IMPROVING MELTING RESISTANCE OF ICE CREAM

BY

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DECLARATION

The work is described in this thesis was carried out by me at the Laboratory of Research and Development Department of Ceylon Cold Stores, Ltd., Ranala. A report on this has not been submitted to any other university for another degree.

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DEDICATED TO MY BELOVED AMMA, THATHTHA, LASITHA AND TEACHERS

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ABSTRACT

Poor melt resistance when exposed to ambient temperature is the major shortcoming in the ice cream industry. Consumers receive the ice cream product at the end of a long distribution chain and face the problem due to poor melt resistance.

The effect of stabiliser emulsifier system and melting point of fat and sensory quality of ice cream was investigated. Twelve samples were prepared changing stabiliser, emulsifier system and different melting point contained fats.

Eleven samples were achieved the company standards and hence used for melting resistance evaluation. Melt resistance was determined as time taken to melt down the 80 ml of ice cream in minutes at 26^{0}C. Melting time between the samples was significantly different at the 5 % level ($P <= 0.05$). After 7, 14 and 21 days of the storage, the sample S_{11} with the stabiliser emulsifier system that comprises of guar gum, sodium aliginate, carboxymethyl cellulose, carrageenan and monoglycerides obtained the highest melting resistance. There was no significance difference for melting time during the storage period in sample eleven. The results showed that the melt resistance of ice cream was increased with subsequent increasing in melting point of the vegetable fat, but application of vegetable fat with high melting point was restricted with the development of off taste. Sensory evaluation of the product revealed that the hand made improved sample was superior to the hand made company standard sample intense of overall acceptability.

Therefore it can be concluded that the stabiliser emulsifier system that comprises of guar gum, sodium aliginate, carboxymethyl cellulose, carrageenan and monoglycerides was the best formulation to improve melting point of the ice cream.

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CHAPTER-1
INTRODUCTION

Ice cream refers to as a frozen dessert and a highly palatable and interesting food for people of every age. It is a frozen mixture of a combination of components of milk, sweeteners, stabilisers, emulsifiers and flavourings. Other ingredients such as egg products; colourings and starch hydrolysates may be added also. Before freezing this mixture is homogenised and pasteurised (Marshall and Arbuckle, 1996).

It is necessary to melt ice cream evenly to the consistence of heavy cream at room temperature. Curdly melt, does not melt, flaky, foamy, wheying off and low viscosity are the major defects of texture, which may lead to poor melting quality of the product. Wheying off, seepage or drainage of liquid from the ice cream may occur during melting of ice cream. Reacting stabiliser with milk protein causes the defect. According to Lampert (1970) presence of curdy particles in the melting ice cream is due to the use of unsuitable stabiliser or improper homogenisation.

The major drawback in most ice cream factories is rapid meltdown of ice cream when exposed to ambient. Melting rate has the greatest significance for the consumers, when it eats from a cone or stick. If it melts too fast, a messy situation occurred. A rapid melting product is undesirable, because it tends to become heat shock readily. During heat shock, ice cream is first exposed to an ambient temperature, which is higher than product temperature. This causes some of the product's ice crystals to melt and the ice cream will contain more free water even if apparently still frozen. After that, the partially thawed product is exposed to the reverse condition. There is an important difference in the way the water in an ice cream mix was originally frozen, and the refreezing of thawed ice crystals that occur during heat shock.

Heat shock also reduces the homogeneity of ice cream. As ice crystal growth progress during several cycles of heat shock, the milk proteins and other solids in the mix may be irreversibly altered and loses some of their former water binding capacity. When this occurs, the free water produced cannot be totally reabsorbed and remains available for ice crystal growth (Keeny, 1996).

If ice cream were consumed shortly after manufacture, there would be no texture problems, because of rapid melting of ice cream. However, the consumers receive the product at the end of a long distribution chain and face the problem due to low melt resistance of ice cream. Therefore to overcome these problems, it is necessary to improve melt resistance of ice cream mix. However, too much slow rate of melting can also be indicative of defective ice cream. Hence it is necessary to improve melt resistance of ice cream without affecting its physical, chemical and textural properties.

Lampert (1970) revealed that too much of melting is due to the use of excessive amounts of stabiliser or emulsifier, low temperature or high-pressure homogenisation treatment of ice cream mix or the use of high fat content. According to Bhandari and Balachandran (1984), research studies on improving melting resistance of ice cream is mainly based on pasteurisation treatments, application of kinds of stabilisers and emulsifiers. Studies of Kilara (1996) described the effects of corn syrup, combination of corn syrup and sucrose and fat replaces on melting properties of ice cream. These findings reveal that the emphasis has been given to increase the melting resistance of ice cream. Problem is still occurred at the local ice cream industries creating inconveniences for both manufacture and consumer. If melting resistance of ice cream would increase without remarkable textural defects, ice cream manufacturers and consumers will benefit at the market.

The main objective of this research was to improve melting properties of ice cream without changing its texture. To achieve this study was carried out with following specific objectives:

i. Determination of effect of melting point of vegetable fat on melting resistance.

ii. Determination of effect of blend of stabilisers and emulsifiers on melting resistance of ice cream.

iii. Determination of effect of blend of stabilisers and emulsifiers on physiochemical and sensory qualities of ice cream

CHAPTER-2

LITERITURE REVIEW

2.1 History of Ice Cream

The creation of iced desserts, by mixing snow with fruit and fruit juices that probably originated in China. It appears to have been introduced to Europe in the late 13th century (Varnam and Sutherland, 1994). In the 13th century Marco Polo returned to Italy from his famous journey to the Orient and brought recipes for water ices and has been used in Asia for thousands of years (Marshall and Arbuckle, 1996).

In the 18th century, Ice cream industry was largely developed in the United States. It was introduced to the United States from Europe. Ice cream probably evolved from the iced beverages and water ices that were popular in Europe during medieval times. Ice cream probably comes to the United States with the early English colonists.

In 1846 Nancy Johnston invented the hand cranked ice cream freezer. Jacob Fussell established the first wholesale ice cream industry in the United States in Baltimore, Mayland in 1851 (Marshall and Arbuckle, 1996).

In 1855 first commercial ice making machine was invented in Australia. Thomas Wall starts Wall's soon to become the largest ice cream Company in the world in 1922. Surveys indicate that ice cream is the favourite American dessert. In 1968, the consumption in the United States of frozen desserts was 23.78 quarts per person, of which 15.5 quarts was ice cream (Lampert, 1970). Ceylon Ice Company (later Ceylon Cold Stores) was started the first commercial ice plant in Sri Lanka, in 1925.

2.2 Varieties of Ice Cream

Classifications of ice cream and related products have been done in many different ways. Within the product ice cream, there are numerous variations of formula, dairy ingredients, sweeteners, stabilisers, and emulsifiers, flavours, fruits, nuts, colours, method of freezing, sizes, shapes, techniques for dispensing into packages, and other variables. These variations create wide variety of products (Marshall and Arbuckle, 1996).

Plain ice cream: Ice cream in which the total amount of colours and flavouring ingredients is less than 5 % of the volume of the unfrozen ice cream. Usually the term refers to vanilla ice cream (Marshall and Arbuckle, 1996).

Fruit: Ice cream made with the addition of fruit or fruit juice.
Nut: Ice cream made with the addition of nutmeats, such as walnuts, almonds, and pecans.

French: This is an ice cream of high fat content with the addition of 1.5 to 3 % of egg yolk solids. Custard: Ice cream is usually the same as ice cream pudding. It is a cooked mixture of milk and egg, which is added to the ice cream mix and then frozen. It usually contains more than 10% of fat and not less than 1.4% of egg yolk solids by weight (Lampert, 1970). Puddings: High fat ice cream contains mixed fruits, nutmeats, spices, etc. Soft serve: Ice cream and related products sold as drawn from the freezer without hardening.

Fruit sherbet: A product made of fruit juices, sugar, stabiliser, and small amounts of milk fat and non-fat milk solids. It contains at least 0.35% acidity. A mixture of 4 parts water ice mix with 1 part ice cream mix can constitute a sherbet mix (Marshall and Arbuckle, 1996).

2.3 Compositions and Structure of Ice Cream

2.3.1 Composition of Ice Cream

Ice cream is composed of a mixture of milk products, sweetening materials, stabilisers, flavours, or egg products, which are referred to as ingredients. Combining the ingredients in different proportions may make any one kind of ice cream. The composition of ice cream is usually expressed as a percentage of its constituents. The composition of ice cream may vary considerably, especially in its content of fat and milk solid not fat (MSNF) (Marshall and Arbuckle, 1996). The typical ingredients of normal ice cream are shown in the Table 2.1.

Table 2.1 Typical ingredients of a simple ice cream mix
(Quantities are averages and are expressed in g per 100g)

Ingredient	Quantity
Water	63
Sugar	15
Non-fat milk solid	11.5
Fat	10
Emulsifier-Stabiliser system	0.5

Source: Rajah, 2002

The quantity of an ice cream depends largely upon its total solids and fat content. Cost is controlled by the fat content. The composition of ice cream varies in different localities and in different market (Lampert, 1970). Table 2.2 given the Sri Lankan standards for ice cream.

Table 2.2 Composition of ice cream according to Sri Lankan Standard (S.L.S.)

Characteristics	Requirement
Total Solids, % by mass	32
Fat, %by mass	8
Lactic acid, % by mass, max.	0.25
Sugar, % by mass, min	10
Milk Solids not fat, % by mass, min	8
Emulsifiers and Stabilisers, % by mass, max.	1
Total colony count, per g. max.	50,000
Ecoli Type 1	Absent

Source: S.L.S. 223:1973

2.3.2 Structure of Ice Cream

(a) Ice crystals- average size, 45 to 55 microns. (b) Air cells- average size, 110-185 microns. (c) Unfrozen material- average distance between ice crystals or ice crystals and air cells, 6 to 8 microns. Average distance between air cells-100 to 150 microns.

