EFFECT OF VARYING FAT VARIETY AND OVERRUN ON THE MELTING RESISTANCE OF ICE CREAM AS A COST REDUCTION APPROACH WHILE RETAINING THE QUALITY

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(03/AS/090)

Thesis submitted in partial fulfillment of the requirements for the
Degree of Bachelor of Science (Special)
In
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Department of Food Science & Technology
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DECLARATION

The work described in this thesis was carried out by me at the Department of Food Science & Technology, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka, under the supervision of Mr.J.Liyanage , Mr. M.R.P.Attanayake and Mr. D.M.Arsekelarathne. The report on this has not been submitted to another university for another degree.

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AFFECTIONATELY DEDICATED

TO

MY EVERLOVING PARENTS & TEACHERS

EFFECT OF VARYING FAT VARIETY AND OVERRUN ON THE MELTING RESISTANCE OF ICE CREAM AS A COST REDUCTION APPROACH WHILE RETAINING THE QUALITY

One of the important manifestations of ice cream structure is its melt-down. When an ice cream is exposed in an ambient environment to melt, two events occur; the melting of the ice and the collapse of the fat-stabilized foam structure. Melting of the ice is principally controlled by the outside temperature (fast on a hot day) and the rate of heat transfer.

The study was preliminarily focused on the Effect of fat variety and overrun on the melting resistance of vanilla ice cream while maintaining the quality to reduce the cost. Samples were prepared with three fat varieties; fat blend (raw milk and vegetable fat; 71:29 ratio), palm kernel oil and palm oil. For each fat variety four samples were produced with 100%, 110%, 120% and 140% overrun. A Total 16 samples were prepared. Ice cream cube (6 cm±0.5 cm length, 3 cm±0.5 cm width and 3.5 ±0.5 cm in height) was cut and placed on a wire mesh of 5mm square size. A container was placed on an analytical scale to collect the dripped ice cream and scale reading was recorded every other two minutes. Room temperature was controlled at 21 °c±1 °C. A Graph was plotted with time vs. Melted ice cream weight.

The results clearly emphasized that melting rate was remarkably reduced with the time when the overrun is increased. Furthermore melting rates of three fat varieties were different while sample with raw milk gave the lowest melting rate and palm kernel oil showed the highest melting rate. Statistical analysis of Sensory analysis results showed that the three samples were significantly different in overall acceptability giving a P value of 0.000.The sample with raw milk has the highest preference with median 3.Cost comparison of three ice cream formulations was done and it can be concluded that while maintaining the same quality, manufacturing ice creams with vegetable fat was economic than use of raw milk to produce ice creams.

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ABBREVIATIONS

App.	Appendix
^0C	Celcius
Et al.	and others
g	grams
Min	minutes
MSNF	Milk-Solids-Not Fat
psi	pressure per square inch
Vs	Versus
Wt	Weight
S	seconds

CHAPTER 01

1.1. Introduction

Ceylon cold stores, a well established food and Beverage Company in Sri Lanka manufacturing ice creams and carbonated soft drinks and the marker leader in ice creams under the name of elephant house. The range of ice creams includes Vanilla, Chocolate, Fruit n' Nut, Strawberry, Mango Twist, Orange Twist under the brand name, Elephant House. Ceylon Cold Stores (former Ceylon Ice Company) started manufacturing ice cream, after acquiring Ceylon creameries in 1925.

Various dairy products are intentionally frozen as a means of preservation; cream, concentrated skim milk, cottage cheese etc. Intentional freezing is practiced in the manufacture of ice cream, sherbet for the purpose of creating a food product to be consumed in the frozen state. The low temperature at which ice cream is stored does permit them to be held for considerable periods of time before consumption, but this, of course is not the primary reason for freezing. The characteristics of ice cream while in the frozen condition are the first consideration and the properties after melting are of lesser importance (Johnson and Alford 1972).

Ice cream is a complex system with many ingredients in its formulation that can interact. Fat and fat structure development in ice cream and related frozen dairy desserts are critical for optimal structure and physical properties, stability, flavor and texture. Melting of ice cream at serving temperature has become a major concern of almost all the ice cream manufacturers as well as the consumers. Varying the recipe and the ingredients used for manufacturing ice cream has long been a practice of improving melting resistance of ice cream at serving temperature (Goff 1995).

Fat variety and overrun (amount of air incorporated in the ice cream) play significant roles in the ice cream structure since fat globules form a network within the ice cream. Study was preliminarily focused on the Effect of fat variety and overrun on the melting resistance of vanilla ice cream while maintaining the quality to reduce the cost.

1.2. Objectives

To study effect of varying fat variety and overrun on the melting resistance of ice cream as a cost reduction approach while retaining the quality

1.2.1. Specific Objectives

1. Studying the ice cream manufacturing process
2. Determination of melting resistance of different overruns of one fat variety
3. Determination of melting resistance of different overruns of three fat varieties
4. Determination of cost effectiveness of three ice creams for different overruns

CHAPTOR 02

REVIEW OF LITERATURE

2.1. History of Ice Cream

In probable that the Chinese some 3000 years ago were the first to mix snow and fruit juices together to form a dessert and the Romans also have used snow to "ice" drinks during summer. Marco polo is credited with bringing a recipe back from Peking to Venice in 1292, which included frozen milk, and was probably the original sherbet.

Ice cream probably came to the US with the early English colonists. In 1851, the first wholesale ice cream industry in the US was established in Baltimore, Maryland, by Jacob Fusel (Bhandari 2001).

It is still uncertain how long ice cream has been produced. Review of ice cream history reveals many stories of ice cream origin. Once upon a time, hundreds of years ago, Charles I of England hosted a sumptuous state banquet for many of his friends and family. The meal, consisting of many delicacies of the day, had been simply superb but the "coup de grace" was yet to come. After much preparation, the King's French chef had concocted an apparently new dish. It was cold and resembled fresh-fallen snow but was much creamier and sweeter than any other after- dinner dessert. The guests were delighted, as was Charles, who summoned the cook and asked him not to divulge the recipe for his frozen cream. The King wanted the delicacy to be served only at the Royal table and offered the cook 500 pounds a year to keep it that way. Sometime later, however, poor Charles fell into disfavor with his people and was beheaded in 1649. But by that time, the secret of the frozen cream remained a secret no more. The cook, named demirco, had not kept his promise (Goff 1995).

2.2. What is ice cream?

Ice cream or **ice-cream** is a frozen dessert which may contain a variety of ingredients in addition to milk, cream and sugar (Clarence. et al 1951).In 1906, the US department of agriculture defined ice cream as follows; "ice cream is a frozen product made from cream and sugar, with or without a natural flavoring and containing not less than 14% of milk fat. Fruit nut ice cream must contain not less than 12% of milk fat. Legal definitions for ice cream are far more inclusive today. They are worded to make it clear that ice cream is a frozen dairy product, made from a combination of milk products together with one or more of other ingredients, such as eggs, sugar, and honey with or without flavoring and coloring, and without edible gelatin or vegetable stabilizer. modern definitions not only specify the per cent of milk fat that must be contained in ice cream, but specifically mention the per cent of milk solids-not-fat, fruits, nuts, cocoa or chocolate or confections included. Further they may specify the per cent of food solids that must be contained in a given volume of ice cream.

2.3. Composition of commercial ice cream

The composition of ice cream, to a large extent is governed by local food legislations. In the united states for example the average composition is (weight%) is 38% total solids of which 11% are milk solids,12% milk fat ,15% sugar and 0.3% stabilizers and emulsifiers. It is impossible to state definitely the composition of commercial ice cream, as it depends upon the ingredients used by the manufacturer. The materials used and the formulae adopted vary with the individual responsible, and as a result there is no standard composition (Clarence. et al 1951).In all cases, however, commercial ice cream must contain milk fat, or the fat of milk, the minimum amount being specified by low in most states of the united states. A high grade commercial ice cream will contain 14 per cent milk fat. This means that milk and cream, or milk products, constitute the principal ingredients.

