substances has been based on their special physiochemical properties. Polyols are noncariogenic. The oral micro flora-does not ferment these, so its consumption does not lead to the formation of acids that demineralize the tooth enamel. People with diabetics tolerate polyols. Several clinical trials have shown that its consumption does not increase blood glucose or insulin level than threshold (Linden & Lorient, 1999).

Above properties of polyols allowed the use of these compounds in dietary treatments for obesity, for diabetics and cardiovascular diseases. But polyols may influence mild flatulence or laxation. The acceptable daily intake of all polyols is not specified, but generally recommended limit of consumption is 50g/day. (Dias, 1999).

2.8.2.1.1. Sorbitol

Sorbitol is an important constituent of numerous natural foods, in particular common edible fruits, The sorbitol use in the food industry is not a product of extraction and is manufactured by means of glucose hydrogenation. Commercially it is available in the form of 70% concentrated syrup or as crystals. This is noncariogenic and suitable for diabetics. In ice cream and frozen desserts the limit of use is 5%(Linden & Lorient, 1999).

2.8.2.1.2 Mannitol

Mannitol is found in abundance in plants and some fungi. It is produce from hydrolyzed sucrose or high fructose syrup derived from starch or inulin. Because of its low solubility in water it crystallizes easily and is available only in powder form. (Dias, 1999). It is metabolize in almost same way as sorbitol. Mannitol is 50% excreted in the feaces and the urine, and the rest is oxidized in the liver (Linden & Lorient, 1999).

2.8.2.1.3. Isomalt

It is also called isomaltulose, which is produced by the hydrogenation of the disaccharide sucrose (Dias, 1999). Isomalt has flavour of pure sugar, similar to that of sucrose, and does not leave any after taste. Isomalt has a synergetic action when it is combined with other polyols. So by adding 10% of these polyols, a sweetning power comparable to that of sucrose can be obtained. Similar synergic effects are obtained when isomalt are used in combination with intense sweetners such as aspartame, saccharine and acesulphame-K. Isomalt reinforces the flavouring effect in foods and does not generate any refreshing effect, unlike the other polyols (Linden & Lorient, 1999).

2.8.2.1.4. Xylitol

This is a pentiol and found very low concentrations in many fruits and plant products. The hemicelluloses is acid hydrolyzed to yield xylose which followed by hydrogenation and chromatographic separation, results xylitol.

Xylitol has the same energy value; appearance and approximately the same sweetning power as sucrose but pocesses all other characteristics of polyols. e. g. noncariogenic, suitable for diabetics. Xylitol causes gastrointestinal distress and osmatic diarrheal if consumed in large quantities. Maximum dose of 30g/day is recommended for adults taking xylitol at the first time. After the digestive system becomes adapted to xylitol 200-300g/day may be tolerated (Linden & Lorient, 1999).

2.8.2.1.5. Lactitol

Lactitol is a disaccharide sugar alcohol. It is produce by the hydrogenation of lactose and available in crystalline form, both as the monohydrate and dehydrate. (Dias, 1999).

Lactitol has a clean, sweet, sugar like taste without any aftertaste. It is very suitable and versatile bulk sweetner. The sweetness of lactitol is approximately 40% that of sugar. In most applications it can be used in conjunction with an intense sweetner like aspartame or acesulphame-K. The taste, sweetening power and profile of such sweetner combinations are very close to that of sucrose. Its mild sweet taste allows other flavours to be clearly perceived. (Blankers, 1995).

2.8.2.1.6. Maltitol

It is obtained by the hydrogenation of the disaccharide, maltose. Maltitol syrup and powdered maltitol are commercially available. (Fausto, 1999). Maltitol has a clean, pleasant, natural sweetness. Relative sweetness varies from 65-90. Due to this inherent sweetness maltitol can be used in bulk products without the addition of intense sweetness.

Excessive ingestion of maltitol may have a laxative effect. It is there for recommended to limit the consumption to 50g/day for adults and 30g/day for children between 5and6yearsofage(AnonymousC).

2.8.2.2. Intense sweetners

Intense sweetners are sweetners that are too much sweeter than sucrose. These can be carbohydrate based, protein based or synthetic or semi synthetic substances. Aspartame, acesulphame-K, cyclamate and saccharin are example for intense sweetners. These can be caloric or non caloric. Because of adding very small quantity of that is enough to meet the desired sweetness of the product, although it is caloric sweetner contribution of the energy value in the final product is negligible.

2.8.2.2.1.Saccharin

The calcium and sodium salts of saccharin are used as non-nutritive sweetners. These are approximately 300-400 times sweeter than sucrose and also has a slightly bitter, metalic after taste in aqueous solutions; however, this can be disminished by employing other sweetners; (e.g. Aspartame) This sweetner is not metabolised and thus non-caloric(Kilara, 1996).

Although all studies have shown that commercial saccharins did not have any mutagenic effect, some countries advice using this sweetner with care for children and pregnant women.

2.8.2.2.2.Cyclamate

Cyclamate are available as sodium or calcium salt of cyclamic acid. It is 30-60 times sweeter than sucrose and leaves no bitter taste under normal consumption patterns. This intense sweetner does not mask fruit flavours.Cyclamate has no caloric value but can be hydrolysed by gut microflora to cyclohexamine, a known cariogenic. (Kilara, 1996).

2.8.2.2.3. Acesulphame-K

Acesulphame is prepared using by products of acetoacetic acid. Only acesulphame-K (salt of potassium) is commercially available. This is about 200 times sweeter than sucrose and has synergetic sweetness effect with aspartame, cyclamate and saccharin. (Kilara, 1996)

2.8.2.2.4. Aspartame

Aspartame is a dipeptide sweetner. The product is available as an odourless white crystalline powder. It is 200 times sweeter than sucrose and it is influenced by pH, temperature, level of sugar been replaced and flavour in the food system. Also it is slightly soluble in water and it depends on temperature and pH. Aspartame can react with reducing sugars (E.g. Glucose) resulting in loss of sweetness (Kilara, 1996).

2.8.3. Stabilizer and emulsifier system

The proper use of stabilizer and emulsifier ingredient in reduce calorie frozen dessert is more critical than with conventional product because of higher levels of water and lower level of fat involved. Because of this large amount of water which must be controlled, it is advisable to use a given stabilizer system at a level as close to the threshold of over stabilization as feasible. That threshold is a factor that must be determined for a given composition, since it varies with water binding ability of the bulking agents and dairy ingredients used. Emulsifier ingredients function in reduce calorie frozen dessert in much as the same manner, and are generally of the same type (blends of mono-and diglycerides and polysorbates) as those in conventional frozen desserts. However there are two major areas in which they are particularly use full in reduce calorie products. First they enhanced the contribution of whatever fat present to the perceived richness of the product even in no-fat products. Also emulsifier system is important in overrun control, a characteristic which can assume increased importance in frozen desserts where a reduce calorie status relies heavily on the incorporation of high levels of overrun. As with stabilizer ingredients, it is usually advisable to use of higher levels of emulsifier in reduce calorie frozen desserts than in conventionalproducts.(Tharp,1996).