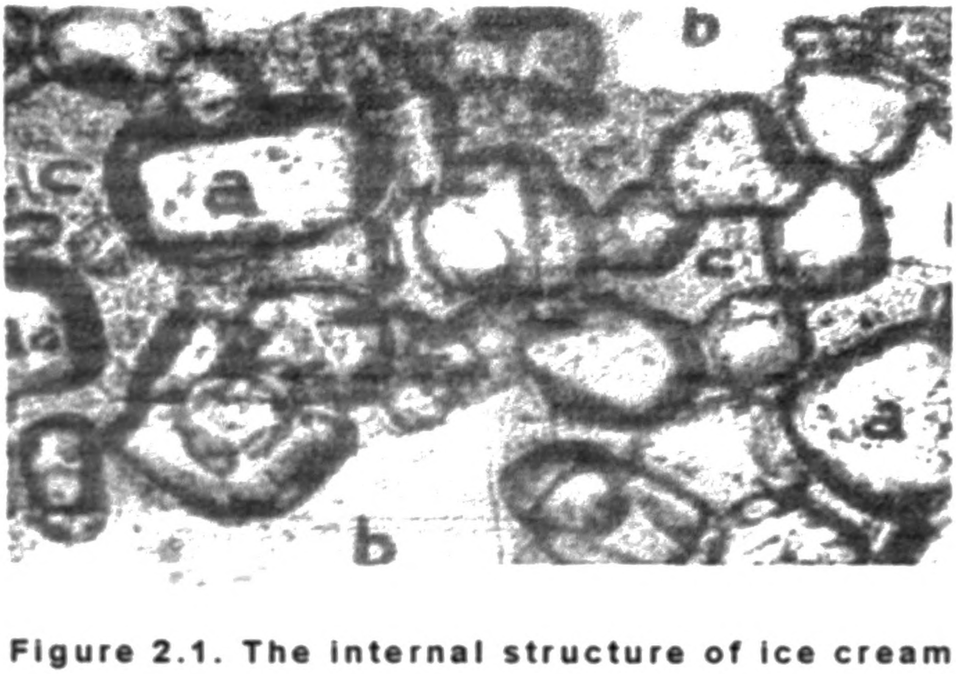


Figure 2.1. The internal structure of ice cream

Source: Frandsen *et al.*, 1961

The physical structure of ice cream represents a complicated physicochemical system. Air cells are dispersed in a continuous liquid phase with embedded ice crystals. The liquid phase also contains solidified fat particles, milk proteins, insoluble salts, and lactose crystals in some cases, stabilisers of colloidal dimension and sucrose, lactose, other sugars and soluble salts in true solution. Such a material consisting of liquid, air and solid is a three-phase system (Marshall and Arbuckle, 1996). The internal structure of ice cream is shown in the figure 2.1.

2.4 Sources and Functions of Ice Cream Ingredients

A wide range of ingredients for ice cream is now available from numerous sources. These can group as dairy and non-dairy products. Dairy products furnish the basic ingredients of milk fat and (Milk Solid Non Fat) MSNF. Some dairy products provide fat, some provide MSNF, others supply both fat and MSNF, and others such as whey solids, supply bulk to the mix. Non-dairy products include sweeteners, stabilisers and emulsifiers, egg products, fruits, nuts, flavours, special products and water. The basic ingredients in ice cream are milk fat, MSNF, sweeteners, stabilisers and emulsifiers, flavourings, and water (Marshall and Arbuckle, 1996).

2.4.1 Milk Fat

Milk fat is an ingredient of major importance in ice cream. The uses of the correct percentages are essential to balance the mix properly and to satisfy legal standards. High fat content may limit consumption because of high caloric value. Also it may increase the cost. The more fat present will smoother the ice cream, too much will reduce its palatability (Hamilton, 1990).

Ice cream exists in oil in water emulsion form. Fat present in ice cream product may be derived from animal or vegetable sources. Common sources of fat are whole milk, fresh cream, butter, butter oil, sweetened condensed milk, concentrated milk blends, and anhydrous milk fat (Rajah, 2002). The fat must be free from off flavours and undesirable taste characteristics. Otherwise these will carry to the finished products.

Fresh cream is the most suitable of concentrated fat sources and imparts a rich character to the end product. However, it is highly perishable and expensive. It contains 35 percentage of milk fat. Phospholipids in the fat globule membrane help to aid whipping (Varnam and Sutherland, 1994). Fresh cream gives structure and smooth mouth feel. It is susceptible to off flavours caused by high temperature excessive shear enzyme (lipase) oxidation, tainting from strong odours. It also available as frozen cream and contains 44-69 percentage of fat content (Ford, 1996). It has 12 months of shelf life, if stored at (_10)°C or less.

Butter is churned cream with buttermilk removed and it contains 82 percent fat. Unsalted butter is generally used. During churning membrane of fat globule is broken down. It can store 6 months properly under cool conditions.

A good quality ice cream can be made from anhydrous milk fat. It is moisture removed pure milk fat and contains 99.9 percent fat. It has clean buttery flavour and standard milk fat source for recombine. It can store 12 months at ambient temperature (Varnam and Sutherland, 1994).

Butter oil is 99.95 percent fat contained and moisture removed pure milk fat source. It is available as different melting point fractions from 21(liquid) to 42°C (hard). If the melting point of fat is lower has strong buttery flavour. It should be stored under cool conditions without exposing to sunlight.

Vegetable fats are permitted to use in some countries in the manufacturing of ice cream. It can use either as the sole fat source or together with milk fat. Most common types of vegetable fat are coconut oil, palm oil and palm kernel oil (Varnam and Sutherland, 1994). Vegetable oil has a neutral taste. Best melting point range is 28 to 32°C. If the melting point is above 37°C, it will remain in a solid state in the mouth. Although it lacks the creamy flavour cost is lower than milk fat. It imparts better melt down characteristics and better shape retention. It can store 12 months at ambient temperature properly.

Primary function of milk fat in ice cream mix is to provide lubrication and warmth to the product. Milk fat imparts richness body or substance and helps to ensure a smooth textured ice cream. It contributes to a subtle flavour quality. Because it is a good carrier and synergist for added flavour compounds and it promotes the desirable tactile qualities (Kilara, 1996). Milk fat contributes to the amount of solids in the ice cream mix (Keeney, 1996). The melting characteristics of fats are important to achieve stability during storage.

2.4.2 Milk Solids Non Fat (MSNF)

MSNF are the solids of skim milk. They consist of protein (37 %), milk sugar (lactose: 55 %), and minerals (8 %). These solids are high in food value and inexpensive (Marshall and Arbuckle, 1996). Amount of MSNF used in ice cream varied inversely with fat content in order to maintain the proper mix balance and to ensure good body, texture and storage properties. Higher fat content will lower the serum solids. However, a high concentration of lactose may crystallise under certain conditions. It causes to sandiness, or affects taste by imparting "saltiness". Therefore amount of MSNF used, which affects to the final eating quality of ice cream (Kilara, 1996).

MSNF increases the viscosity and melting resistance of ice cream. Higher MSNF content give a smoother texture. Because the proteins present in ice cream absorb free moisture and holding it as water of hydration. Also this prevents the growth of large ice crystals, which cause to give a coarse texture. The milk proteins help to emulsify the fat in the product (Hamilton, 1990).

MSNF play an important role in the final eating quality of ice cream. Therefore they must not be used as filler. At the optimum level of addition they give body as well as enhance the certain properties (Rajah, 2002).

The proteins in MSNF help to make the ice cream more compact and smooth. They tend to prevent a week body and coarse texture. MSNF increases viscosity and resistance to melting, but also lower freezing point. Lactose adds slightly sweet taste to the final product (Marshall and Arbuckle, 1996). Protein is essential to the emulsification of both air and fat, and together with the calcium in skim milk solids imparts nutritional value to the finished product (Tharp, 1996). MSNF can be obtained from a number of sources such as skim milk concentrate, skim milk powder, buttermilk powder, and whey powder and whey protein concentrate.

Spray dried skim milk powder is used widely because it has the advantage of a relatively long storage life under good conditions. Medium heat powder is most suitable with respect to emulsification, foaming and water absorption. Skim milk powder (SMP) contains fat (0.8 %), protein (39 %t), lactose +

minerals (57 %) and water (3 %). Low heat spray dried powder has better solubility and less denatured whey protein.

Ice cream may be produced with butter milk powder, which gives rich clean flavour and enhance the whipping qualities (Varnam and Sutherland, 1994). The increasing costs of conventional sources of MSNF have stimulated interest in alternatives. Ultra filtration retentates which used at 25 percent, produce and ice cream of better body, flavour and texture than whey protein concentrate and which has very good storage quality and heat shock stability (Lee and White, 1991).

Whey protein products are of increasing interest as sources of MSNF. It is a by-product of cheese manufacture. It contains fat (1 percent), protein (14.5 percent), and lactose + minerals 81 percent. It is the cheapest source of MSNF. But usage in ice cream restricted because of excessive saltiness and high lactose content that tends to lactose crystallisation. However, demineralised, delactosed whey proteins can be used at high level and can overcome these problems (Varnam and Sutherland, 1994). It can be properly stored 6 months at ambient temperature.

2.4.3 Sugars and Sweeteners

Although dairy SNF contributes to sweetness of ice cream, it is not sufficient and therefore additional sweetener is required. The quantity added largely depends on the market preferences. Sucrose is the still most widely used sweetener. It may be used alone or in combination and it is manufactured from cane sugar or sugar beet. It provides body or mouth feel to the ice cream and main contributor to softness (Varnam and Sutherland, 1994).