Commercial ice cream, being made principally from milk and cream, will contain in addition to milk fat, milk solids not fat or serum solids. When it is intended to include all the solids contained in ice cream, the term total solids is used, which includes the fat, the milk solids not fat, and all other solids added to ice cream mix from other sources. Sugar is included when the total composition of ice cream is discussed, since it makes up a large portion of the mixture (Clarence et al 1951).

2.4. Quality of dairy products for ice cream

All dairy products used in the manufacture of ice cream should possess a clean, sweet flavor indicative of sanitary methods of production and handling. A high grade ice cream cannot be produced from poor quality raw products. Most off flavors occurring in milk or milk products are intensified after freezing. In some instances they may be masked slightly y making a chocolate or caramel ice cream (Clarence. et al 1951).

2.5. Classification of ice creams

The classification includes those frozen foods commonly prepared by commercial ice cream manufactures. Ice cream and frozen dairy foods are prepared in a variety of ways as to composition, flavor and color, shape and form. A simplified classification is set forth below.

2.5.1. Standard ice cream

The composition of standard ice cream mix is generally made to conform with the legal requirements of state in which it is intended to sell the finished ice cream. There are two in general

2.5.1.1. Types of standard ice cream

A. Standard ice cream of various flavors, vanilla, chocolate, fruits, candies and nuts, etc. The flavor materials are uniformly distributed in the finished ice cream.

B. Variegated or ripple ice cream. This is generally a vanilla ice cream into which flavored syrups and fruit or nut preparations are mechanically injected to produce a variegated or marbalised effect.

2.5.2. Special ice creams

Special ice creams differ from standard ice creams in that they are high in milk fat, color in eggs or in some fruits. Typical of the ice creams that may be grouped in this classification are

2.5.2.1. Types of special ice creams

A. Custard, a highly colored ice cream, which may be or may not above the milk fat content of standard ice cream and usually, contains a liberal portion of whole eggs.

B. Parfait is an ice cream high in milk fat, containing eggs and a liberal amount of fruit or nuts or a combination of each.

C. Bisque ice cream is usually rich in milk fat and flavored with macaroons, grape nuts or cake.

D. Mousse is frozen whipped cream, usually highly flavored (Clarence. et al 1951).

2.6. Categories of ice cream

- Dairy ice cream - a frozen, aerated mixture of dairy ingredients, sugars and flavors.
- Non-dairy ice cream - made with milk proteins and vegetable fat.
- Gelato - an Italian-style custard-based ice cream that contains egg yolks.
- Frozen yoghurt - which may contain lactic acid organisms, or simply yoghurt flavor.
- Milk ice - similar to ice cream, but unaerated and containing less dairy fat.
- Sorbet - fruit based, aerated sugar syrup that contains neither fat nor milk.
- Sherbet - similar to a sorbet, but containing some milk or cream.
- Water ice - frozen sugar syrup with flavor and color, such as an' ice lolly'.
- Fruit ice - similar to water ice, but made with real fruit juice.

2.7. Typical ice cream formulae

Table 2.1 typical ice cream formulae

TYPE OF ICE CREAM	*FAT* %Wt	*MSNF* %Wt	*SUGAR* %Wt	*E/S* %Wt	*WATER* %Wt	*OVRRUN*
Dessert ice	15	10	15	0.35	9.7	110
Ice cream	10	11	14	0.4	64.6	100
Milk ice	4	12	13	0.6	70.4	85
Sherbet	2	4	22	0.4	71.6	50
Water ice	0	0	22	0.2	77.8	0

(Source: Herrington 1948)

Fat -milk, cream, butter, or vegetable fat

Water -flavoring or coloring mater

MSNF -milk solids-not-fat (protein, salts, lactose)

E/S -emulsifier and stabilizer (monoglycerides, gelatin, alginate)

Overrun-the amount of air in the product

Other ingredients-egg, fruit & chocolate pieces may be added during processing

2.8. Ice cream ingredients and their functions

2.8.1. Fat

Fat in general, including that from dairy and non dairy sources is important to ice cream for the following reasons:

- Increases the richness of flavor in ice cream
- Produces a characteristic smooth texture by lubricating the palate
- Helps to give body to the ice cream, due to its role in fat destabilization
- Aids in good melting properties, also due to its role in fat destabilization
- Aids in lubricating the freezer barrel during manufacturing (Non-fat mixes are extremely hard on the freezing equipment)

During freezing of ice cream, the fat emulsion which exists in the mix will partially destabilize or churn as a result of the air incorporation, ice crystallization and high shear forces of the blades. This partial churning is necessary to set up the structure and texture in ice cream. (Arbuckle and Marshall 1996)

2.8.2. Milk Solids-not-fat

The serum solids or milk solids-not-fat (MSNF) contain the lactose, caseins, whey proteins, minerals, and ash content of the product from which they were derived. They are an important ingredient for the following beneficial reasons:

- improve the texture of ice cream, due to the protein functionality
- help to give body and chew resistance to the finished product
- are capable of allowing a higher overrun without the characteristic snowy or flaky textures associated with high overrun, due also to the protein functionality
- may be a cheap source of total solids, especially whey powder

The limitations on their use include off flavors which may arise from some of the products, and an excess of lactose which can lead to the defect of sandiness prevalent when the lactose crystallizes out of solution. Excessive concentrations of lactose in the serum phase may also lower the freezing point of the finished product to an unacceptable level.

The best sources of serum solids for high quality products are:

- Concentrated skimmed milk
- spray process low heat skim milk powder

Other sources of serum solids include: sweetened condensed whole or skimmed milk, frozen condensed skimmed milk, buttermilk powder or condensed buttermilk, condensed whole milk, or dried or condensed whey. Superheated condensed skimmed milk, in which high viscosity is promoted, is sometimes used as a stabilizing agent but does, then, also contribute to serum solids.

It has recently become common practice to replace the use of skim milk powder or condensed skim with a variety of milk powder replacers, which are blends of whey protein concentrates, caseinates, and whey powders. The proteins, which make up approximately 4% of the mix, contribute much to the development of

Structure in ice cream including:

• Emulsification properties in the mix

• whipping properties in the ice cream

• Water holding capacity leading to enhanced viscosity and reduced iciness (Goff 1995).

2.8.3. Sweeteners

A sweet ice cream is usually desired by the consumer. As a result, sweetening agents are added to ice cream mix at a rate of usually 12 - 16% by weight. Sweeteners improve the texture and palatability of the ice cream, enhance flavors, and are usually the cheapest source of total solids.

In addition, the sugars, including the lactose from the milk components, contribute to a depressed freezing point so that the ice cream has some unfrozen water associated with it at very low temperatures typical of their serving temperatures, -15° to -18° C. Without this unfrozen water, the ice cream would be too hard to scoop.

Sucrose is the main sweetener used because it imparts excellent flavor. Sucrose is a disaccharide made up of glucose (dextrose, cerelose), and fructose (levulose). Sucrose is dextrorotatory - meaning it rotates a plane of polarized light to the right, + 66.5°.

It has become common in the industry to substitute all or a portion of the sucrose content with sweeteners derived from corn syrup. This sweetener is reported to contribute a firmer and chewier body to the ice cream, is an economical source of solids, and improves the shelf life of the finished product (Goff 1995).