2.8.4. Flavours

Flavours are very important in reduce calorie ice cream due to absence of fat and sugar. Flavours such as cream and butter are more suitable in flavouring of such products (Kilara, 1996).

CHAPTER -3

MATERIALS AND METHODS

3.1. Materials

3.1.1. Ingredients

1. Skim milk powder (Medium Heated)
2. Whey powder
3. Pure sucrose
4. Vegetable fat- Marvo™ (Unilliever Ceylon Company, Sri Lanka)
5. Protein based fat replacer- Simpleese[R] Dry 100 -(Nutrasweet Kelo Company, San Diego, USA)
6. Carbohydrate based fat replacer- Maltrin[R]-M40 – (Grain Processing Corporation, Muscatine, USA)
7. Low calorie sweetner-Maltitol- (Cerestar *Gruppo Ferruzzi*, Europe)
8. Stabilizer/Emulsifier-Dricoid™ – (Nutrasweet Kelo Company)
9. Vanillin flavour- (Ceylon Cold Stores Ltd.)
10. Butter flavour- (Danisco Ingredients, Denmark)

3.1.2. Chemicals

1. 0.1 mol/l NaOH
2. Phenolphthalein indicator
3. 40% v/v Formaldehyde solution
4. 90% H_2SO_4
5. Amyle Alcohol (Density 0.809)
6. Rosaniline acetate
7. 95%v/v Ethyl alcohol

3.1.3. Equipments & others

1. Electrical balance (accuracy 1g)& Analytical balance (accuracy0.0001g)
2. Heavy Duty Mixing Grinder (Kenwood Chef)
3. Hand operating batch type freezer (Food Research Unit, Department of Agriculture, Gannoruwa,Peradeniya)
4. Thermometers
5. Miscellaneous items
6. Glass wares
7. Deep freezer

9. Centrifuger (11000-15000 rpm)

10. Butyrometer tubes

11. Clean Sea sand

3.2. Method

3.2.1. Product formulation

Ice cream mixes were formulated by using dry ingredients Maltrin- M 40R and SimpleeseR to replace fat. Maltitol was used as sweetner instead of sucrose. Vegetable fat and sucrose was combined in basic ice cream formulation to give 10% fat and 15% sucrose.

This ice cream was used as the control sample. Mix compositions were shown in Table 3.1. Preliminary study was conducted to determine the amount of fat replacer, stabilizer and flavourings. In the mix formulation sweetner was added to maintain the relative sweetness comparable with control.

Table 3.1. Ice Cream Mix Composition

Ingredient	Control	SimpleeseR Dry100 And Maltitol		MaltrinR-M40 and Maltitol	
		A	B	A	B
			(W/W%)		
Skim Milk Powder	9	10	10	10	10
Whey Powder	2	2	2	2	2
Vegetable Fat	10	-	-	-	-
Sucrose	15	-	-	-	-
SimpleeseR Dry100	-	4	4	-	-
MaltrinR-M40	-	-	-	7	7
Maltitol	-	16.67	16.67	16.67	16.67
Stabilizer / Emulsifier	0.3	0.4	0.4	0.4	0.4
Vanillin Flavour	0.25	0.25	0.25	0.25	0.25
Butter Flavour	-	-	0.01	-	0.01
Water	63.7	66.93	66.93	63.93	63.93

3.2.2. Preparation of mixes

Each mix was prepared in 2L volumes. After mixing all dry ingredients with water, each mix was pasteurized at 70^0C for 20 minutes. Because of unavailability of laboratory scale homogenizer, heavy-duty mixing grinder was used under maximum speed to 'homogenize' the mix. After 'homogenization', for 10 min, mixes were cooled to 4^0C using 8:1 ice: salt mixture within 30 minutes and stored at the same temperature for 24 hours for aging.

Before freezing, flavouring of the mixes was carried out as in Table 4. Two types of flavours were added to each composition. Those were 0.25% vanillin flavour alone and 0.25% vanillin flavour together with 0.1% butter flavour.

Samples were frozen using hand operating batch freezer while maintaining the temperature (-10^0C- - 11^0C) using 8:1, ice: salt mixture. Air was incorporated using a beater nearly to double the volume. The frozen ice cream (-4- -5^0C) was transferred into 80 ml and 1l cups with lids and held at –19^0C for hardening.

3.2.3. Analysis and calculation of chemical and physical properties of ice cream samples

3.2.3.1. Sampling and sample preparation

Representative samples of ice cream were taken from 1l containers of each formulation in to beakers. Three samples were taken from each formulation. Samples were melted on a water bath at a temperature not exceeding 45^0C. Then mixes were shaken and cooled to room temperature. (Specification for ice cream, SLSI)

3.2.3.2. Preparation of Phenolphthalein Indicator

1g of phenolphthalein was dissolved in 110ml of ethyl alcohol(95%v/v)and 0.1mol/l NaOH was added drop wise until gives a faint pink colouration (SLS 735:Part2:1987).

3.2.3.3. Preparation of Rosanilin acetate stock solution

0.1g of rosaniline acetate was dissolved in 50 ml of ethyl alcohol (95%v/v) containing 0.5ml of glacial acetic acid. Volume was made up to 100ml with ethyl alcohol (95%v/v) and stored in dark (SLS 735:part2:1987).

3.2.3.4. Determination of total solids

About 25g of clean sand were placed in the dish. The dish with the lid and glass rod was transferred to the oven and dried for about 2 hours. Then transferred to dessicator and cooled to room temperature and weight was obtained to the nearest 0.1mg(X g). The dish was tilled until the sand move to one side and 3g of the sample was placed in the other side of the dish. Weight was obtained to nearest 0.1g(Yg).About the 3ml of distill water was added to the test sample and mixed using the glass rod. . Then evaporated over a water bath with constant stirring for about 30 minutes . Then open dish with the lid was transferred to the oven and dried for3 hours. Then closed dish was transferred to desiccator and cooled to room temperature and weight was obtained to the nearest 0.1mg.The process of drying, cooling and weighing was repeated at 1 hour intervals until the difference in mass between two successive weighings does not exceed 0.1g (Z g).