The perçentage of the sweetening agent that can obtained from other sources is influenced mainly by

- The desired concentration of sugar in the mix
- The total solid content of the mix
- The effect on the properties of the mix, such as freezing point, viscosity, and whipping quality
- The concentration in the sweetener of substances other than sugar
- The relative inherent sweetening power of the sweeteners other than sucrose (Marshall and Arbuckle, 1996).

The sweetness of ice cream is contributed by sucrose, corn sweetness and to a slight degree by lactose (Kilara, 1996). However it is commonly agreed that the best ice cream is made from sucrose, but corn sweeteners can replace approximately 45% of the sucrose.

Corn syrups have a clean sweet taste. Increased Dextrose Equivalent (DE) produces sweetness than sucrose, but combinations of corn syrups and sucrose have greater sweetness than expected. The moisture absorption or resistance to changes in moisture content is dependent, on DE and RH. Freezing point depression of corn syrup is depended on the average molecular weight of the sugars (Kilara, 1996). Ice cream contains corn syrups from the sweetest to the very low (20DE).

The syrups: Provide better melt down characteristics; inhibit crystallisation of sucrose, lactose, and other sugars; provide freezing point control; contributes to the body, mouth feel and chewiness of the products; provide a balanced sweetness; and provide heat shock protection. Corn syrups are also important in low fat mixes, and in cost reduction (Kilara, 1996).

Artificial sweeteners have no beneficial effect on body and texture. High maltose dextrose syrup is used as a sweetener and provides good body without excess sweetness provides stability against crystallisation and maintains the high melting point required in hand held ice cream (Jackson, 1991). Although lactose has low sweetness level it contributes bulk to the formulation. If high levels of lactose are present crystallisation may occur and causing a sandy or gritty texture.

The main function of added sugar in ice cream is to provide sweetness and increasing the palatability. Also it increases the food value of the product (Rajah, 2002). Sugar enhances the flavour of the fat and true fruit flavours. It increases the viscosity and the total solids content and imparts the body and texture of ice cream (Hamilton, 1990). Sugars are primarily responsible for freezing and thawing characteristics of frozen desserts (Keeney, 1996).

Total amount of sucrose may vary from 12-20 percent, while 14-16 percent is usually most desirable. Sweeteners present in the solution depress the freezing point and result lower freezing and lower temperatures needed for proper hardening (Marshall and Arbuckle, 1996).

2.4.4 Stabilisers

The word stabiliser is known as holders, colloids, binders and fillers (Frandsen and Markham, 1915). The primary function of stabilisers in ice cream is their ability to influence the rheological condition of the water phase.

The water content of ice cream is never completely frozen. Therefore when temperatures of ice cream rise and fall, ice crystals melt and then refreeze. Stabilisers bind some of the water; thereby reduce the amount of water available to participate in the phase changes from ice to water and water to ice (Marshall and Arbuckle,. 1996).

Stabilisers or hydrocolloids are polymer substances and when dispersed in water large numbers of water molecules are bound primarily by hydrogen bonds. Because of intra and inter molecular links between single stabiliser molecule and or between several stabiliser molecules in combination with protein a three dimensional network is formed. Thereby the mobility of residual aqueous phase is limited (Nielson, 1976).

Some of the milk constituents used in ice cream have stabilising properties, however that is not sufficient for ice crystal stability. Therefore addition of stabilisers to the ice cream mix is needed (Ramzan, 1972).

Stabilisers use either alone or in an appropriate combination. They maintain the texture of the ice cream up to the time it reaches consumer. A good stabiliser is odourless, tasteless and readily dispersible in the ice cream mix (Ramzan, 1972).The role of stabiliser in ice cream depends mainly on their water binding effect. Other important properties of a good stabiliser are shown in the following Figure 2.2.

- Improve mix viscosity
- Improve air incorporation
- Improve body and texture
- Retard ice crystal formation and growth (interact with protein)
- Improve melting properties
- Inhibit syneresis

Figure 2.2 Role of stabilisers in ice cream
Source: Nielsen, 1976

Various types of stabilisers used in ice cream manufacture are (frequently used ones in bold type):

Proteins: gelatine, milk protein (casein, casenate)

Plant exudates: Arabic, ghatti, karaya and tragacanth gums

Seed gums: **Locust bean, guar**, psyllium

Microbial gum: Xanthum

Seaweed extracts: agar, **aliginates, carrageenan**

Pectins: low and high methoxyl

Cellulosic: Sodium carboxymethyl cellulose, microcrystalline cellulose

Gelatine: It improves the body and texture of ice cream, produces good viscosity and increases the food value. High temperature, which is required to dissolve gelatine in water, reduces its strength. It increases the cost of ice cream as compared to the cost of gums. But it does not impart good melting characteristics when compared with the sodium aliginate. Excess use of gelatine causes, a thick and sticky body in the ice cream, may produce a slightly stale flavour, greatly increased viscosity, lower the whipping quality of the mix and increases the cost (Ramzan, 1972).

Sodium aliginate: It is sold under the trade name of Dariloid. It dissolves in cold water. Aliginate has excellent whipping property. It requires no aging, produces a very good texture and melts down properties in ice cream. The chief advantage of using sodium aliginate is that the mix has its final viscosity at the time it leaves the surface cooler. Also it is ready to freeze without the customary aging period. However, to obtain satisfactory solution, the mix temperature must be up to 160°F before adding Sodium aliginate (Ramzan, 1972).

Carboxymethyl cellulose (CMC): It is prepared from cellulose and easily dissolved in the mix. It has a high water binding capacity. CMC has good viscosity characteristics, but is relatively poor in producing stabilising properties in the finished ice cream. It produces a clean body as well as good texture needed for a good ice cream. Also it enhances the whipping properties of ice cream mix (Marshall and Arbuckle, 1996).

Locust bean: Also known as carob bean gum. It needs high temperature to dissolve and is not influenced by pH. When used alone it coarse the development of curdy appearance in the melted ices cream. This difficulty can be eliminated by the addition of carrageenan (Ramzan, 1972). Locust bean gum can be used in blend with many other hydrocolloids in order to modify the texture of a particular application. It is a highly functional stabiliser and thickener, imparts uniquely creamy texture.

Carrageenan: It is also known as Irish moss in the market. It may be mixed with locust bean gum or CMC to reduce the wheying off in ice cream (Ramzan, 1972).

Guar gum: It is derived from the natural seed of the guar plant. Guar gum is a cold soluble gum therefore full viscosity can be obtained without heating. It is very suitable for High Temperature Short Time (HTST). Guar gum is the most cost efficient thickener and provides food products with a variety of functionality, such as: crystal control, texture modification, mouth feel enhancement and water binding to retard syneresis (Marshall and Arbuckle, 1996).

Xanthum is the medium viscosity gum, when used in ice cream at the usual levels impart body to the product. Average application ranges of stabilisers are given in the Table 2.4.

Table 2.3. Application ranges of stabilisers in ice cream

Stabiliser	Percent Used in Ice Cream
Gelatin-150 bloom	0.50
Gelatin-200 bloom	0.42
Gelatin-250 bloom	0.35
Sodium aliginate (Dariloid)	0.27
CMC	0.16
Irish Moss	0.10
Locust bean gum	0.25
Guar gum	0.25
Pectin	0.15

Source: Frandsen *et al.*, 1961

2.4.5. Emulsifier

An emulsifier is a substance that produces a stable suspension of two liquids that do not mix naturally. The main function of an emulsifier in the manufacture of ice cream is to produce dry, stiff and smooth product. They are amphiphilic substances, because according to their chemical structures possess both hydrophilic and lipophilic properties (Krog, 1997).

The principal function of added emulsifiers in ice cream is to destabilise the globular fat. Ice cream is oil in water emulsion. Emulsifiers promote the emulsification of the oil and the aqueous phase without separation. The use of emulsifier increases the ease of formation and promotes the stability of emulsion by reducing the amount of work required to form a homogeneous mixture of two immiscible phases, oil and water (Rajah, 2002).

Mono and diglycerides and polyoxyethylene derivatives of hexahydric alcohol are the two major types of emulsifiers, used in ice cream (Marshall and Arbuckle, 1996). Monoglycerides are used in the range 0.25-0.5 percent. Most effective emulsifiers have hydrophilic lipophilic balance

(HLB) values in the range 8-14. However, still the most widely used emulsifiers in ice cream are the saturated monoglycerides with HLB values in the range 3-4.

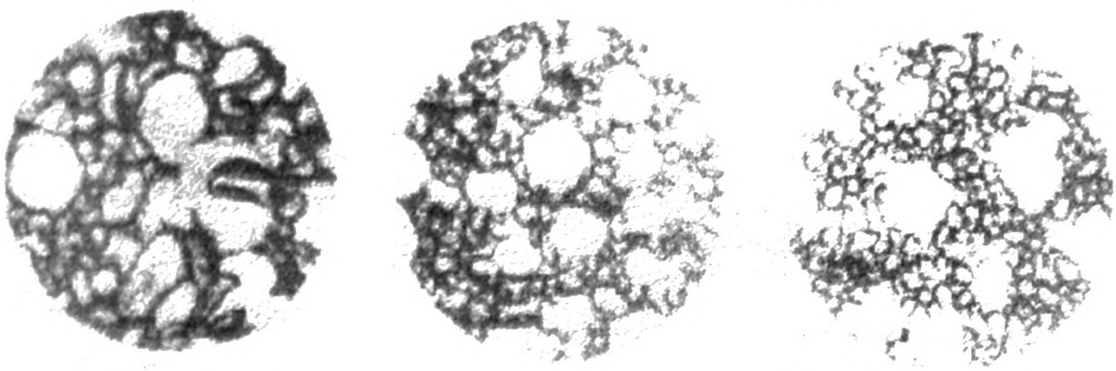
The added monoglycerides interact with the milk proteins present to form a protective hydrophilic layer of adsorbed protein around the fat globules. These layers prevent the globule from coalescing and thus stabilise the fat emulsion. In addition to that bonding take place between neighbouring protein layers causing the fat globules to clump. This effect is responsible for the dryness, texture and stand up properties of ice cream (Rajah, 2002).