2.8.4. Stabilizers

The stabilizers are a group of compounds, usually polysaccharide food gums that are responsible for adding viscosity to the mix and the unfrozen phase of the ice cream. This result in many functional benefits, listed below, and also extends the shelf life by limiting ice recrystallization during storage. Without the stabilizers, the ice cream would become coarse and icy very quickly due to the migration of free water and the growth of existing ice crystals. The smaller the ice crystals in the ice cream, the less detectable they are to the tongue. Especially in the distribution channels of today's marketplace, the supermarkets, the trunks of cars, and so on, ice cream has many opportunities to warm up, partially melt some of the ice, and then refreeze as the temperature is once again lowered (see also the discussion on the fundamental aspects of freezing and ice cream shelf life for a more in-depth look at this process, and some discussion regarding the role of stabilizers in inhibiting it). This process is known as heat shock and every time it happens, the ice cream becomes icier tasting. Stabilizers help to prevent this. The functions of stabilizers in ice cream are:

- In the mix: To stabilize the emulsion to prevent creaming of fat and, in the case of carrageenan, to prevent serum separation due to incompatibility of the other polysaccharides with milk proteins, also to aid in suspension of liquid flavors

- In the ice cream at draw from the scraped surface freezer: To stabilize the air bubbles and to hold the flavorings, e.g., ripple sauces, in dispersion

- In the ice cream during storage: To prevent lactose crystal growth and retard or reduce ice crystal growth during storage (see also the discussion on ice cream shelf life, which discusses the mode of action of stabilizers in affecting ice recrystallization), also to prevent shrinkage from collapse of the air bubbles and to prevent moisture migration into the package (in the case of paperboard) and sublimation from the surface

- In the ice cream at the time of consumption: To provide body and mouth feel without being gummy, and to promote good flavor release

The stabilizers in use include Locust Bean Gum, Guar Gum, Carboxymethyl cellulose (CMC), Xanthan gum, Sodium alginate and Carrageenan. Gelatin, a protein of animal origin, was used almost exclusively in the ice cream industry as a stabilizer but has gradually been replaced with polysaccharides of plant origin due to their increased effectiveness and reduced cost (Goff 1995).

2.8.5. Emulsifiers

The emulsifiers are a group of compounds in ice cream which aid in developing the appropriate fat structure and air distribution necessary for the smooth eating and good meltdown characteristics desired in ice cream. Since each molecule of an emulsifier contains a hydrophilic portion and a lypophilic portion, they reside at the interface between fat and water. As a result they act to reduce the interfacial tension or the force which exists between the two phases of the *emulsion*. The emulsifiers actually promote a destabilization of the fat emulsion which leads to a smooth, dry product with good meltdown properties. The original ice cream emulsifier was egg yolk, which was used in most of the original recipes. Today, two emulsifiers predominate in most ice cream formulations are mono- and di-glycerides, Polysorbate 80. (Robinson 1981)

2.8.5.1. Mono- and di-glycerides:

Derived from the partial hydrolysis of fats or oils of animal or vegetable origin

2.8.5.2. Polysorbate 80:

A sorbitan ester consisting of a glucose alcohol (sorbitol) molecule bound to a fatty acid, oleic acid, with oxyethylene groups added for further water solubility. Other possible sources of emulsifiers include buttermilk, and glycerol esters. All of these compounds are either fats or carbohydrates, important components in most of the foods we eat and need. Together, the stabilizers and emulsifiers make up less than one half percent by weight of our ice cream. They are all compounds which have been exhaustively tested for safety and have received the **"generally recognized as safe"** or **GRAS** status (Robinson 1981).

2.8.6. Flavoring

Flavoring additives are very important to the customer's choice of ice cream. The most commonly used flavors are vanilla, nougat, chocolate, strawberry and nut. These can be added at the mixing stage. If flavoring takes the form of larger pieces such as nougat, nuts, fruit or jam, it is added when the mix has been frozen. Cocoa is widely used to give ice cream bars, cones and bricks a coating of chocolate.

2.8.7. Coloring

Coloring agents are added to the mix to give the ice cream an attractive appearance and to improve the colour of fruit flavoring additives. The colouring agent is usually added in the form of a concentrate. Only approved coloring agents and sterilants may be used.

2.9. Physical behavior of dairy ingredients during ice cream processing

Dairy ice cream is a complex matrix consisting of ice, air, fat and the concentrated unfrozen serum. The formulation and stability of the ice cream emulsion is an integral part of ice cream manufacture and has a significant effect on the properties of the final ice cream. The stability of emulsions is influenced by the surface coverage of the fat globule, the dimensions of the adsorbed layer and the surface viscosity. The ability of a protein to form and stabilize an emulsion is dependent on its ability to adsorb, rapidly unfold and spread at the droplet interface. During emulsification of the ingredients (i.e. Before heating), caseins are preferentially transferred to the oil - water interface in comparison to whey proteins, dominating the adsorbed layer thickness and producing a stabilizing layer. Upon heating, the whey proteins competitively displace the caseins from the interface except κ-casein which resists displacement due to complex formation with β-lactoglobulin. Agitating during aging of the ice cream mix prior to freezing sets up the ice cream structure as it results in fat destabilization and the partial coalescence of globules that leads to the formation of a fat network. The agglomerated fat network is capable of stabilizing the foam lamellae and reducing drainage which leads to increased melt resistance in ice cream (Udabage. et al 2005).

2.10. Ice cream manufacturing process

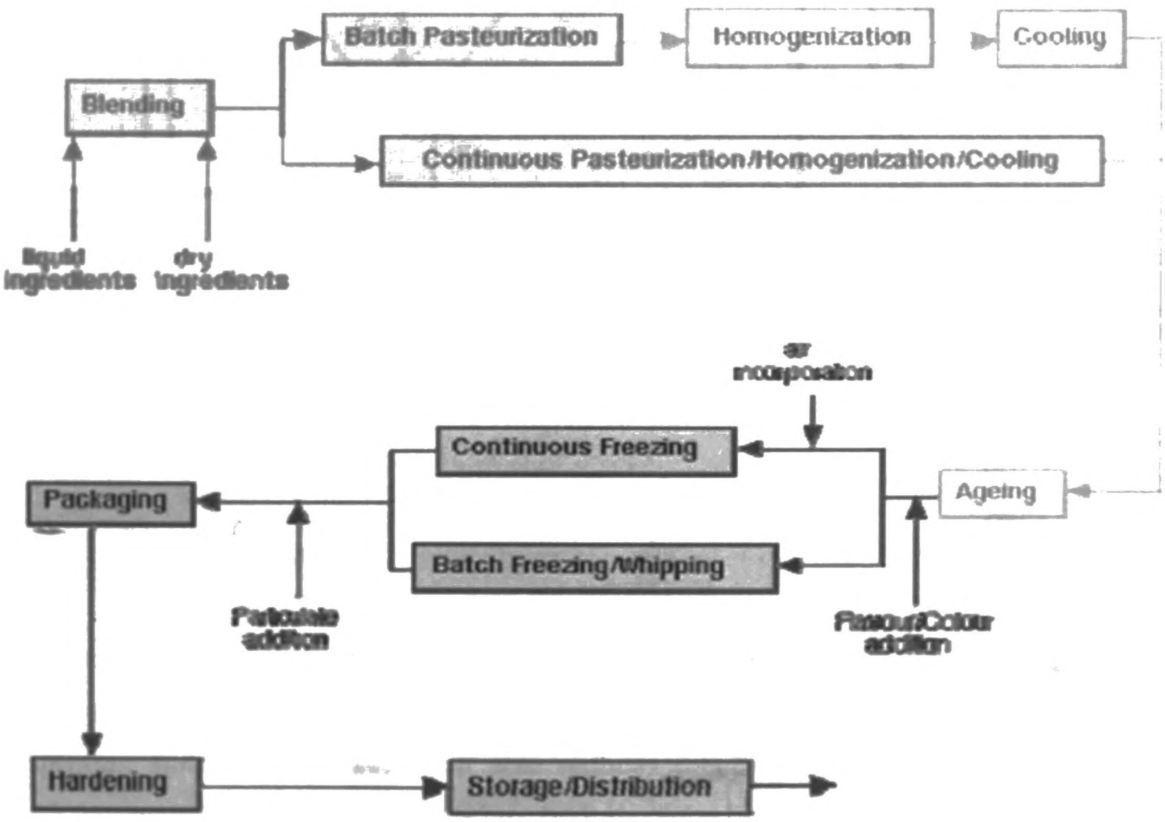

Fig. 2.1.Ice cream manufacturing process

(Source: Goff 1995)