Percentage of total solids by mass = ((Y – X) g / (Z-X) g) X 100

(SLS 735: Part5:1988)

3.2.3.5. Determination of acidity as lactic acid

10 ml of prepared sample was pipetted out in to each of two clean porcelain dishes. 1ml of rosaniline solution (1ml of rosaniline acetate stock solution was dialuted with 500ml of solution containing ethyl alcohol (95%v/v) and distilled water in equal proportion by volume) was added to one dish , stirred well and used as a colour controller. . Then 1 ml phenolphthalein indicator was added to other dish and tritrated with 0.1 mol / l NaOH until faint pink colour was matched to controller and burette reading was obtained (Y ml).

1 ml of 0.1 mol / l NaOH = 0.0090 g lactic acid

Therefore percentage of lactic acid by mass = ((Y X 0.00090) / 10) X 100

(SLS 735:Part2: 1987)

3.2.3.6.Determination of milk solids non-fat

The prepared sample was weighed about 10 g to a nearest milligram in to a clean porcelain dish, 1 ml of phenolphthalein was added and tritrated with 0.1 mol / l NaOH until a faint pink colour was appeared and burette reading was obtained.

Then 3.00 ml of 40% (V/V) formaldehyde solution was added to the neutralized ice cream and mixed with a glass rod and tritrated with the 0.1 mol/l NaOH using phenolphthalein as indicator and burette reading was obtained (Y ml).

Blank titration was carried out using 3.00 ml of 40% (v/v) formaldehyde solution with 0.1 mol/l NaOH and burette reading was obtained (Z ml).

Percentage of milk solid non fat by mass = 5.67 X (Y - Z)

(SLS 223:1989)

3.2.3.7. Determination of fat

Approximate fat percentage was determined by Gerber method (Pearson). 10 ml of 90% H_2SO_4 was transferred to butyrometer tubes and 4 g of prepared sample was transferred in to it using a pipette. Then 1ml of fat free amyl alcohol (density 0.809) was added. Tube was closed with a stopper and content was mixed thoroughly. Then immediately centrifuged at 1100 rpm for 4 minutes and reading was obtained (Y).

Approximate percentage of fat = 2.85 X Y

3.2.3.8. Determination of over run

A jar was filled with ice cream mix and weight was obtained (X g). Then same jar was filled with ice cream and weight was obtained (Y g).
Percentage of over run = ((X – Y) g / Y g) X 100

(Kilara, 1996)

3.2.3.9. Determination of melting characteristics

Melting characteristics of samples were determined at room temperature (27°C) as described by Ohmes *et. al.*. The 80 ml polystyrene cup was cut away carefully, and the samples were placed in an incubator at 27°C on top of a wire mesh over a funnel, which was supported by a ring stand. Each funnel was emptied into 80 ml polystyrene cups that had been previously weighed. The cup under each sample was replaced after every 10 minutes and the melted ice cream was weighed and weight was recorded.

3.2.3.10. Calculation of sucrose equivalent and freezing point

Sucrose equivalent and freezing point were calculated according to the method described by Arun Kilara.

Total amount of sucrose equivalent = % lactose + % sucrose equivalent

$$\text{Sucrose equivalent in 100 parts of water} = \frac{\text{\% lactose + \% sucrose equivalent} * 100}{\text{The water content of the mix}}$$

According to the result obtained for sucrose equivalent in 100 parts of water corresponding freezing point was obtained from data in appendix B.

3.2.4. Sensory evaluation

Sensory evaluation was conducted for samples after 10 days of storage (At –19 ^{0}C). Six selected staff members of the Research and Development Department of Ceylon Cold Stores who have experience in the field of sensory evaluation participated as panelists. The sensory evaluation was conducted under air conditioning and normal fluorescent lightning in the sensory evaluation booths.

Panelists evaluated all five samples during one sitting that were coded using three digit numbers. Attributes evaluated included creaminess, waterIness, gumminess, coldness, coarseness, waxiness, colour, aroma, vanillin flavour, butter flavour, aftertaste, sweetness and overall acceptability. Before evaluating the samples, brief explanation was carried out about the attributes and test. Panelists recorded their responses on 1-6 scale provided for them for each attribute with increase in intensity as value increases for each attribute (Appendix C). Hot water was provided to clean the mouth before tasting the next sample.

Results of the sensory evaluation were analyzed by the analysis of variance followed by LSD (least significance difference) techniques using SAS statistical package at 5% level (Appendix D and E).

CHAPTER-4
RESULTS AND DISCUSSION

4.1. Preliminary Study

In this study, Dricoid™ that comprises of guar gum, mono-diglycerides, xanthan gum, carageenan and polysorbate 80, was used as the stabilizer/ emulsifier system. The recommended level by manufacture in ice cream is less than 0.5%(Anonymous D). The recommended ranges by manufactures for Simpleese® is 3-5% (Anonymous A) and for Maltrin®-M40 it is 6-9% (Anonymous C) by weight.

The level of Dricoid™ used in the control was 0.3%. Therefore first samples were formulated with Simpleese® 3%, 4%, 5% and Maltrin®-M40 6%, 7%, 8%, 9% in combination with 0.3% Dricoid™ and very soft and light product was resulted due to excess over run. Then 0.4% Dricoid™ was used in product formulation and above 4% Simpleese® (5%) and 7% Maltrin®-M40 (8%, 9%) the mixes were thick and gummy product was resulted on melting.

Samples with fat and sucrose substitutes contain higher amount of water than standard product. There for it is advisable to use higher levels of stabilizer and emulsifier in reduced calorie ice cream than conventional products (Tharp, 1996). Therefore 4% Simpleese® and 7% Maltrin®-M40, with 0.4% Dricoid™ was used for further formulations.

The percentage of vanillin used in the standard product is 0.25%. Other samples were also flavoured by using 0.25% vanillin because higher than that resulted some bitterness. When butter flavour was used more than 0.01%, the butyric flavour was more pronounced.

4.2. Analytical and calculated results

Table 4.1. Chemical and Physical properties of ice cream

Property	Control	Simpleese® Dry 100 and Maltitol		Maltrin® M40 and Maltitol	
		A	B	A	B
Total Solids%	38.333	34.794	34.583	36.453	36.441
Milk solids non fat%	10.3005	17.011	17.011	11.6235	11.718
Fat%	9.975	Not Detected			
Acidity as lactic acid%	0.147	0.2085	0.207	0.15	0.1515
Sucrose equivalent %	20.984	24.845	24.845	23.049	23.049
Freezing point °C	- 1.99	- 2.33	- 2.33	- 2.15	- 2.15
Over run%	95	64	64	80	80
Energy Kcal/100g	194.000	103. 328	103.328	116. 008	116.008

Total solid %, Milk solid non fat%, Fat%, Acidity%= Mean values of three determinations. (Appendix C)

Table 4.1, contains analytical and calculated results of some selected chemical and physical properties of ice cream formulations.

The percentage of total solids was highest in control. The maximum acidity and highest milk solid non fat amount were resulted from samples formulated with Simpleese®. Simpleese® is a whey based dairy ingredient. Because of that it contains lactose and other milk solids that increased the milk solid non fat content and acidity in these samples.