The effectiveness of an emulsifier depends on the percentage of monoglycerides and on the particular fatty acids. If the carbon chain length of fatty acids increases, stiffness produced in the ice cream tends to reduce (Kilara, 1996). The functions of emulsifiers used in ice cream are shown in figure 2.3.

• Improve melting properties • Promote fat protein interaction • Control fat agglomeration and coalescence • Facilitate air incorporation • Impart dryness at extrusion • Impart smoother texture and consistency • Improve resistance against shrinkage • Improve melting properties

Figure 2.3. The function of emulsifiers in Ice Cream
Source: Nielsen, 1976

The effects of emulsifiers and stabilisers on internal structure of ice cream are shown in figure 2.4.



No Stabiliser or emulsifier **Stabiliser** **Stabiliser plus emulsifier**

Figure 2.4 Effect of the use of stabilisers and emulsifiers on the internal structure
Source: Frandsen *et al.*, 1961

2.4.6 Flavours and Colours

Addition of flavouring and colouring materials to ice cream mixes varies according to the consumer preferences. Many flavouring materials are available. Most commonly used flavouring materials in ice cream are vanilla, chocolate, fruit and fruit extracts, nuts, spices and sweeteners (Rajah, 2002).

Colouring and flavouring materials are added to almost all ice cream. In the past artificial colours and flavours are used widely, but now there is a tendency to natural flavourings. Vegetable fat imparts little intrinsic flavour. Therefore it is necessary to add flavouring of sufficient quality to overcome the bland property without appearing in excess (Varnam and Sutherland, 1994).

When product is made from mixed flavours, right flavour balance is important. Type and the intensity are the two important characteristics of flavours. The delicate flavours are easily blended and tend not to be objectionable at high concentrations. Harsh flavours tend to be objectionable, even at low concentrations. The intensity of the flavours should only be sufficient for the consumer to perceive it. Colours are chosen in accordance with flavour. Fruit flavoured ice may require only a small amount of added colour. Because the fruit it self may give sufficient colouring (Rajah, 2002).

2.4.7 Water and Air

Water and air are important constituents of ice cream. Water is found in all ice creams and is necessary to allow freezing to take place. It gives palatability and cooling effect to ice cream (Hamilton, 1990).

Continuous phase in ice cream is water. It is present as a liquid, a solid and a mixture of the two physical states. The air is dispersed through the fat in serum emulsion. Water in the ice cream mix comes from dairy products and syrups or from added water. Water should be clean and purified.

In the manufacture of ice cream, the overrun, or the increase in volume of ice cream over the volume of mix used is produced by incorporation of air. The amount of air in ice cream is important because it influences quality and profit. Also amount of incorporated air depends on the legal standards. Therefore maintaining a uniform amount of air is essential in controlling both quality of ice cream (Marshall and Arbuckle, 1996).

2.6 Manufacture of Ice Cream

Figure 2.5 illustrated the typical ice cream manufacturing process.

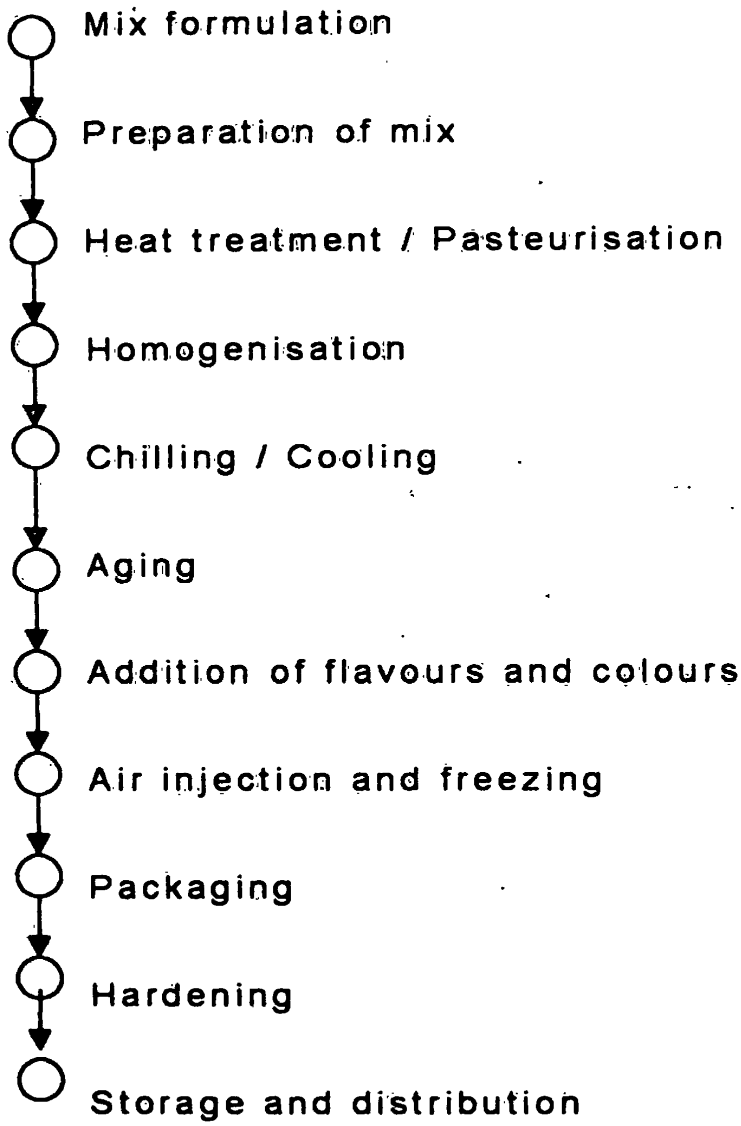


Figure 2.5 Flow diagram of typical ice cream manufacturing process

2.6.1 Mix formulation

The quantities of the ingredients are calculated then weighed or metered out as appropriate (Ramzan, 1972). When determining mix formulation numbers of factors are considered. It depends on the legal standards. A fundamental requirement of formulation is that mixes must be balanced.

In order to prevent "fatty" mouth feels the correct fat: sugar ratio is need. In addition to that balance is required for the total solids to water ratio. If this is too high there is a risk of sandiness and rough texture due to lactose crystallisation. If too low, large ice crystals may form (Varnam and Sutherland, 1994).

A balanced mix is produced a satisfactory finished product. A poorly balanced mix indicates defects such as (1) lack of flavour- insufficient concentration of flavouring, (2) lack of richness- insufficient concentration of fat, (3) sandiness- too high concentration of lactose, or (4) weak body- low total solids or low stabiliser. These may be corrected by changing the composition of the mix (Marshall and Arbuckle, 1996).

2.6.2 Preparation of Mix

Mix is blended using High Temperature Short Time (HTST) or Ultra High Temperature (UHT), before the heat treatment. Blending is a batch process and several blending vessels are used to ensure a continuous product flow to the pasteurisation or UHT plant (Varnam and Sutherland, 1994). Sometimes preliquefaction into slurries is used, because dry ingredients may disperse. Dried milk powder is difficult to wet, disperse and hydrate at temperatures below 35°C. This problem may be overcome by the use of hydration tanks (Varnam and Sutherland, 1994).

Some ingredients such as stabilisers required a higher temperature for dispersion in the mix, so they are added after the mixture has reached about 160°F (Lampert, 1970). Finally all the ingredients are blended together so that they are in solution or in suspension (Ramzan, 1972).

2.6.3 Homogenisation

Generally ice cream mixes are always homogenised. The purpose is to reduce fat globule sizes, the object of which is to impart smoothness to the ice cream (Marshall and Arbuckle, 1996).

After homogenisation the fat globules are reduced in diameter, and new membranes are formed to cover the new fat globules. The mix is homogenised at 40-50°C and then returned to the heat exchanger for pasteurisation. Homogenisation is an essential step because it prevents churning of the mix in the freezer, reduces the time needed to age the mix, affects its viscosity and improves the body and texture of the ice cream (Lampert, 1970).

Homogenisation carried out either before or after heat treatment. The pressure used varies with the type and quantity of fat present. Over homogenisation is a fault leading to clumping or clustering of fat globule and buttering during freezer (Varnam and Sutherland, 1994).

2.6.4 Heat Treatment / Pasteurisation

The ice cream is heat-treated to selected time and temperature according to legal standards. Batch, High Temperature Short Time (HTST) or Ultra High Temperature (UHT) plant may be used (Ramzan, 1972). The fat and sugar present in ice cream mix give some protection to bacteria in the mix. Therefore it is necessary to pasteurise at a higher temperature than is needed for milk (Lampert, 1970). According to the SLS: 223, four minimum temperature / time treatments are permitted, 65.6°C /30 min, 71.1°C / 10 min, 79.4°C / 15 sec and 148.8°C / 2 sec. More severe heat treatments have been suggested to ensure destruction of *Listeria monocytogenes by* Varnam and Sutherland, 1994.

Also heat treatment affects to the physiochemical structure of the ice cream mix. It allows mixing and blending of ingredients, dissolves sugars and milk powders, and activates stabilisers and emulsifier. Availability of binding sites of protein increase due to denaturation and partially denatured whey protein begin to act as emulsifiers (Holdworth and Haylock, 1995).

2.5.5 Chilling / Cooling

After the heat treatment, cooling is done to satisfy legal requirement and for fat crystallisation to begin (Ramzan, 1972). The mix must be cooled as rapidly as possible to 4°C, within 1.5 hours. For this operation plate heat exchangers are widely used (Varnam and Sutherland, 1994).

2.5.6 Aging

The mix is aged for 4 to 24 hours at 4°C. This is an important step. During the aging partial desorption of the fat globule membrane takes place and the globules agglomerate. During the aging period hydration of milk proteins, the crystallisation of fats and the absorption of water by any added hydrocolloids occur.