2.10.1. Blending

First the ingredients are selected based on the desired formulation and the calculation of the recipe from the formulation and the ingredients chosen, then the ingredients are weighed and blended together to produce what is known as the "ice cream mix".

Blending requires rapid agitation to incorporate powders, and often high speed blenders are used.

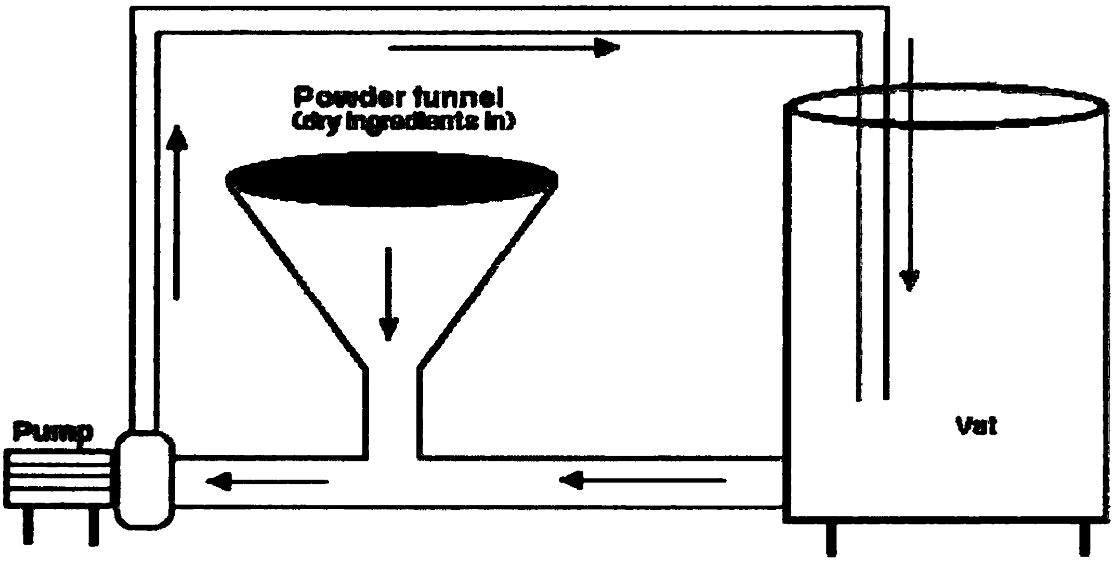

Fig. 2.2.Ice Cream ingredients blending

(Goff 1995)

2.10.2. Pasteurization

The mix is then pasteurized. Pasteurization is the biological control point in the system, designed for the destruction of pathogenic bacteria. In addition to this very important function, pasteurization also reduces the number of spoilage organisms such as psychrotrophs, and helps to hydrate some of the components (proteins, stabilizers).

Pasteurization: 69° C/30 min. 80° C/25s

Both batch pasteurizers ~~and continuous~~ (HTST) methods are used.

Batch pasteurizers lead to more whey protein denaturation, which some people feel gives a better body to the ice cream. In a batch pasteurization system, blending of the proper ingredient amounts is done in large jacketed vats equipped with some means of heating, usually steam or hot water. The product is then heated in the vat to at least 69 C (155 F) and held for 30 minutes to satisfy legal requirements for pasteurization, necessary for the destruction of pathogenic bacteria. Various time temperature combinations can be used. The heat treatment must be severe enough to ensure destruction of pathogens and to reduce the bacterial count to a maximum of 100,000 per gram. Following pasteurization, the mix is homogenized by means of high pressures and then is passed across some type of heat exchanger (plate or double or triple tube) for the purpose of cooling the mix to refrigerated temperatures (4 C). Batch tanks are usually operated in tandem so that one is holding while the other is being prepared. Automatic timers and valves ensure the proper holding time has been met.

Continuous pasteurization is usually performed in a high temperature short time (HTST) heat exchanger following blending of ingredients in a large, insulated feed tank. Some preheating, to 30 to 40 C, is necessary for solubilization of the components. The HTST system is equipped with a heating section, a cooling section, and a regeneration section. Cooling sections of ice cream mix HTST presses are usually larger than milk HTST presses. Due to the preheating of the mix, regeneration is lost and mix entering the cooling section is still quite warm.

2.10.3 Homogenization

The mix is also homogenized which forms the fat emulsion by breaking down or reducing the size of the fat globules found in milk or cream to less than 1 μ m. Two stage homogenization is usually preferred for ice cream mix. Clumping or clustering of the fat is reduced thereby producing a thinner, more rapidly whipped mix. Melt-down is also improved. Homogenization provides the following functions in ice cream manufacture:

- Reduces size of fat globules
- Increases surface area
- Forms membrane
- Makes possible the use of butter, frozen cream, etc.

By helping to form the fat structure, it also has the following indirect effects:

- Makes a smoother ice cream
- Gives a greater apparent richness and palatability
- Better air stability
- Increases resistance to melting

Homogenization of the mix should take place at the pasteurizing temperature. The high temperature produces more efficient breaking up of the fat globules at any given pressure and also reduces fat clumping and the tendency to thick, heavy bodied mixes. No one pressure can be recommended that will give satisfactory results under all conditions. The higher the fat and total solids in the mix, the lower the pressure should be. If a two stage homogenizer is used, a pressure of 2000 - 2500 psi on the first stage and 500 - 1000 psi on the second stage should be satisfactory under most conditions. Two stage homogenization is usually preferred for ice cream mix. Clumping or clustering of the fat is reduced thereby producing a thinner, more rapidly whipped mix. Melt-down is also improved.

2.10.4. Ageing

The mix is then aged for at least four hours and usually overnight. This allows time for the fat to cool down and crystallize, and for the proteins and polysaccharides to fully hydrate. Aging provides the following functions:

- Improves whipping qualities of mix and body and texture of ice cream

It does so by:

- Providing time for fat crystallization, so the fat can partially coalesce;
- Allowing time for full protein and stabilizer hydration and a resulting slight viscosity increase;
- Allowing time for membrane rearrangement and protein/emulsifier interaction, as emulsifiers displace proteins from the fat globule surface, which allows for a reduction in stabilization of the fat globules and enhanced partial coalescence.

Aging is performed in insulated or refrigerated storage tanks, silos, etc. Mix temperature should be maintained as low as possible without freezing, at or below 5 C. An aging time of overnight is likely to give best results under average plant conditions. A "green" or unaged mix is usually quickly detected at the freezer.