Samples containing maltitol resulted a higher sucrose equivalent than the control, which contain sucrose. Maltitol is relatively less sweet than sucrose. Therefore to obtain equal relative sweetness, a higher amount of maltitol (16.67%) was added instead of 15% sucrose in the control. This resulted a higher sucrose equivalent in samples containing maltitol than control.

Samples containing Simpleese[R] resulted a higher sucrose equivalent than samples containing Maltrin[R]; although they contained same maltitol content. Simpleese[R] contains considerable amount of lactose (35.9%, Anonymous); which contribute to increase of the sucrose equivalent where as there is no contribution to sucrose equivalent from Maltrin[R] since there high molecular weight makes them relatively insoluble (Tharp, 1996).

Due to these differences in sucrose equivalent, freezing points of samples formulated with fat and sucrose substitutes were lower than the control. The lowest freezing point was resulted from the samples formulated with Simpleese[R]. The lowering of freezing point resulted rapid melting of samples formulated with fat and sucrose substitutes than the control. Samples formulated with Simpleese[R], melted faster than samples formulated with Maltrin[R]. (Fig.4.1)

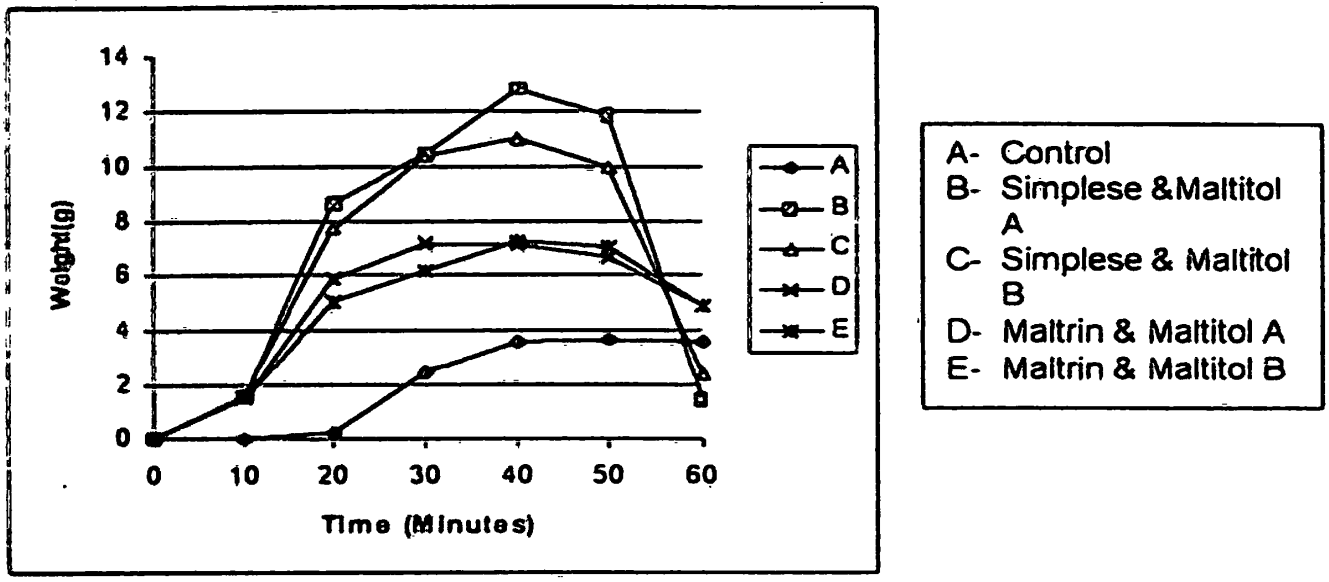
Fat replacers, Simpleese[R] and Maltrin[R] provide 3.83kCal/g and 4kCal/g respectively instead of 9kCal/g provide by fat. Maltitol provide 2.4kCal/g instead of 4kCal/g provide by sucrose. Therefore these resulted lower energy values in samples with fat and sucrose substitutes than control.

Table 4.2. Weight of melted ice cream accumulated in every 10 min for 60 min

Time (min)	Weight of ice cream accumulated (g)				
	Control	Simpleese[R] Dry100 and Maltitol		Maltrin[R] M40 and Maltitol	
	(A)	A(B)	B(C)	A(D)	B(E)
0	-	-	-	-	-
10	-	1.5665	1.6001	1.5186	1.4909
20	0.2081	8.6426	7.7421	5.8441	4.9986
30	2.4060	10.4501	10.3883	7.1441	6.1442
40	3.5480	13.7729	11.0108	7.0738	7.2447
50	3.6638	11.8908	9.8990	6.6259	7.0100
60	3.5436	1.4111	2.3567	4.8437	4.8528

Figure. 4.1 Weights of melted ice creams accumulated every 10 minutes for 60 minutes.

Weight of ice cream melted for 60 minutes



4.3 Sensory Evaluation Results.

Table 4.3. Mean Sensory Scores of Ice Cream Samples.

Sensory Attribute	Control	Simpleese^{R}Dry100 & Maltitol		Maltrin^{R}M40 & Maltitol	
		A	B	A	B
	(947)	(162)	(257)	(385)	(842)
Creaminess	4.167^{A}	2.333^{B}	2.833^{B}	2.667^{B}	3.000^{B}
Wateriness	1.833^{C}	4.000^{A}	3.167^{B}	2.833^{B}	2.667^{B}
Guminess	1.500^{B}	2.833^{A}	2.833^{A}	2.000^{AB}	2.000^{AB}
Coldness	1.667^{B}	3.500^{A}	3.333^{A}	3.000^{A}	3.000^{A}
Corseness	1.167^{D}	2.833^{C}	3.000^{BC}	3.833^{A}	3.500^{AB}
waxiness	4.000^{A}	1.833^{C}	2.833^{B}	1.833^{C}	2.833^{B}
Colour	3.333^{C}	4.833^{A}	4.167^{BA}	3.500^{BC}	3.500^{BC}
Aroma	4.167^{A}	3.000^{B}	4.167^{A}	3.000^{B}	4.000^{A}
Vanillin Flavour	4.333^{A}	2.500^{B}	2.500^{B}	3.000^{B}	3.000^{B}
Butter flavour	1.500^{B}	2.167^{B}	5.000^{A}	2.167^{B}	4.667^{A}
Sweetness	4.500^{A}	4.000^{B}	4.000^{B}	4.000^{B}	4.000^{B}
After taste	1.167^{D}	4.500^{B}	3.667^{C}	5.167^{A}	4.167^{BC}
Overall acceptability	4.667^{A}	1.833^{C}	3.000^{B}	2.333^{BC}	2.500^{BC}

^{A,B,C,D} Means followed by the same letter in the same row are not significantly different($p>0.05$).