Aging is completed within 24 hours and longer periods should be avoided to prevent spoilage by psychotropic (cold loving) microorganisms (Varnam and Sutherland, 1994). Clumping of the fat globules and increasing the viscosity of the mix is permitted, aging. It allows the mix to freeze more quickly and gives the ice cream a better body and texture (Lampert, 1970).

2.6.7 Addition of Flavour and Colour

Generally flavours and colours are added just prior to freezing, because they not heat stable. Flavours and colours are added after the heat treatment; therefore care must be taken to prevent contamination of the mix.

2.6.8 Air Injection and Freezing

Vertical, horizontal, batches or continuous types of freezers are used. Each process gives a different product and requires the composition of the mix to be balanced. During freezing the temperature is lowered and air is incorporated into the ice cream. It leads to an increase of the mix, overrun. It is an important quality determinant. It is economically desirable to have an overrun as high as possible without adversely affecting the character of the ice cream (Ramzan, 1972).

The freezer is usually operated at (_10) to (_20)^{0}C this temperature permitting sufficiently fast freezing to minimise ice crystal size. But it is allowing sufficient time for air incorporation.

The final structure of ice cream is determined during the freezing and aeration of the mix. During the freezing the fat globules collect at the air water interface and stabilise the air bubbles. Ice cream texture is largely determined by the size of the ice crystals. Fast freezing rates are desirable to ensure that crystals are too small to be detectable in the mouth (Varnam and Sutherland, 1994).

2.6.9 Packaging

Wide ranges of packaging materials are used for ice cream. Retail packs such as waxed, aluminium foil laminated or plastic coated cardboard and plastic containers are widely used now. Packaging can have a sufficient effect on the storage properties of ice cream (Mitten, 1996). Closed plastic packages are of superior performance during retail storage. Aluminium foil laminate is the most effective one of the cardboard-based materials.

2.5.10 Hardening

During this operation the temperature of the ice cream is further reduced to (−18)°C. Continuous hardening tunnels are most commonly used in the large-scale operations. It gives the advantage of faster hardening and less formation of large ice crystals. Hardening tunnels are operated at air temperatures of (_30) to (_35)°C and it is completed within 2-5hours (Varnam and Sutherland, 1994).

2.5.11 Storage and Distribution

Ice cream should be stored at constant temperatures. Otherwise fluctuations lead to migration and accumulation of water and the formation of large crystals on refreezing. A temperature of (_20) to (_25)°C is used for long-term storage, but higher temperatures of (_13) to (_18)°C are acceptable during transport and short-term display (Varnam and Sutherland, 1994).

2.6 Nutritive Value of Ice Cream

Ice cream is an excellent food and a concentrated source of energy. But it is an unbalanced food, because of its high fat and carbohydrate content if made the principal part of the diet (Lampert, 1970). The energy value and nutrients of ice cream depend upon the food value of the ingredients from which it is made. Table 2.5 gives the average composition of ice cream.

Table 2.6 Composition of plain ice cream (per 100g edible portion)

Constituent	Good Average Ice Cream
Water (%)	61.7
Food energy (cal)	196.7
Protein (%)	4.1
Fat (%)	12.0
Total carbohydrate (%)	20.7
Weight per 100 cal portion (g)	50.8

Source: Marshall and Arbuckle, 1996.

The milk products, which go into the mix, contain the same constituents of milk, but in different amounts. Also ice cream contains three or four times as much fat, and about 12 to 16 % more protein than milk. In addition it may contain other food products such as fruit, nuts, eggs, and sugar which enhance its nutritive value (Frandsen *et al.*, 1961).

Ice cream has a high concentration of MSNF. It contains 34 to 36 percent milk proteins. They have excellent biological value, because they contain all the essential amino acids (Marshall and Arbuckle, 1996).

Milk fat used in ice cream consists mainly of triglycerides of fatty acids, 95.8% on a weight basis. Milk fat is highly complex containing almost 400 fatty acids. Among milk and its products ice cream is a richest source of Calcium and Phosphorous (Frandsen *et al.*, 1961). Like milk, ice cream is an important sources of s several vitamins such as vitamin A.

Ice cream is easily digested, especially because of the homogenisation and the heat treatment of the mix favour the formation of soft curd in the stomach. Its coldness is acceptable to persons suffering from irritations and infections of the mouth or throat and also desirable during hot whether (Lampert, 1970).

2.7 Production and Consumption of Ice Cream

United States is the leading nation in the ice cream production and consumption. Then next five countries, which are famous for ice cream production and consumption, are New Zealand, Australia, Belgium, Sweden and Canada. Annual per-capita consumption of frozen desserts in USA is about 23.5 quarts. In recent years consumption of ice cream and related product gradually decrease.

Earlier production consumption of ice cream is high. Today's prices of some items of frozen dessert limit their consumption to wealthy person. Also its controlled consumption finds a place in the diet of persons who need to reduce or who do not wish to gain weight (Marshall and Arbuckle, 1996)

2.8. Melting Quality of Ice Cream

Melting rate has the greatest significance to the consumer, when it is eaten from a cone or a stick. If it melts too fast, it is difficult to eat and also tends to become heat shocked readily. Rapid Melt down may occur due to high drawing of temperature during freezer operation. Low solids content, inadequate stabilisation and low freezing point due to high salt and sugar content lead to rapid melt down. Extremely slow meltdown is occurred due to high acidity, excessive homogenisation pressure, excessive amount of stabiliser, over emulsification and type of emulsifier (Marshall and Arbuckle, 1996).

Ice cream should melt evenly to the consistence of heavy cream at room temperature. If the product resists melting, usually it is due to the use of too much stabiliser or emulsifier. Excess amount of fat may also favour for resistance to melting. Homogenisation of the ice cream mix at low temperature or with excessive pressure leads to this defect.

Due to destabilisation of protein and or high fat content, seepage of liquid from the ice cream during melting called "wheying-off" may occur. Because of the use of unsuitable stabiliser or improper homogenisation procedure curd particles can be seen in the melting ice cream. Presence of dry film over the surface of melted ice cream may be due to prolonged storage of the product or destabilisation of milk protein during freezing of the mix.

Thin appearance in the mix, called low viscosity occurs due to use of low solids in the mix. Excessive overrun favoured by the use of too many stabilisers or emulsifier as well as the use of a mix that has a high viscosity caused to foamy product. Foamy means that large air bubbles retain their shape and presence the melting product (Lampert, 1970).

CHAPTER-3

MATERIALS AND METHODOLOGY

Studies were carried out at Ceylon Cold Stores, Ranala under their development programme.

3.1 Materials

3.1.1 Basic Ingredients and Chemicals

3.1.1.1 Basic Ingredients

1. Skim milk powder
2. Whey powder
3. Sucrose
4. Vegetable fats
5. Stabiliser / Emulsifier
6. Vanilla ice cream flavours (Ceylon Cold Stores, Ltd).

3.1.1.2 Chemicals

1. 0.1 mol / l NaOH
2. Phenolphthalein indicator
3. 40 % (v/v) Formaldehyde solution
4. 90 % Sulphuric acid
5. Amyl Alcohol (Density 0.809)

3.1.2 Equipment and Instruments

1. Electrical balance (accuracy 1g) and Analytical balance (accuracy 0.0001g) (Shimadzu)
2. Mixing blender (National)
3. Thermometer (0-100^{0}C)
4. Hand beater (Philips Mixer HR 1500)
5. Empty plastic containers and tubs
6. Glass wares
7. Basin, Saucepan

8. Deep freezer, Refrigerator (Sisil)
9. Centrifuger (1100-1500rpm)
10. Butyrometer (0-10ml)
11. Clean sea sand
12. Petridishes

3.2 Methods

3.2.1 Product Formulation

All the ice cream mixes were formulated; using dry ingredients according to the Standards of Ceylon Cold Stores, Ltd. Changes were done to existing formula, maintaining company standards. Existing formula was used as the standard controlled sample. Twelve Sample formulas were prepared by altering stabiliser, emulsifier system and fat type at the ranges compiled to company standards. Accuracy of ingredient amounts was maintained up to three decimal points.

3.2.2 Preparation of Ice Cream

Each ice cream mix was prepared in 2L volumes. Measured amount of filtered water was heated up to 55-60°C for 5-15 minutes. Skim milk and whey powders were mixed gradually to heated water and mixed well. Cane sugar (sucrose) mixed with stabiliser emulsifier system was mixed to the blend and vegetable fat was added thereafter. Mixture was cooled to room temperature and homogenised for 15 minutes at high speed using an electrical blender.

Homogenised sample was pasteurised for 25 sec at 83°C and rapidly cooled to 4°C within 90 minutes using brine mixture of ice and salt at 10:1 respectively. Aging of ice cream mix was done at 4°C for 24 hours. Vanilla ice cream flavour was added at the rate of 0.25 % to aged ice cream mix and it was mixed using hand held beater (National) while maintaining its temperature at (-4) °C. Air incorporation (beating) was continued until mix gets twice of its original volume. Prepared ice cream was poured into 80 ml and 1l plastic cups and covered with lids. Cups were transferred to cold room maintained at (-19) °C ± 1 for hardening process.

The preparation procedure of ice cream is illustrated in the following diagram.