2.10.5. Freezing and Hardening

Following mix processing, the mix is drawn into a flavor tank where any liquid flavors, fruit purees, or colors are added. The mix then enters the dynamic freezing **process** which both freezes a portion of the water and whips air into the frozen mix. The "barrel" freezer is a scraped-surface, tubular heat exchanger, which is jacketed with a boiling refrigerant such as ammonia or Freon. Mix is pumped through this freezer and is drawn off the other end in a matter of 30 seconds, with about 50% of its water frozen. There are rotating blades inside the barrel that keep the ice scraped off the surface of the freezer and also dashers inside the machine which help to whip the mix and incorporate air.

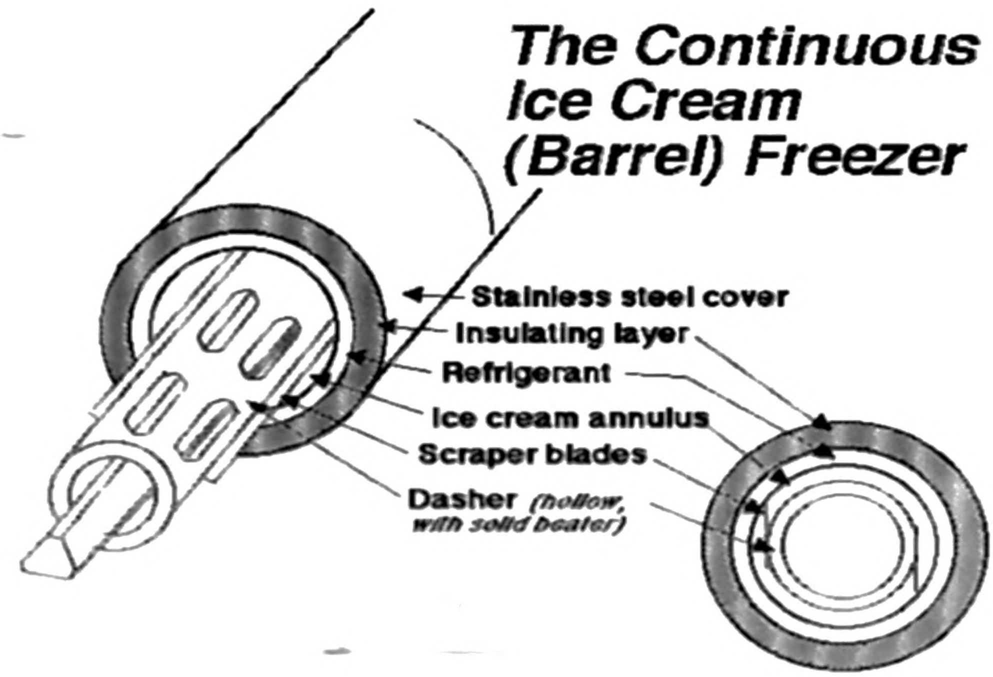

Fig. 2.3.continuous barrel freezer

(Source: Goff 1995)

Ice cream contains a considerable quantity of air, up to half of its volume. This gives the product its characteristic lightness. Without air, ice cream would be similar to a frozen ice cube. The air content is termed its overrun, which can be calculated mathematically.

As the ice cream is drawn with about half of its water frozen, particulate matter such as fruits, nuts, candy, cookies, or whatever you like, is added to the semi-frozen slurry which has a consistency similar to soft-serve ice cream. In fact, almost the only thing which differentiates hard frozen ice cream from soft-serve, is the fact that soft serve is drawn into cones at this point in the process rather than into packages for subsequent hardening.

2.10.6. Hardening

After the particulates have been added, the ice cream is packaged and is placed into a blast freezer at -30° to -40° C where most of the remainder of the water is frozen. Below about -25° C, ice cream is stable for indefinite periods without danger of ice crystal growth; however, above this temperature, ice crystal growth is possible and the rate of crystal growth is dependant upon the temperature of storage. This limits the shelf life of the ice cream.

Hardening involves static (still, quiescent) freezing of the packaged products in blast freezers. Freezing rate must still be rapid, so freezing techniques involve low temperature (-40oc) with either enhanced convection (freezing tunnels with forced air fans) or enhanced conduction.

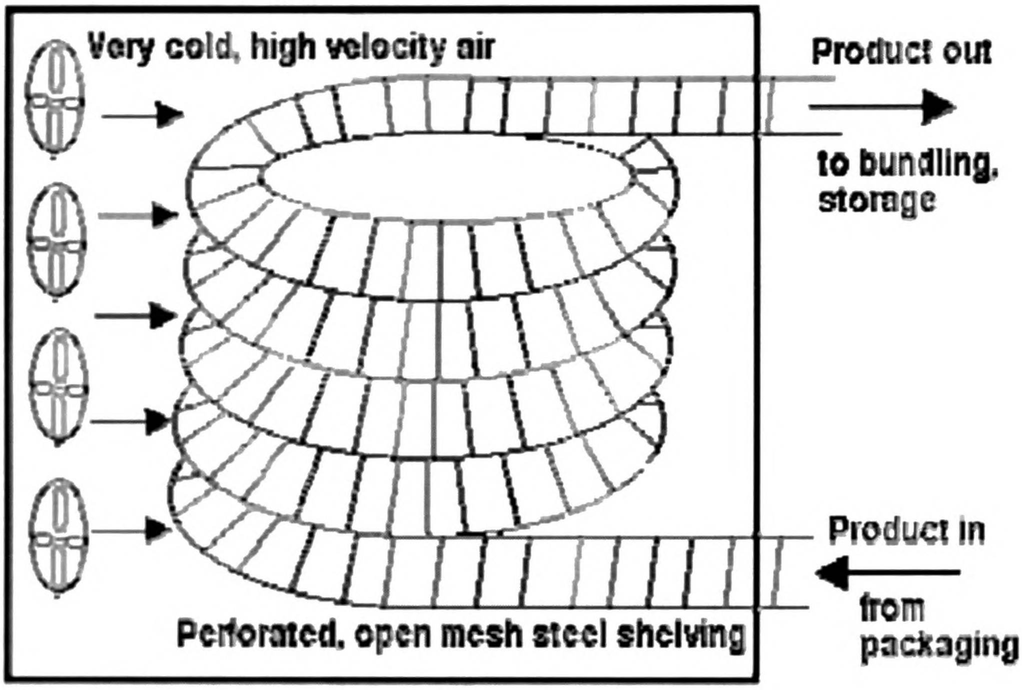

Fig. 2.4.Ice Cream hardening tunnel

(Source: Goff 1995)

The rate of heat transfer in a freezing process is affected by the temperature difference, the surface area exposed and the heat transfer coefficient. Thus, the factors affecting hardening are those affecting this rate of heat transfer:

- Temperature of blast freezer - the colder the temperature, the faster the hardening, the smoother the product.
- Rapid circulation of air - increases convective heat transfer.
- Temperature of ice cream when placed in the hardening freezer - the colder the ice cream at draw, the faster the hardening; - must get through packaging operations fast.
- Size of container - exposure of maximum surface area to cold air, especially important to consider shrink wrapped bundles - they become a much larger mass to freeze. Bundling should be done after hardening.
- Composition of ice cream - related to freezing point depression and the temperature required to ensure a significantly high ice phase volume.

- Method of stacking containers or bundles to allow air circulation. Circulation should not be impeded - there should be no 'dead air' spaces (e.g., round vs. Square packages).
- Care of evaporator - freedom from frost - acts as insulator.
- Package type, should not impede heat transfer - e.g., styrofoam liner or corrugated cardboard may protect against heat shock after hardening, but reduces heat transfer during freezing so not feasible.