Table 4.3 contains mean Sensory Scores from 6 panelists. According to these results there were significant differences between control and samples formulated with fat and sucrose substituted for most of the sensory attributes.

There were significant differences between control and samples formulated with fat and sucrose substitutes for creaminess. The control sample scored the highest. There were no significant differences among samples formulated with fat and sucrose substitutes for creaminess.

Carbohydrate fat replacers such as Maltrin[R] contribute to the perception of creaminess by swelling of hydrated carbohydrate molecules creating large granules (Specter & Sester, 1994). In the case of protein based fat replaces such as Simpleese[R], large number of small particles ranging from 0.1-3.0 microns gives perception of creaminess (Ohmes *et. al.*, 1998).

There was a significance difference between control and samples formulated with fat and sucrose substitutes for wateriness. The control sample scored the lowest. Among samples formulated with fat and sucrose substitutes, sample 162 was significantly different from others and it scored the highest. There was no significance difference among other samples.

There were no significance differences among control and samples formulated with Maltrin[R] for gumminess. There were significance differences among control and samples formulated with Simpleese[R], for gumminess. The control was scored the lowest and samples formulated with Simpleese[R] scored the highest. This may be due to combined stabilization effect of Simpleese[R] (Simpleese[R] Ingredient Review) and Dricoid[TM].

There was a significant difference between control and samples formulated with fat and sucrose substitutes for coldness. The most easily recognizable difference between low fat and high fat Ice Cream is the sensation of coldness, low fat Ice Cream feels colder in the mouth (Keeney, 1996). The main cooling effect of ice cream is due to the large quantity of heat required to change ice in to water, due to high latent heat of fusion, of water. High total solid content mean less water and product feel less cold (Sommer, 1956). The control scored the lowest for coldness and the highest for total solid content (Table 4.1). Although there were differences among samples formulated with fat and sucrose substitutes for total solid content, there were no significant differences among them for coldness.

There was a significant difference between control and samples formulated with fat and sucrose substitutes for coarseness. The control scored the lowest. Mean values of samples formulated with Simpleese[R] were lower than Maltrin[R] . Because samples formulated with Simpleese[R] contained higher MSNF content (Table 4.1), Protein in MSNF is able to hold water as "water of hydration" and course small ice crystals. As a result of this coarseness may scored lower for samples formulated with Simpleese[R] than samples formulated with Maltrin[R].

There was a significant difference between control and samples formulated with fat and sucrose substitutes for waxiness. The control sample scored the highest for waxiness. There were significant differences among the samples formulated with fat and sucrose substitutes for waxiness. It was higher for sample formulated with butter flavour than samples formulated with vanillin falvour. This may be due to the ability of butter flavour to provide feeling of fat up to certain extent.

There were no significant differences for colour between control and samples formulated with Maltrin[R]. There were significant differences between control and samples formulated with Simpleese[R] for colour. Control scored the lowest and samples formulated with Simpleese[R] scored the highest. This may be due to less total solid content of samples formulated with Simpleese[R].

There were no significant differences among control and samples flavoured with vanillin and butter flavours for aroma. But there were significant differences among control and samples flavoured only with vanillin flavour for aroma.

There was a significant difference between control and samples formulated with fat and sucrose substitutes for vanillin flavour. The control sample scored the highest. There was no significant difference among samples formulated with fat and sucrose substitutes for vanillin flavour. Flavours that are largely fat soluble such as vanillin, are carried by fat in to the mouth where the flavours are volatilized prior to sensory reception in the olfactory system. When there is not enough fat to carry these flavours, they are rapidly volatilized in the mouth and then quickly disappear from the perceived flavour profile. Therefore, the synergic action between the fat and flavouring is eliminated (Ohmes *et. al*., 1998).

Panelists were able to identify the samples flavoured with butter flavor and there was a significant difference between these samples with other samples.

There were significant differences between control and samples formulated with fat and sucrose substitutes for sweetness. The control scored the highest. There were no significant differences among samples formulated with fat and sucrose substitutes for sweetness. During the mix formulations, relative sweetness of samples formulated with fat and sucrose substitutes was maintained relative to control. But relative sweetness depends on temperature, acidity and the nature of other ingredients and there by change the sweetness of the final product.

There were significant differences between control and samples formulated with fat and sucrose substitutes for after taste. The control sample scored the lowest. There were significant differences between samples flavoured with both butter and vanillin flavours, and samples flavoured only with vanillin flavour. Samples formulated with Maltrin^{R} scored highest for after taste. Maltrin^{R} is a carbohydrate-based ingredient and it has its own starchy flavour. Simpleese^{R} is a protein based dairy ingredient and it has relatively less off flavours. Above reasons may have resulted the above differences in aftertaste and butter flavour was able to over come this after taste up to certain extent.

There were significant differences between control and samples formulated with fat and sucrose substitutes for overall acceptability. Control sample scored the highest. Evidently, none of the fat and sugar replacer combinations used to replace fat and sugar in this study can completely replace all attributes of fat and sugar in ice cream.

CHAPTER-5

CONCLUSIONS

1. There were significant effects on physical, chemical and sensory properties of ice cream when, fat and sucrose are substituted by fat and sucrose replacers used in this study.

2. Fat and sucrose have very pronounced effect on the complex structure of ice cream. Therefore actually all the properties are not similar to standard product when fat and sucrose, are substituted by other ingredients. Further studies are needed to improve these properties and bring them closer to standard product.

3. After taste is one of the major problem resulted from these fat replacers. It is better to use flavours that are specially developed for use in reduced calorie ice cream to over come this unacceptable after taste.

4. Rapid melting can be overcome by increasing the freezing point. One way is to achieve this is by using maltitol in combination with an intense sweetner. Because an intense sweetner is not gong to participate in freezing point depression the relative sweetness can be maintained without lowering the freezing point. Maltitol and other ingredients should be adjusted to maintain freezing point closer to standard product. Bulking agent is needed to compensate the total solid requirement that reduces due to the intense sweetner. Bulking agents with relatively high molecular weight are more suitable because they increase the total solid requirement without lowering the freezing point. The negative texture attributes such as coldness, coarseness, and wateriness may reduce when bulking agents are used to increase the total solid requirement. Bulking agents are relatively costly materials than fat replacers and there fore use of bulking agents will increase the cost of production and thereby the price of these products.

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7. APPENDIX

Appendix A: Sucrose equivalent for common sweeetners and freezing point depression caused by these sweetners.