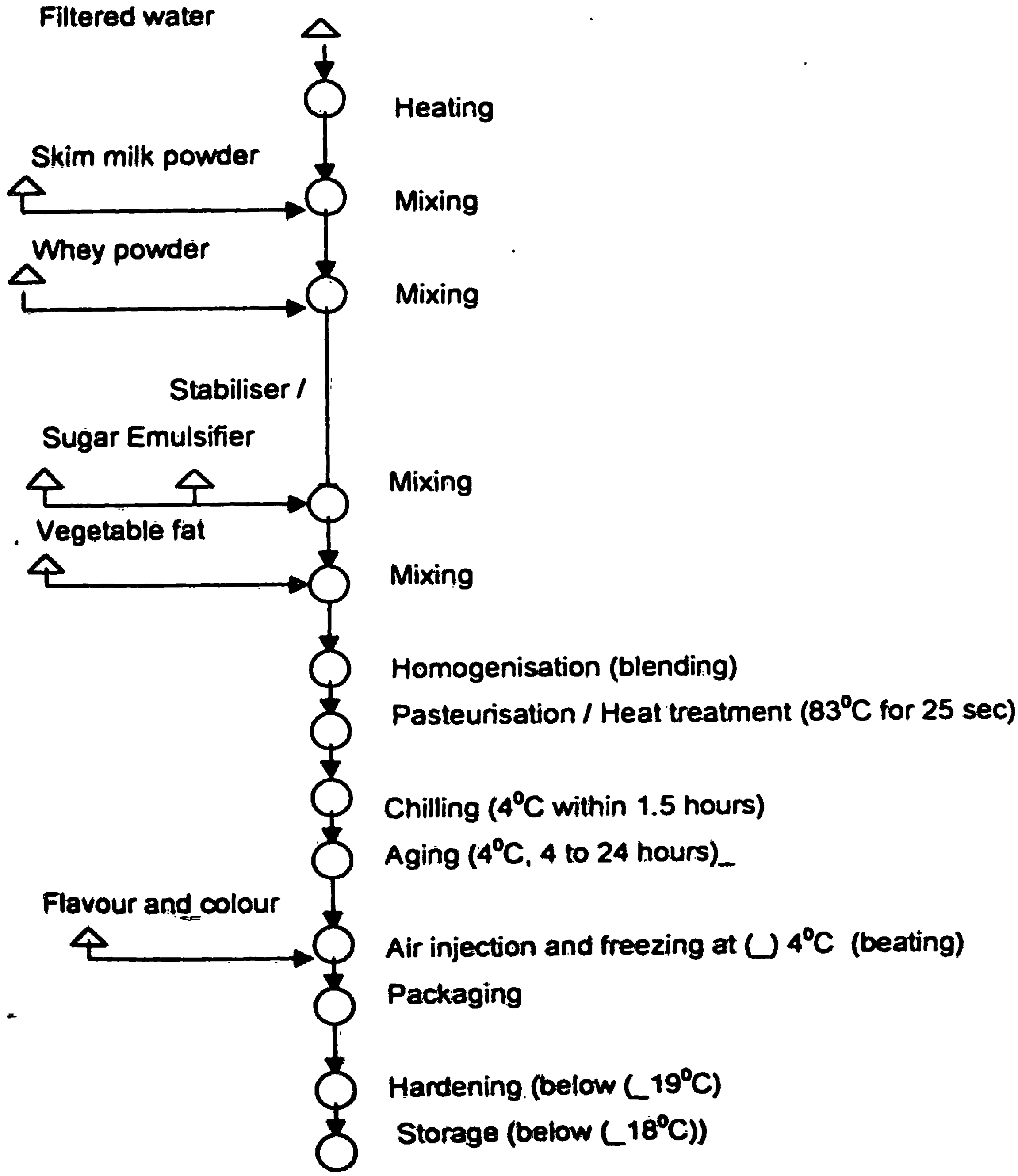


Figure 3.1 Preparation procedure of ice cream

3.2.3 Physiochemical Analysis of Ice Cream Samples

Chemical analyses were concluded according to the table 3.1.

Table 3.1. Reference test method for chemical analysis

% by mass	Test method
Total solids	SLS 735: Part 5: 1988
MSNF	SLS 223: 1989
Fat	SLS 223
Acidity as lactic	SLS 735: Part 2: 1987

3.2.3.1 Experiment 1- Determination of Melting Time of Ice Cream

Melting was carried out at room temperature (26^{0}C). The 80 ml polystyrene tubs were cut away carefully, and the ice cream samples were placed in clean and dried, petridishes of same diameter and height. Time taken to flatten the ice cream was measured. Procedure was shown in figure 3.2 and 3.3. Experiment was designed as a Randomised Design with three replicates.

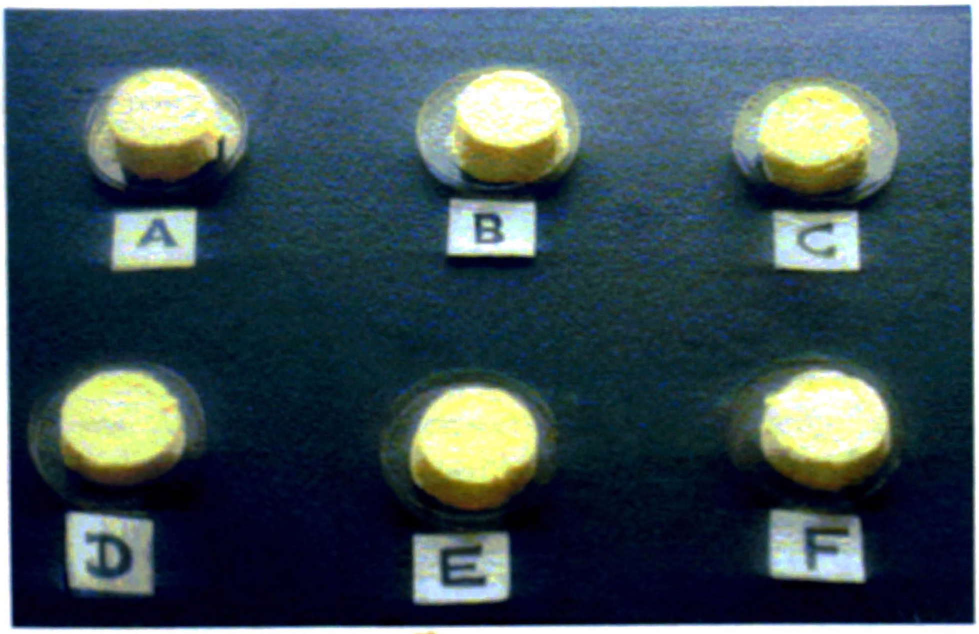


Figure 3.2 Initial stage

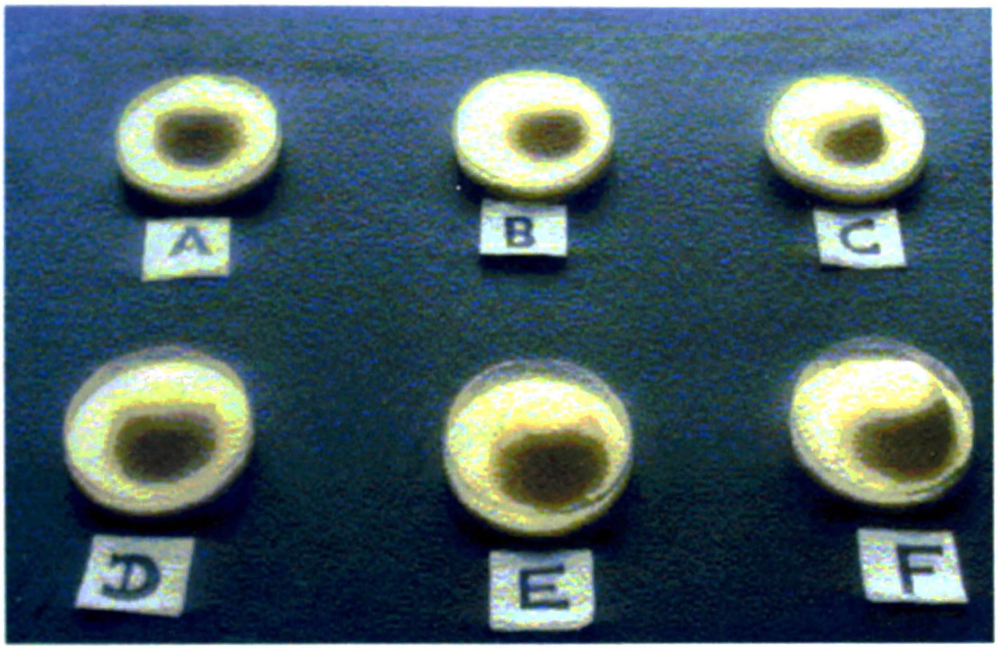


Figure 3.3 Melting of ice cream after 30 minutes

3.2.3.2 Experiment 2- Determination of Total Solids

Nearly content 25mg of clean sand was placed in flat bottom dish and transferred to the oven with the lid and glass rod. Dish was dried for 2 hours at 105^{0}C. Then it was cooled to the room temperature in the descicator and weight was obtained to the nearest 0.1mg (m_1 g). 8-10g of ice cream sample was added to the dish and weight was obtained to the nearest 0.1mg (m_2 g). Three millilitres of distilled water was added and mixed well using the glass rod. Samples were evaporated over water bath for 2 ½ hours. Then it was placed inside the oven maintained at 105^{0}C ± 1 with opened lids. After 15 minutes closed dish was transferred to the descicator and weight was obtained to the nearest 0.1mg after it cooled to room temperature.

The processes of drying, cooling and weighing were repeated that at 1-hour intervals until the difference of two weighing did not exceed 0.1mg (m_3 g). The procedure illustrated in the flow diagram (Figure 3.4)

Weighing clean sand (25g)

↓

Drying (105^{0}C for 2 hours)

↓

Cooling

↓

Weighing (m_1g)

↓

Add ice cream sample

↓

Weighing (m_2g)

↓

Add distilled water (3ml)

↓

Mixing

↓

Evaporating over a water bath (2 ½ hours)

↓

Drying (105^{0}C for 15 minutes)

↓

Cooling and weighing (m_3g)

Figure 3.4 Procedure of total solids determination

Experiment was carried out with three replicates for each sample and percentage of total solid was calculated according to the formula given below.