2.11. What is overrun?

Overrun, expressed as percentage, is generally defined as the volume of ice cream obtained in excess of the volume of the ice cream mix. The excess volume is composed mainly of the air incorporated during the freezing process. The over run due to air provides proper body, texture and palatability essential to a good quality product. Too much and too little quantity of air incorporation will affect the body, texture and palatability. The softy ice cream, ice cream packaged in bulk and retail packed ice cream will have over run of 30-50%, 90-100% and 70-80% respectively.

A guide for maximum overrun

(Fat+ MSNF+ Total solids) x2=%overrun

2.11.1. Overrun calculation

$$\text{Overrun} = \frac{(\text{Weight of ice cream mix used} - \text{Weight. Of ice cream})}{\text{Weight of Ice cream}} \times 100\%$$

2.12. Ice Cream Shelf-Life

The most frequently occurring textural defect in ice cream is the development of a coarse, icy texture. Iciness is also the primary limitation to the shelf life of ice cream and probably also accounts for countless lost sales through customer dissatisfaction with quality. There is no answer to the question "What is the shelf-life of ice cream?", it depends entirely on its conditions of storage. It might be one year, or it might be two weeks or less. Although the source of and the contributing factors to the problem of iciness are well known, it is also one of the defects about which I am most often asked.

Processors have known for a long time how to prevent iciness and the answer is still the same: formulate the ice cream properly to begin with, freeze the ice cream quickly in a well-maintained barrel freezer, harden the ice cream rapidly, and avoid as much as possible temperature fluctuations during storage and distribution. Ice crystals need to be numerous and of small, uniform size so they are not detected when eaten. It is heat shock, large temperature fluctuations, which is the greatest culprit to the loss of these small, uniform ice crystal size distributions and resulting coarse, icy texture. Perhaps it is time another message was added to the prevention of iciness and that is to educate the retailer's and the consumer about the causes of iciness and preventative action to maintain a smooth-textured ice cream.

2.12.1. Maintaining Shelf-life

A. Formulate the ice cream properly
- Freezing point depression and sugar considerations
- Stabilizers

B. Freeze the ice cream quickly in a well-maintained barrel freezer
- Continuous freezers with high rates of heat exchange
- Free of fouling (eg., oil) on refrigerant side
- Blades with a good, even edge
- Short, insulated process lines through ingredient feeder, packaging equipment
- Precooling of ingredients

C. Harden the ice cream rapidly
- High rates of heat transfer: convection (high ΔT and forced air with free air flow) or conduction
- Importance of thermal centre and shrink-wrapping of bundles

D. Avoid temperature fluctuations during storage and distribution
- Importance of low, constant temperatures
- Avoid mishandling at all stages

E. Educate retailers and consumers about shelf stability
-Mishandling is usually not at the manufacturing level but quality losses affect consumer acceptance of your product.

2.13. Ice cream structure

Ice cream structure is both fascinating and confusing. The way we perceive the texture of ice cream when we consume it (smooth, coarse, etc.) Is based on its structure, and thus structure is probably one of its most important attributes.

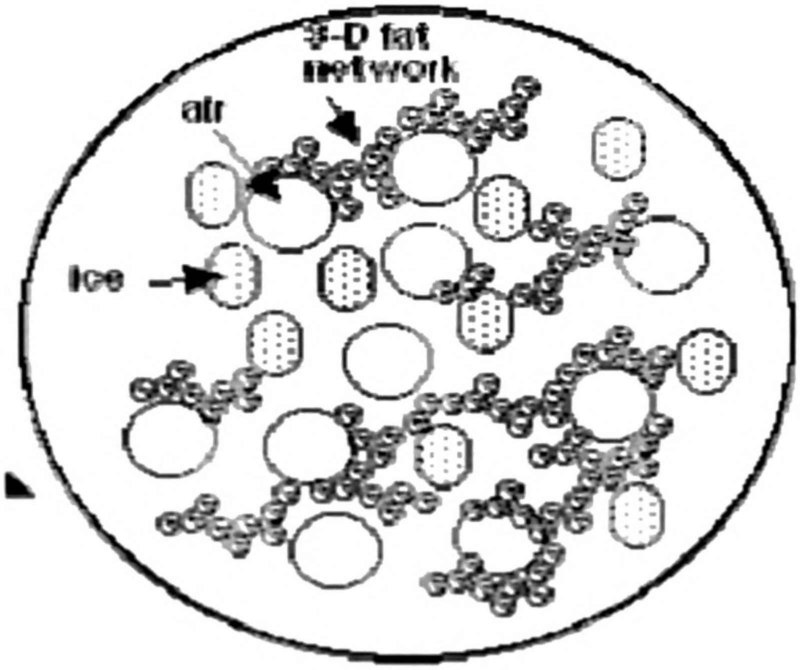

Fig.2.5. Ice Cream structure

(Source: Goff 1995)

Ice cream is both an emulsion and a foam. The milk fat exists in tiny globules that have been formed by the homogenizer. There are many proteins that act as emulsifiers and give the fat emulsion its needed stability. The emulsifiers are added to ice cream to actually reduce the stability of this fat emulsion by replacing proteins on the fat surface, leading to a thinner membrane more prone to coalescence during whipping. When the mix is subjected to the whipping action of the barrel freezer, the fat emulsion begins to partially break down and the fat globules begin to flocculate or destabilize. The air bubbles which are being beaten into the mix are stabilized by this partially coalesced fat. If emulsifiers were not added, the fat globules would have so much ability to resist this coalescing, due to the proteins being adsorbed to the fat globule, that the air bubbles would not be properly stabilized and the ice cream would not have the same smooth texture (due to this fat structure) that it has. (Goff 1995)

2.14. Fat

Fats consist of a wide group of compounds that are generally soluble in organic solvents and largely insoluble in water. Chemically, fats are generally triesters of glycerol and fatty acids. Fats may be either solid or liquid at normal room temperature, depending on their structure and composition. Although the words "oils", "fats", and "lipids" are all used to refer to fats, "oils" is usually used to refer to fats that are liquids at normal room temperature, while "fats" is usually used to refer to fats that are solids at normal room temperature. "Lipids" is used to refer to both liquid and solid fats, along with other related substances.

2.14.1. Fat in ice cream

Fat used for ice cream manufacturing can either be dairy or non dairy. Non airy fat includes vegetable fat while dairy fat is butter, cream and anhydrous milk fat. Dairy or non dairy fat forms a network within the ice cream upon partial coalescence.

This fat structure which exists in ice cream is the same type of structure which exists in cream during freezing of ice cream; the fat emulsion which exists in the mix will partially destabilize or churn as a result of the air incorporation, ice crystallization and high shear forces of the blades. This partial churning is necessary to set up the structure and texture in ice cream.

2.14.2. Milk fat

Milk fat is generally regarded as being of complex composition. Triacylglycerols are dominant and constitute approximately 98 per cent of milk fat, together with small amounts of di- and triacylglyceroles and free fatty acids. Measurable quantities of phospolipids, cholesterol and cholesterol esters and cerebrosides are also present (Table 2.2).Other ingredients are present only in very small quantities but may be of importance in determining the organoleptic character and nutritional status of milk. These are the fat soluble vitamins, mainly A, D and E, together with small quantities of vitamin K, flavor components, identified ad aldehydes, ketones and lactones and carotinoid pigments. . (Varnam and Sutcherland 1994)

Table 2.2 Lipids present in milk fat by percentage

Lipid	*% by weight*
Triacylglyceroles	97-98
Diacylglyceroles	0.3-0.6
Monoacylglyceroles	0.02-0.04
Free fatty acids	0.1-0.4
Free sterols	0.2-0.4
Sterol esters	Trace only
Phospholipids	0.2-1.0
Hydrocarbons	Trace only

(Source: Varnam and Sutcherland 1994)

2.14.3. Vegetable fat

Vegetable (non-dairy) fats are used extensively as fat sources in ice cream in the United Kingdom, parts of Europe, the Far East, and Latin America but only to a very limited extent in North America. Five factors of great interest in selection of fat source are the crystal structure of the fat, the rate at which the fat crystallizes during dynamic temperature conditions, the temperature-dependent melting profile of the fat, especially at chilled and freezer temperatures, the content of high melting triglycerides (which can produce a waxy, greasy mouth feel) and the flavor and purity of the oil. It is important that the fat droplet contain an intermediate ratio of liquid: solid fat at the time of freezing. It is difficult to quantify this ratio as it is dependent on a number of composition and manufacturing factors, however, 1/2 to 2/3 crystalline fat at 4-5oc is a good, working rule. Palm oil and palm kernel oil are common in the manufacture of non dairy ice cream as well as in other food manufacturing processes such as bakery products.