Sweeetener	Molecular Weight	Sweetness Relative to Sucrose	Freesing Point Depression Factor
Dissaccharides			
Sucrose	342	100	1.00
Lactose	342	20	1.00
Maltose	342	30	0.98
Monosaccharides			
Glucose	180	80	1.86
Galactose	180	30	1.92
Fructose	180	170	1.92
High Fructose Corn Syrups			
42% Fructose(52% Glucose)	190	100	1.76
55% Fructose (45% Glucose)	185	120	1.78
90% Fructose (10 Glucose)	182	160	1.78
Corn Syrup Solids		5	0.21
10 DE Maltodextrin	543	20	0.64
36 DE Corn Syrup	428	30	0.80
64 DE Corn Syrup	296	60	1.15
Sugar Alcohols			
Sorbitol	182	50	1.9
Glycerol	92	80	3.7
Ethanol	46	-	7.4
Xylitol	182	100	1.9
Maltitol	344	90	0.994

Source: Arun Kilara 1996.

Appendix B: The freezing point lowering caused by various concentrations of sucrose

Parts of sucrose per 100 parts of water	Percentage of sucrose in the solution	Freezing point lowering (^{0}C)
3.59	3.47	0.21
6.58	6.41	0.40
10.84	9.78	0.65
15.83	13.67	0.95
19.80	16.53	1.23
22.58	18.42	1.37
25.64	20.41	1.68
28.51	22.19	1.77
32.22	24.37	1.99
35.14	26.00	2.15
37.86	27.46	2.33
43.72	30.42	2.71
45.60	31.33	2.82
50.02	33.35	3.13
54.74	35.37	3.47
59.46	37.29	3.81
64.55	39.23	4.22
69.74	41.09	4.60
75.91	43.15	5.07
82.35	45.16	5.65
88.67	47.00	6.11
95.94	48.97	6.74
107.70	50.65	7.38
111.30	52.67	8.06
121.00	54.75	9.02
131.60	56.82	9.93
143.10	58.86	10.90
153.80	60.60	11.69
165.60	62.35	12.72
181.70	64.49	13.80

Source: Arun Kilara, 1996

Appendix C:Analytical Results of Ice Cream Samples.

Property	Control			Simplese and Maltitol						Maltrin M 40 and Maltitol					
				A			B			A			B		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Total Solids%	38.222	37.939	38.838	34.794	34.861	34.727	34.433	34.483	34.833	36.805	36.212	36.342	36.861	36.332	36.130
Milk solids Non-Fat	10.4895	10.206	10.206	17.577	16.7365	16.7265	16.7565	17.577	16.7265	11.34	11.6235	11.907	11.907	11.6235	11.6235
Fat%	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected
Acidity	0.144	0.1485	0.1485	0.207	0.2115	0.207	0.207	.0.207	0.207	0.144	0.153	0.153	0.1485	0.153	0.153

Appendix D:Sensory Evaluation Sheet.

Name- ____________________ Date- ________________

Analyse five ice cream samples provided for each attribute mentioned below and mark at the most suitable position in 1-6 scale as you recommended. Please evaluate the samples according to the order mentioned .

Attribute	Sample number				
1. Creaminess	**947**	**162**	**385**	**257**	**842**
1 Not creamy	___	___	___	___	___
2 Very slight	___	___	___	___	___
3 Slight	___	___	___	___	___
4 Creamy	___	___	___	___	___
5 Very creamy	___	___	___	___	___
6 Extremely creamy	___	___	___	___	___
2. Wateriness	**947**	**162**	**385**	**257**	**842**
1 Not watery	___	___	___	___	___
2 Very slight	___	___	___	___	___
3 Slight	___	___	___	___	___
4 Watery	___	___	___	___	___
5 Very watery	___	___	___	___	___
6 Extremely watery	___	___	___	___	___
3. Gumminess	**947**	**162**	**385**	**257**	**842**
1 Not gummy	___	___	___	___	___
2 Very slight	___	___	___	___	___
3 Slight	___	___	___	___	___
4 Gummy	___	___	___	___	___
5 Very gummy	___	___	___	___	___
6 Extremely gummy	___	___	___	___	___
4. Coldness	**947**	**162**	**385**	**257**	**842**
1 Not cold	___	___	___	___	___
2 Very slight	___	___	___	___	___
3 Slight	___	___	___	___	___
4 Cold	___	___	___	___	___
5 Very cold	___	___	___	___	___
6 Extremely cold	___	___	___	___	___
5. Hardness	**947**	**162**	**385**	**257**	**842**
1 Very soft	___	___	___	___	___
2 Slightly soft	___	___	___	___	___
3 Soft	___	___	___	___	___
4 Slightly hard	___	___	___	___	___
5 Hard	___	___	___	___	___
6 Extremely hard	___	___	___	___	___

6. Coarseness	947	162	385	257	842
1 No	—	—	—	—	—
2 Very slight	—	—	—	—	—
3 Slight	—	—	—	—	—
4 Coarse	—	—	—	—	—
5 Very coarse	—	—	—	—	—
6 Extremely coarse	—	—	—	—	—

7. Mouth coating (Waxiness)	947	162	385	257	842
1 No	—	—	—	—	—
2 Very slight	—	—	—	—	—
3 Slight	—	—	—	—	—
4 Good	—	—	—	—	—
5 Very good	—	—	—	—	—
6 Extremely good	—	—	—	—	—

8.Colour	947	162	385	257	842
1 White	—	—	—	—	—
2 Slightly white	—	—	—	—	—
3 Slightly yelow	—	—	—	—	—
4 Yellow	—	—	—	—	—
5 Very yellow	—	—	—	—	—
6 Extremely yelow	—	—	—	—	—

9.Aroma	947	162	385	257	842
1No aroma	—	—	—	—	—
2 Very slight	—	—	—	—	—
3 Slight	—	—	—	—	—
4 Pleasant	—	—	—	—	—
5 Strong	—	—	—	—	—
6 Very strong	—	—	—	—	—

10. Vanila flavour	947	162	385	257	842
1 No	—	—	—	—	—
2 Very slight	—	—	—	—	—
3 Slight	—	—	—	—	—
4 Moderate	—	—	—	—	—
5 Strong	—	—	—	—	—
6 Very strong	—	—	—	—	—

11. Butter flavour	947	162	385	257	842
1 No	—	—	—	—	—
2 Very slight	—	—	—	—	—
3 Slight	—	—	—	—	—
4 Moderate	—	—	—	—	—
5 Strong	—	—	—	—	—
6 Very strong	—	—	—	—	—

12. Sweetness	947	162	385	257	842
1 No	___	___	___	___	___
2 Very slight	___	___	___	___	___
3 Slight	___	___	___	___	___
4 Sweet	___	___	___	___	___
5 Very sweet	___	___	___	___	___
6 Extremely sweet	___	___	___	___	___