Percentage of total solid by mass = $((m2\_m1)\ g\ /\ (m3\_m1)\ g) \times 100$

3.2.3.3 Experiment 3- Determination of Titrable Acidity as Lactic Acid

1g of phenolphthalein was dissolved in 110 ml of ethyl alcohol (95% v/v). 0.1mol/l NaOH was added drop wise until a faint pink coloration was given (SLS 735: part 2: 1987).

10 ml of the prepared ice cream sample was pipetted out into a clean porcelain basin. It was diluted using 50 ml distilled water. 1 ml of phenolphthalein indicator was added to the sample. The contents in the basin were rapidly titrated against the standard 0.1 mol / l NaOH solution, till the first definite change to a pink colour was persisted for 10 to 15 seconds. Sample was continuously stirred with a glass rod during the titration. The titration was completed within 20 seconds and burette reading was obtained (Xml). A second basin containing similar quantity of ice cream was diluted with 50 ml of water and used as the blank to facilitate observation of the colour change.

Titration was repeated for each sample for three times to obtain accurate reading and percentage lactic acid is calculated according to the following formula.

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

Percentage of lactic acid by mass = ((X × 0.0090 / 10) × 100)

3.2.3.4 Experiment-4 Determination of Milk Solid Non Fat (MSNF)

10 g of prepared ice cream sample was weighed accurately into a porcelain dish. 50 ml of distilled water was added into it. 1ml of phenolphthalein indicator was added and titrated with 0.1 mol / l NaOH, until an end point indicated by a faint pink colour. 3 ml of 40 % (v/v) formaldehyde solution was added to this neutralised ice cream. It was titrated to neutrality as before while stirring the mixture with a clean glass rod and burette reading was taken (V_1 ml). Then 3 ml of 40 % (v/v) formaldehyde solution was titrated separately with 0.1 mol / l NaOH to determine the blank (V_2 ml). Readings were obtained with three replicates and percentage of MSNF was calculated according to the following formula.

Percentage of MSNF by mass = 5.67 (V1_V2)

3.2.3.5 Experiment 5- Determination of Fat Content

Fat percentage was determined approximately using Gerber method (Pearson). 10 ml of 90 % H_2SO_4 was taken to butyrometer tube and 4g of prepared ice cream sample were transferred into it. 1 ml of fat free amyl alcohol (density 0.809) was added, inside the fume cupboard. Then tube was closed with a stopper and content was mixed thoroughly and carefully. Then it was centrifuged at 1100rpm for 4 minutes and reading was obtained (Y ml).

Approximate percentage of fat = 2.85 x Y

3.2.3.6 Experiment 6- Determination of Ice Cream Overrun

A beaker was filled with ice cream mix and weight was obtained (m_1g). Then same beaker was filled with ice cream and weight was obtained (m_2 g).

Percentage of overrun = $((m_1 \_ m_2) / m_2) \times 100$).

3.2.4 Sensory Evaluation of Ice Cream Samples

Sensory evaluation was carried out for the sample with best melt resistance. Evaluations were carried out at the clean, well-lighted sensory evaluation booths at the Ceylon Cold Stores Laboratory with seven trained panellists. Three identical samples (hand made best formula, hand made standard formula and machine made standard sample) coded with 3 digits random numbers were presented to panellists at the same time. All the samples were simultaneously presented to each panellist in random order. Warm water was presented as pallet cleanser between two samples and retasting was allowed. Assessors were asked to rank coded samples for overall acceptability in the order from least acceptable to most acceptable using the ballet paper (Appendix A). Sample given equal acceptable ranks were not allowed. Rank sum test was carried out to determine the difference between samples using Statistical Chart shown in Appendix B.

CHAPTER-4
RESULTS AND DISCUSSION

4.1 Results

4.1.1 Physiochemical Analysis of Ice Cream

Physiochemical properties of the samples were matched with the company standards except sample S_{12}. Calculated results of ice cream samples were shown in Table 4.1.

Table 4.1 Physiochemical analysis of ice cream

Property %	Samples												
	Std Ctrl (S_C)	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
TS	35.2	35.7	35.3	35.8	35.1	35.0	35.6	35.8	35.4	35.7	35.1	35.6	39.8
MSNF	10.96	10.86	10.65	10.61	11.15	11.24	10.74	10.48	10.59	10.51	11.15	10.67	14.37
Fat	10.10	9.72	10.28	9.81	9.58	10.1	9.94	9.57	9.90	9.89	10.11	9.92	11.42
Acidity as lactic	0.17	0.16	0.15	0.17	0.16	0.17	0.14	0.12	0.17	0.18	0.16	0.16	0.17
Overrun	82.17	80.83	81.5	80.17	80.17	80.5	82.67	79	79.33	81.33	79.67	80.5	111

Each data value represents mean of three replicates.

4.1.2 Melting Time of Ice Cream Samples

Time taken to melt different ice cream formulations during the storage was shown in Table 4.2.

There was a significance difference between samples during the storage at 5 % level of significance. Highest mean value contained sample (S_{11}) was the best sample with high melting point. Melt resistance of the sample S_{11} during the storage shown in Table 4.3.

Table 4.2 Melting of ice cream samples during the storage

Sample	After 7 days	After 14 days	After 21 days
S_C	61.0000^{E}	61.0000^{E}	60.0000^{E}
S_1	59.0000^{F}	59.0000^{F}	59.0000^{E}
S_2	68.0000^{B}	68.0000^{B}	67.5000^{B}
S_3	65.0000^{C}	65.0000^{C}	64.0000^{C}
S_4	58.0000^{F}	58.0000^{F}	$54.0000^{F\ G}$
S_5	55.0000^{G}	55.0000^{G}	$54.0000^{F\ G}$
S_6	54.0000^{G}	54.0000^{G}	$53.0000^{H\ G}$
S_7	58.0000^{F}	58.0000^{F}	55.0000^{F}
S_8	53.0000^{H}	53.0000^{H}	52.0000^{H}
S_9	51.0000^{I}	51.0000^{I}	52.0000^{H}
S_{10}	63.0000^{D}	63.0000^{D}	62.5000^{D}
S_{11}	78.0000^{A}	78.0000^{A}	78.5000^{A}
Significance effect at 5 % level	**	**	**

**- Significance at 5 % level

Means with the same letter in same column are not significantly different.

Table 4.3 Melting time of sample S_{11} during storage

Days	Mean Time
After 7 (1)	78.0000
After 14 (2)	79.0000
After 21 (3)	78.5000

There was no significance difference for melt resistance in S_{11} during the storage. It was shown in Table 4.4.

Table 4.4 Analysis of variance procedure

Days	Mean Time
1[A]	78.000
2[A]	79.000
3[A]	78.000

Means with the same letter are not significantly different at 5 % level of significance.

4.1.3 Relationship between Melting Point (MP) of Vegetable Fat and Time Taken to Melt

Melt resistance of ice cream, increased with the subsequent increasing of MP of vegetable fat. This was shown in Figure 4.1.

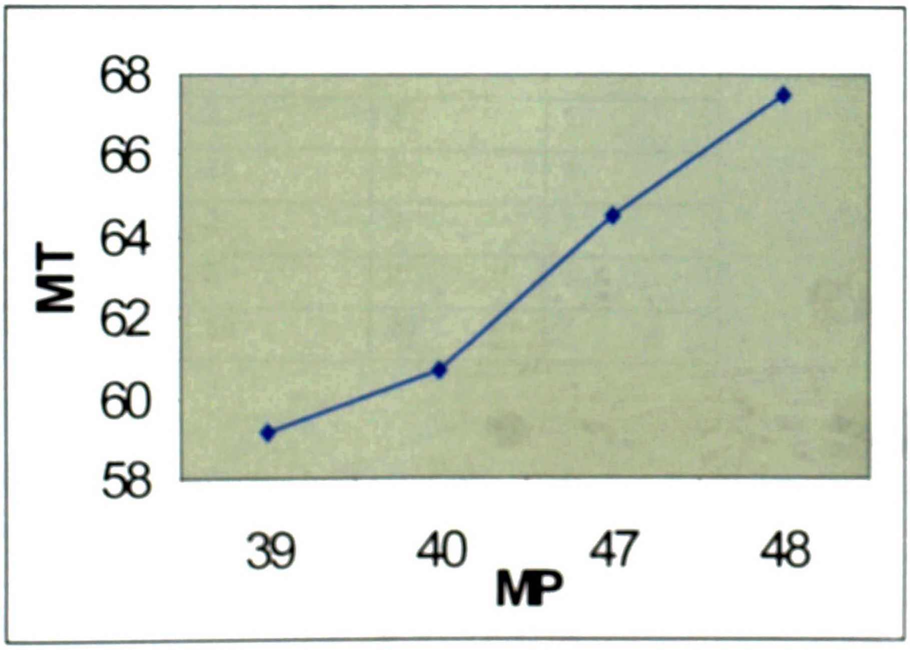


Figure 4.1 Relationship between MP of vegetable fat and melting time

MT- Melting Time (Time taken to melt)

MP- Melting Point of vegetable fat

4.1.4 Sensory Evaluation

Melting point of selected best product was greater than standard and it was compared with hand made and machine made standard samples for sensory qualities.

Rank total was higher in sample coded with 316 and lower in sample coded with 454 giving best acceptability of the improved ice cream sample. Rank totals for overall acceptability is shown in the Table 4.5.

Table 4.5 Overall acceptability of the samples

Panellist (Reps)	Samples		
	212	316	454
1	2	3	1
2	2	3	1
3	2	3	1
4	2	3	1
5	2	3	1
6	2	3	1
7	3	2	1
Total	15	20	7

212 – Hand made selected best sample
316 – Hand made standard sample
454 – Machine made standard sample

The rank totals were compared with the values in Appendix B.