Table 2.3 Typical percentage composition and iodine value of milk and vegetable fat triacylglycerols

Typical percentage composition and iodine value			
Fatty acid	Butter	Palm oil	Palm kernel oil
Butyric4	3	-	-
Caproic6	3	-	-
Caprylic8	2	-	3
Capric10	3	-	4
Lauric12	3	-	51
Myristic14	10	1	17
Myristoleic14	1	-	-
Palmitic16	26	48	8
Palmitoleic16	1	-	-
Stearic18	15	4	2
Oleic18	29	38	13
Linoleic18	2	9	2
Linolenic18	2	-	-
Iodine value	35	51	16

(Source: Potter 1978)

2.14.4. Melting and crystallization of milk fat triacylglycerols

The melting and crystallization properties of milk fat are of major importance in determining the physical attributes of high-fat dairy products such as butter and ice cream. Melting behavior is complex as a result of the complex nature of the fatty acid composition of the triglycerides. Melting commences at a particular temperature and is complete at another particular temperature depending on the type of fat; for instance melting of mil fat commences at -40^{0}C and is complete at +40^{0}C.at any intermediate temperature, both liquid and solid fat is present; the ratio of solid to liquid, at any given temperature, largely determining the rheological properties of the milk fat.

Crystallization commences as the temperature of the liquid fat is reduced. The first stage, nucleation, requires a considerable degree of super cooling and, when fat is cooled in bulk, occurs at the surface of impurities (heterogeneous nucleation).the second stage, crystal growth, tends to be slow because of competitive inhibition,a process whereby a triacylglycerol not sufficiently similar to those already present is rejected at the surface of the growing crystals. Although significant in terms of slowing crystal growth, competitive inhibition is of less importance in milk fats than other crystal systems due to the general level of similarity between the triacylglycerole species. The formation of mixed crystals, containing more than one triacylglycerol species is common and the melting behavior of milk fat has been explained in terms of the formation of a series of mixed crystals with extensively overlapping melting ranges (Varnam and Sutcherland 1994).

2.14.5. Melting point of fat

The melting point of a fat is a measure of the bonding forces between fatty acids within the crystals. The greater the attraction between molecules, the less they need to be slowed down (by removal of heat) in order to crystallize. Fats that contain such molecules have melting points. Much less energy in the form of heat is needed to melt the crystals of the latter; that is, they have a lower melting point. The melting points of the glycerides that make up a fat determine whether the fats will e a liquid, a plastic solid, or hard and brittle at room temperature. The consistency of a fat influences its functional properties in preparation. Characteristic of fatty acids that influence the attractive forces between adjacent molecules of fat within the crystal are the length of the carbon chain, the number of double bonds in the chain, and whether the unsaturated fatty acids is in cis or trans form(Charley and Weaver 1998).

The longer the chain, the higher is the melting point of the compound.

Table 2.4 Melting point of fatty acids

Fatty acid	Number of carbons	Melting point(°c)
Butyric	4	- 4.5
Stearic	18	71.2

(Source: Charley and Weaver 1998)

Buturic acid liquifies at a temperature below the freezing point of water, yet stearic acid is still in crystalline form at room temperature.

The melting point decreases with an increase in the number of double bonds. Unsaturated fatty acids do not fit together well enough for maximum attraction because of the blends in the carbon chain at the double bonds. The greater the number of double bonds, the poorer the fit. (Charley and Weaver 1998).

Table 2.5 Melting point vs Unsaturation of fatty acids

Fatty acid	Number of double bonds	Melting point(°c)
Stearic	0	71.5oc
Oleic	1	16.3
Linoleic	2	-5
Linolenic	3	-11.3

(Source: Charley and Weaver 1998)

2.14.6. Physical characteristics of food fats

Table 2.6 Solid fat index of fats

Fat	Solid fat index at °c					
	10	21	27	33	38	melting point °c (Capillary)
Butter	32	12	9	3	0	36
Cocoa butter	62	48	8	0	0	29
Coconut oil	55	27	0	0	0	26
Lard	25	20	12	4	2	43
Palm oil	34	12	9	6	4	39
Palm kernel oil	49	33	13	0	0	29
Tallow	39	30	28	23	18	48

(Source: Potter 1978)

2.14.7. Typical percentage composition and iodine value of butter, palm oil and palm kernel oil

Table 2.7 Typical percentage composition and iodine value of fatty acids

Typical percentage composition and iodine value				
Fatty acid	Carbon atoms	Butter	Palm oil	Palm kernel oil
Butyric	4	3	-	-
Caproic	6	3	-	-
Caprylic	8	2	-	3
Capric	10	3	-	4
Lauric	12	3	-	51
Myristic	14	10	1	17
Myristoleic	14	1	-	-
Palmitic	16	26	48	8
Palmitoleic	16	1	-	-
Stearic	18	15	4	2
Oleic	18	29	38	13
Linoleic	18	2	9	2
Linolenic	18	2	-	-
Iodine value		35	51	16

(Source: Potter 1978)

2.14.8. Fat Destabilization

While homogenization is the principal method for achieving stabilization of the fat emulsion in milk, fat destabilization is necessary for structure formation in butter, whipping cream and ice cream. Fat destabilization refers to the process of clustering and clumping (partial coalescence) of the fat globules which leads to the development of a continuous internal fat network or matrix structure in the product. Fat destabilization (sometimes "fat agglomeration") is a general term that describes the summation of several different phenomena.

2.14.8.1Coalescence

An irreversible increase in the size of fat globules and a loss of identity of the coalescing globules

2.14.8.2 Flocculation

A reversible (with minor energy input) agglomeration/clustering of fat globules with no loss of identity of the globules in the floc; the fat globules that flocculate; they can be easily redispersed if they are held together by weak forces, or they might be harder to redisperse to they share part of their interfacial layers;

2.14.8.3 Partial coalescence

An irreversible agglomeration/clustering of fat globules, held together by a combination of fat crystals and liquid fat, and a retention of identity of individual globules as long as the crystal structure is maintained (i.e., temperature dependent, once the crystals melt, the cluster coalesces). They usually come together in a shear field, as in whipping, and it is envisioned that the crystals at the surface of the droplets are responsible for causing colliding globules to stick together, while the liquid fat partially flows between they and acts as the "cement". Partial coalescence dominates structure formation in whipped, aerated dairy emulsions, and it should be emphasized that crystals within the emulsion droplets are responsible for its occurrence. (Arbuckle and Marshall 1996)