13. After taste	947	162	385	257	842
1 No	___	___	___	___	___
2 Very slight ___	___	___	___	___	
3 Slight	___	___	___	___	___
4 Moderate	___	___	___	___	___
5 Strong	___	___	___	___	___
6 Very strong	___	___	___	___	___

14. Overall acceptability	947	162	385	257	842
1 Very unacceptable ___	___	___	___	___	
2 Unacceptable	___	___	___	___	___
3 Slightly acceptable	___	___	___	___	___
4 Acceptable	___	___	___	___	___
5 Very acceptable	___	___	___	___	___
6 Extremely acceptable	___	___	___	___	___

Comments

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Appendix D: SAS Statistical Program Used to analyse sensory evaluation results.

```
data stat;
input judges sample cream water gum
cold coarse waxi colour aroma vani but
sweet after over;
cards;
1 947 4 2 1 2 1 4 3 4 4 1 4 1 5
1 162 2 4 3 4 3 2 5 2 3 2 4 5 2
1 385 3 3 2 3 4 2 3 3 3 2 4 5 2
1 257 3 3 4 3 3 3 4 4 2 5 4 4 3
1 842 3 3 3 3 3 3 4 5 3 5 4 4 3
2 947 4 2 1 2 1 4 4 5 4 1 5 1 4
2 162 3 5 3 3 3 2 5 4 3 2 4 4 2
2 385 3 2 2 3 4 2 4 3 3 1 4 5 2
2 257 3 3 4 4 3 3 4 5 3 4 4 4 4
2 842 2 2 1 3 4 2 2 2 3 6 4 5 2
3 947 4 1 2 2 1 4 4 4 5 1 4 1 5
3 162 2 4 3 3 3 2 4 3 3 2 4 5 2
3 385 3 3 2 3 4 2 4 3 3 2 4 6 3
3 257 3 4 3 3 3 2 4 4 2 6 4 3 2
3 842 3 3 2 3 3 3 4 4 3 5 4 4 3
4 947 4 2 2 1 1 4 3 4 4 2 5 1 5
4 162 2 3 1 4 2 2 5 3 2 2 4 5 1
4 385 3 3 2 3 4 1 4 3 3 3 4 5 2
4 257 2 3 2 4 3 3 4 4 3 4 4 4 3
4 842 4 3 2 3 4 3 3 5 3 4 4 4 3
5 947 4 2 2 2 2 4 3 4 4 2 5 2 4
5 162 3 4 2 3 3 2 5 3 3 3 4 4 2
5 385 2 3 2 3 3 2 3 3 3 3 4 5 3
5 257 3 3 2 3 3 3 4 4 2 5 4 3 2
5 842 3 2 2 3 3 3 4 4 3 3 4 4 3
6 947 5 2 1 1 1 4 3 4 5 2 4 1 5
6 162 2 4 4 4 3 1 5 3 2 2 4 4 2
6 385 2 3 2 3 4 2 3 3 3 2 4 5 2
6 257 3 3 2 3 3 3 5 4 3 5 4 4 4
6 842 3 3 2 3 4 3 4 4 3 5 4 4 1
run;
proc anova;
classes judges sample;
model cream=judges sample;
means judges sample/lsd;
run;
proc anova;
classes judges sample;
model water=judges sample;
means judges sample/lsd;
run;

proc anova;
classes judges sample;
model gum=judges sample;
means judges sample/lsd;
run;

proc anova;
ssclasses judges sample;
model cold=judges sample;
means judges sample/lsd;
run;
proc anova;
classes judges sample;
model coarse=judges sample;
means judges sample/lsd;
run;
proc anova;
classes judges sample;
model waxi=judges sample;
means judges sample/lsd;
run;

proc anova;
classes judges sample;
model colour=judges sample;
means judges sample/lsd;
run;

proc anova;
classes judges sample;
model aroma=judges sample;
means judges sample/lsd;
run;

proc anova;
classes judges sample;
model vani=judges sample;
means judges sample/lsd;
run;

proc anova;
classes judges sample;
model but=judges sample;
means judges sample/lsd;
run;

proc anova;
classes judges sample;
model sweet=judges sample;
means judges sample/lsd;
run;

proc anova;
classes judges sample;
model after=judges sample;
means judges sample/lsd;
run;
proc anova;
classes judges sample;
model over=judges sample;
means judges sample/lsd;
run;
```

Appendix E: SAS statistical output of sensory evaluation Results

1. Dependent Variable: CREAM (CREAMINESS)

Source	DF	Anova SS	Mean Square	F Value	Pr > F
JUDGES	5	0.00000000	0.00000000	0.00	1.0000
SAMPLE	4	11.66666667	2.91666667	9.21	0.000

T Grouping	Mean	N	JUDGES
A	3.000	5	1
A			
A	3.000	5	2
A			
A	3.000	5	3
A			
A	3.000	5	4
A			
A	3.000	5	5
A			
A	3.000	5	6

T Grouping	Mean	N	SAMPLE
A	4.167	6	947
B	3.000	6	842
B			
B	2.833	6	257
B			
B	2.667	6	385
B			
B	2.333	6	162

2. Dependent Variable: WATER (WATERINESS)

Source	DF	Anova SS	Mean Square	F Value	Pr > F
JUDGES	5	0.30000000	0.06000000	0.22	0.9512
SAMPLE	4	14.86666667	3.71666667	13.43	0.0001

T Grouping	Mean	N	JUDGES
A	3.000	5	1
A			
A	3.000	5	6
A			
A	3.000	5	3
A			
A	2.800	5	4
A			
A	2.800	5	5
A			
A	2.800	5	2

T Grouping	Mean	N	SAMPLE
A	4.000	6	162
B	3.167	6	257
B			
B	2.833	6	385
B			
B	2.667	6	842
C	1.833	6	947

3. Dependent Variable: GUM (GUMMINESS)

Source	DF	Anova SS	Mean Square	F Value	Pr > F
JUDGES	5	1.36666667	0.27333333	0.56	0.7309
SAMPLE	4	8.20000000	2.05000000	4.18	0.0127

T Grouping	Mean	N	JUDGES
A	2.600	5	1
A			
A	2.400	5	3
A			
A	2.200	5	2
A			
A	2.200	5	6
A			
A	2.000	5	5
A			
A	2.000	5	4

Grouping	Mean	N	SAMPLE
A	2.833	6	162
A			
A	2.833	6	257
A			
B A	2.000	6	842
B A			
B A	2.000	6	385
B			
B	1.500	6	947

4. Dependent Variable: COLD (COLDNESS)

Source	DF	Anova SS	Mean Square	F Value	Pr > F
JUDGES	5	0.30000000	0.06000000	0.31	0.9009
SAMPLE	4	12.53333333	3.13333333	16.21	0.0001