4.2 Discussion

Ice cream is a frozen dairy dessert and is highly popular in the market due to convenience, variety, adaptability, and refreshing, appetising and nutritious characteristics of it. Improved melt resistance is the way to maintain its consistency during retailing and transporting of the product.

According to Rajah (2002) melting characteristics of fats are greatly affected to achieve stability of ice cream during storage. Varnam and Sutherland (1994) revealed that the range of melting point 28-32^{0}C was best for ice cream and if the melting point was above 37^{0}C it was remained in a solid state in the mouth and imparted fatty mouth feel.

The results revealed that gradual increasing of melting point of fat caused to subsequent increasing in melt resistance of the ice cream. Positive correlation ship was observed between the melting time and melting time of vegetable fat. Although high melt resistance was observed application of high melting point vegetable fat was restricted due to off taste development.

The study revealed that a melting point in the range of 39-40$_0$C was the best to obtain better melting properties.

Among prepared twelve samples, eleven samples achieved the company standards in term of chemical composition and texture. Excess homogenisation and beating of the rejected sample lead the high overrun, which was not compatible to company standards. On the other hand Total Solids, Milk Solid Non Fat and fat percentages were over the company standards in sample S_{12}.

When quantity of company recommended stabiliser emulsifier system "Dricoid", which comprises of guar gum, monoglycerides, xanthum gum, carrageenan and polysorbate 80, was increased more than 4 %, heavy or gummy texture with poor meltdown properties were observed. Studies indicated that usage range between 3.5-4 % of stabiliser emulsifier system produced ice cream with acceptable texture.

The primary purpose of using stabilisers in ice cream is to produce smoothness in body and texture, retard or reduce ice crystal growing during storage, provide uniformity of product and increase resistance to melting (Marshall and Arbuckle, 1996). Further stabiliser dispersed in water either to form gel structures or to combine with water as water of hydration, thus increasing viscosity.

According to Varnam and Sutherland (1994) stabiliser can minimise the effects of temperature variations during storage (heat- shock).

Studies of Frandsen *et al.* (1961) revealed that the use of emulsifier decreased the rate of melting in the finished ice cream and produced smaller ice crystals more evenly distributed and smaller air cells that result in a smoother ice cream. However, Marshall and Arbuckle (1996) described that the better textural properties of ice cream were obtained using 0.1-0.5 % stabiliser and emulsifier system. In this study it was revealed that 3.5-4 % stabiliser emulsifier system produced the good textured product.

Samples which were made from stabiliser emulsifier system, that comprises of mono and diglycerides of Fatty Acids, guar gum, polyoxyethylene, sorbitan monodeate, carrageenan and sodium aliginates were melted rapidly and required overrun was easily achieved. It was found that when quantity of sodium aliginate is increased in the stabiliser emulsifier system, melt resistance got reduced.

Hamilton (1990) showed that the sodium aliginate has excellent whipping property. This property could enhance the overrun and texture of the product.

Studies revealed that the desired melting characteristics were obtained when the combination of stabiliser emulsifier used than they were used alone. Carrageenan, sodium aliginate, and carboxymethyl cellulose (CMC) were not longer effective for when they were used alone. Frandsen *et al.* also concluded this in 1961.

Guar gum incorporated product formulations shown high melt resistance characteristics. Sample S_{11} identified as the best sample with high melting point. Stabiliser emulsifier system that comprises of guar gum, sodium aliginate, carboxymethyl cellulose, carrageenan and monoglyceride was used in its product formulation.

In 1990 Hamilton revealed that the guar gum was very suitable for High Temperature Short Time (HTST) processing. Recently Rajah (2002) reported that the guar gum greatly increased the viscosity of the aqueous phase of the ice cream.

Sensory evaluation of the product revealed that there was a significant difference for acceptability among samples. The sample S_{11} coded as 212 obtained the highest acceptability over the hand made and machine made standard samples.

During this study some problems were occurred. Very first samples were very soft and light due to excess overrun, when quantity of both stabiliser and emulsifier was increased, too hardy, gummy and poor melting characteristics were observed. And it was very difficult to maintain same temperature and environmental conditions, when determined time taken to melt ice cream. Due to slow freezing and temperature fluctuation, formation of ice crystals was the major problem. At laboratory level it was very difficult to homogenised and obtained overrun.

Kilara (1996) revealed that the melting point of ice cream was increased when combination of corn syrups and sucrose. Therefore further studies are necessary to study the effect of blends of sucrose with high fructose corn syrup to improve melt resistance of ice cream. It is necessary to do further study to develop more effective stabiliser and emulsifier systems to improve melt resistance of ice cream at commercial scale.

Application of good stabiliser, emulsifier system at the commercial production will enable handling of product at wholesale and retail market.

CHAPTER-5
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Melting point of vegetable fat affects the melting point of ice cream. With the increasing of melting point of fat, melt resistance of ice cream can be improved.

The stabiliser and emulsifier system that comprises of guar gum, sodium aliginate, carboxymethyl cellulose, carrageenan and monoglycerides was the best formulation to improve the melt resistance of ice cream.

Finally it can be concluded that both melting point of vegetable fat and blends of stabiliser emulsifier system greatly affect the melting point of ice cream.

5.2 Recommendations and Suggestions

According to studies of Kilara (1996) showed that the melting point of ice cream could increase using combination of corn syrups and sucrose. Therefore further studies are necessary to study the effect of blends of sucrose with high fructose corn syrup to improve melt resistance of ice cream.

Also further studies are needed to identify further development in stabiliser emulsifier system, which can improve melting properties of ice cream.

Commercial production of the improved formula is needed to compare it at the commercial environment.

Furthermore, another perfect method for determine melting time of ice cream samples, should be identified.

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Appendix A

Ballot paper

Name:..................

Date:...................

Please taste each of the samples of ice cream in order listed below. Assign the samples with the most overall acceptability a rank value of 1, the samples with the next most overall acceptability a rank value of 2, and the sample with least overall acceptability a rank value of 3. Do not give the same rank to two samples.

Code	Rank Assigned
....	....
....	....
....	....

Appendix B

Statistical Chart

Rank Totals

Rank totals required for significance at the 5 % level (P<=0.05). The four figure blocks represent; lowest insignificant rank sum, any treatment-highest insignificant rank sum, any treatment. Lowest insignificant rank sum, predetermined treatment-highest insignificant rank sum predetermined treatment.

No of reps.	Number of treatments or samples									
	2	3	4	5	6	7	8	9	10	11
2	....	....	....	 3-9	 3-11	 3-13	 4-14	 4-16	 4-18	 5-19
3	....	 4-8	 4-11	4-14 5-13	4-17 6-15	4-20 6-18	4-23 7-20	5-25 8-22	5-28 8-25	5-31 9-27
4	....	5-11 5-11	5-15 6-14	6-18 7-17	6-22 8-20	7-25 9-23	7-29 10-26	8-32 11-29	8-36 13-31	8-40 14-34
5	 6-9	6-14 7-13	7-18 8-17	8-22 10-20	9-26 11-24	9-31 13-27	10-35 14-31	11-39 15-35	12-43 17-78	12-48 18-42
6	7-11 7-11	8-18 9-15	9-21 11-19	10-26 12-24	11-31 14-28	12-36 16-32	13-41 18-36	14-46 20-40	15-51 21-45	17-55 23-49
7	8-13 8-13	10-18 10-18	11-24 13-22	12-30 15-27	14-35 17-32	15-41 19-38	17-46 22-41	18-52 24-46	18-58 26-51	21-63 28-58
8	9-15 10-14	11-21 12-20	13-27 15-25	15-33 17-31	17-39 20-36	18-46 23-41	20-52 25-47	22-58 28-52	24-64 31-57	25-71 33-63
9	11-16 11-16	13-23 14-22	15-30 17-28	17-37 20-34	19-44 23-40	22-50 26-46	24-57 29-52	26-64 32-58	28-71 35-64	30-78 38-70
10	12-18 12-18	15-25 16-24	17-33 19-31	20-40 23-37	22-48 26-44	25-35 30-50	27-63 33-57	30-70 37-63	32-78 40-70	34-88 44-76
11	13-20 14-19	16-28 18-26	19-36 21-34	22-44 25-41	25-52 29-48	28-60 30-55	31-68 37-62	34-76 41-69	36-85 45-76	38-93 49-83
12	15-21 15-21	18-30 19-29	21-39 24-36	25-47 28-44	28-56 32-52	31-65 37-59	34-74 41-67	38-82 45-75	41-91 50-82	44-100 54-90
13	16-23 17-22	20-32 21-31	24-41 26-39	27-51 31-48	31-60 35-56	35-69 40-64	38-79 45-72	42-88 55-80	45-98 54-89	49-107 59-97
14	17-25 18-24	22-34 23-33	26-44 28-42	30-54 33-51	34-64 38-60	38-74 44-68	42-84 49-77	46-94 54-88	50-104 59-95	54-114 65-103
15	19-26 19-26	23-37 25-35	28-47 30-45	32-58 36-54	37-68 42-63	41-79 47-73	46-89 53-82	50-100 58-91	54-111 64-101	58-122 70-110
16	20-28 21-27	25-39 27-37	30-50 33-47	35-61 39-57	40-72 45-67	45-83 51-78	49-95 57-87	54-106 63-97	59-117 69-107	63-129 75-117
17	22-29 22-29	27-41 28-40	32-53 35-50	38-64 41-61	43-76 48-71	48-88 54-82	53-100 61-92	58-112 67-103	63-124 74-113	68-136 81-123
18	23-31 24-30	29-43 30-42	34-56 37-53	40-68 44-64	46-80 51-75	51-93 58-86	57-105 65-97	62-118 72-108	68-130 79-119	73-143 86-130
19	24-33 25-32	30-46 32-44	37-58 39-56	43-71 47-67	49-84 54-79	56-97 62-90	61-110 69-102	67-123 76-114	73-136 84-125	78-150 91-137

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