T Grouping	Mean	N	JUDGES
A	3.000	5	1
A			
A	3.000	5	2
A			
A	3.000	5	4
A			
A	2.800	5	3
A			
A	2.800	5	5
A			
A	2.800	5	6

T Grouping	Mean	N	SAMPLE
A	3.500	6	162
A			
A	3.333	6	257
A			
A	3.000	6	842
A			
A	3.000	6	385
B	1.667	6	947

5. Dependent Variable:COARSE (COARSENESS).

Source	DF	Anova SS	Mean Square	F Value	Pr > F
JUDGES	5	0.26666667	0.05333333	0.29	0.9154
SAMPLE	4	25.46666667	6.36666667	34.11	0.0001

T Grouping	Mean	N	JUDGES
A	3.000	5	2
A			
A	3.000	5	6
A			
A	2.800	5	1
A			
A	2.800	5	3
A			
A	2.800	5	5
A			
A	2.800	5	4

T Grouping		Mean	N	SAMPLE
	A	3.833	6	385
	A			
B	A	3.500	6	842
B				
B	C	3.000	6	257
	C			
	C	2.833	6	162
D		1.167	6	947

6. Dependent Variable: WAXI (WAXINESS)

Source	DF	Anova SS	Mean Square	F Value	Pr > F
JUDGES	5	0.26666667	0.05333333	0.35	0.8776
SAMPLE	4	19.33333333	4.83333333	31.52	0.0001

T Grouping	Mean	N	JUDGES
A	2.800	5	1
A			
A	2.800	5	5
A			
A	2.600	5	2
A			
A	2.600	5	4
A			
A	2.600	5	3
A			
A	2.600	5	6

T Grouping	Mean	N	SAMPLE
A	4.000	6	947
B	2.833	6	257
B			
B	2.833	6	842
C	1.833	6	162
C			
C	1.833	6	385

7. Dependent Variable: COLOUR

Source	DF	Anova SS	Mean Square	F Value	Pr > F
JUDGES	5	0.26666667	0.05333333	0.14	0.9814
SAMPLE	4	9.46666667	2.36666667	6.12	0.0022

T Grouping	Mean	N	JUDGES
A	4.000	5	3
A			
A	4.000	5	6
A			
A	3.800	5	1
A			
A	3.800	5	4
A			
A	3.800	5	5
A			
A	3.800	5	2

T Grouping		Mean	N	SAMPLE
	A	4.833	6	162
	A			
B	A	4.167	6	257
B				
B	C	3.500	6	842
B	C			
B	C	3.500	6	385
	C			
	C	3.333	6	947

8. Dependent Variable: AROMA

Source	DF	Anova SS	Mean Square	F Value	Pr > F
JUDGES	5	0.26666667	0.05333333	0.11	0.9880
SAMPLE	4	9.00000000	2.25000000	4.79	0.0071

T Grouping	Mean	N	JUDGES
A	3.800	5	2
A			
A	3.800	5	4
A			
A	3.600	5	1
A			
A	3.600	5	3
A			
A	3.600	5	5
A			
A	3.600	5	6

T Grouping	Mean	N	SAMPLE
A	4.167	6	947
A			
A	4.167	6	257
A			
A	4.000	6	842
B	3.000	6	162
B			
B	3.000	6	385

9. Dependent Variable: VANI (VANILLA FLAVOUR)

Source	DF	Anova SS	Mean Square	F Value	Pr > F
JUDGES	5	0.66666667	0.13333333	0.73	0.6111
SAMPLE	4	13.53333333	3.38333333	18.45	0.0001

T Grouping	Mean	N	JUDGES
A	3.200	5	3
A			
A	3.200	5	2
A			
A	3.000	5	6
A			
A	3.000	5	5
A			
A	3.000	5	4
A			
A	2.800	5	1

T Grouping	Mean	N	SAMPLE
A	4.333	6	947
B	3.000	6	385
B			
B	3.000	6	842
B			
B	2.500	6	162
B			
B	2.500	6	257

10. Dependent Variable: BUT (BUTTER FLAVOUR)

Source	DF	Anova SS	Mean Square	F Value	Pr > F
JUDGES	5	0.30000000	0.06000000	0.10	0.9913
SAMPLE	4	62.20000000	15.55000000	25.49	0.0001

T Grouping	Mean	N	JUDGES
A	3.200	5	5
A			
A	3.200	5	6
A			
A	3.200	5	3
A			
A	3.000	5	4
A			
A	3.000	5	1
A			
A	3.000	5	2

T Grouping	Mean	N	SAMPLE
A	5.000	6	257
A			
A	4.667	6	842
B	2.167	6	385
B			
B	2.167	6	162
B			
B	1.500	6	947

11. Dependent Variable: SWEET (SWEETNESS)

Source	DF	Anova SS	Mean Square	F Value	Pr > F
JUDGES	5	0.30000000	0.06000000	1.00	0.4430
SAMPLE	4	1.20000000	0.30000000	5.00	0.0059

T Grouping	Mean	N	JUDGES
A	4.200	5	5
A			
A	4.200	5	2
A			
A	4.200	5	4
A			
A	4.000	5	3
A			
A	4.000	5	1
A	4.000	5	6

T Grouping	Mean	N	SAMPLE
A	4.500	6	947
B	4.000	6	162
B			
B	4.000	6	385
B			
B	4.000	6	257
B			
B	4.000	6	842

12. Dependent Variable: AFTER (AFTER TASTE)

Source	DF	Anova SS	Mean Square	F Value	Pr > F
JUDGES	5	0.26666667	0.05333333	0.21	0.9541
SAMPLE	4	56.53333333	14.13333333	55.79	0.0001

T Grouping	Mean	N	JUDGES
A	3.800	5	1
A			
A	3.800	5	2
A			
A	3.800	5	3
A			
A	3.800	5	4
A			
A	3.600	5	5
A			
A	3.600	5	6

T Grouping		Mean	N	SAMPLE
	A	5.167	6	385
	B	4.500	6	162
	B			
C	B	4.167	6	842
C				
C		3.667	6	257
	D	1.167	6	947

13. Dependent Variable: OVER (OVERALL ACCEPTABILITY)

Source	DF	Anova SS	Mean Square	F Value	Pr > F
JUDGES	5	0.26666667	0.05333333	0.10	0.9911
SAMPLE	4	28.46666667	7.11666667	13.26	0.0001

T Grouping	Mean	N	JUDGES
A	3.000	5	1
A			
A	3.000	5	3
A			
A	2.800	5	2
A			
A	2.800	5	4
A			
A	2.800	5	5
A			
A	2.800	5	6

T Grouping		Mean	N	SAMPLE
	A	4.667	6	947
	B	3.000	6	257
	B			
C	B	2.500	6	842
C	B			
C	B	2.333	6	385
C				
C		1.833	6	162

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