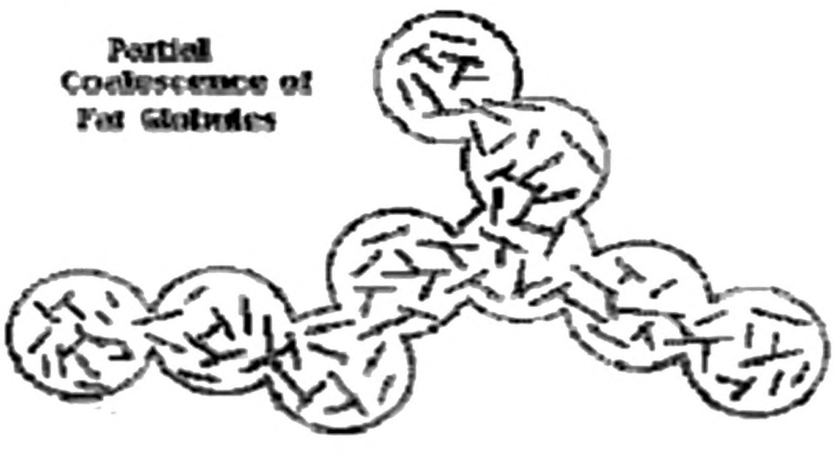

Fig. 2.6 partial coalescence of fat

(Source: Goff 1995)

2.14.9. Fat structure in ice cream

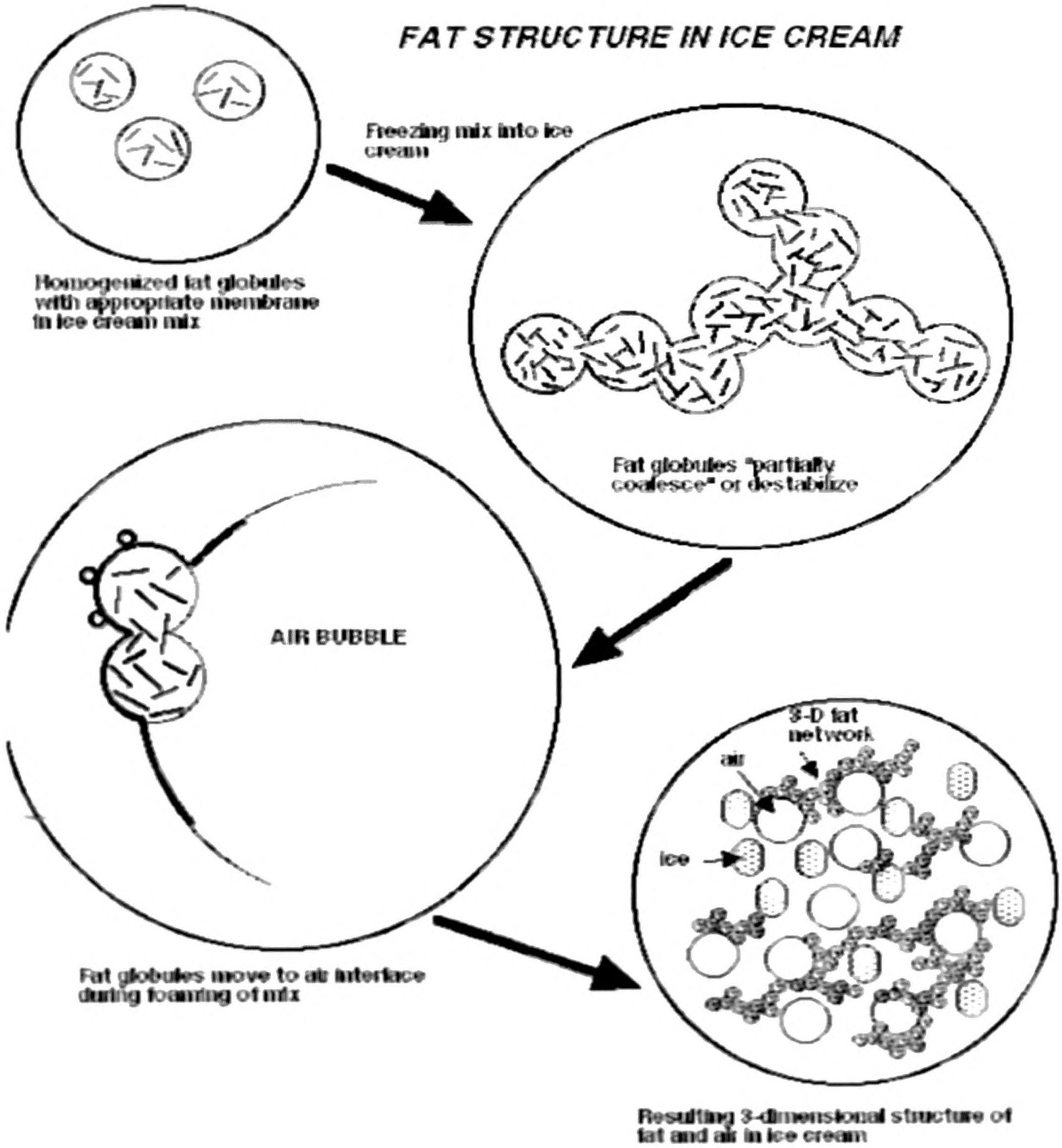

Fig. 2.7 Fat structure in ice cream

(Source: Goff 1995)

2.15. Palm-based Non-dairy Ice Cream

Non-dairy ice cream is also a common feature in many countries and in the US such products are termed as 'mellorine'. These are frozen products, which differ from ice cream in such a way that the milk fat is replaced with suitable vegetable fats. Palm-based non-dairy ice cream is formulated using palm-based fats to replace milk fat. These palm-based fats are functionally and nutritionally desired and have become a common ingredient in non-dairy ice cream products in many parts of the world. Palm kernel oil and palm oil are commonly used in the manufacture of palm based non dairy ice cream.

2.16. Advantages of Using Palm based Non-dairy Ice Cream

A fat base with sharp melting properties at body temperature is highly desirable to ensure good organoleptic characteristics. Palm-based fats can be formulated with less than 5% solids at body temperature. For persons who are lactose intolerant, palm-based non-dairy ice cream formulated with reduced milk fats and milk solids can be a desirable product. Milk fat is an expensive ingredient in many developing countries and palm based fats provide an inexpensive, yet high quality, alternative. (Goff 1995)

CHAPTER 03

MATERIAL AND METHODOLOGY

3.1. Materials

3.1.1. Materials for the estimation of slip melting point of fat varieties

500 ml glass beaker
Capillary tube
Mercury thermometer
Raw Water (25°C)
Stirrer
Holding stand
Water bath
Piece of thread

3.1.2. Materials for the preparation of samples

Ingredients	**Equipments**
Skimmed milk powder	Mixing vat
Raw bovine milk	Pasturizer
Whey Powder	Homogenizer
Vegetable fat	Aging vat
Water	Freezer
Emulsifier/stabilizer system	Plastic ice cream containers
Vanilla flavors	Hardening tunnel
	Deep freezer

3.1.3. Materials for determining the melting resistance

Ice cream samples
Analytical scale (accuracy 0.0001g)
Plastic container
Stainless steel wire mesh of 5mm square size

Holding stand

Temperature controlled room (21 ±1°C)

Stop watch

Knife

3.1.4. Materials for Sensory Evaluation

Temperature controlled room (Air conditioned)

Sensory evaluation ballot paper

Coded ice cream samples

Paper Serviette

Glasses of portable water

Spoons

3.2. Methodology

3.2.1. Preparation of fat blend for determining slip melting point.

Fat blend was prepared according to the milk fat: palm kernel oil ratio in the recipe; 29%:71%

Cream sample was taken and heated to 85 °C and remaining milk was removed. During heating milk contained in the cream is clotted

Pure milk fat was solidified by cooling.

From the solidified milk fat and palm kernel oil was mixed according to the ratio in the recipe and heated to ensure complete mixing

Heated fat blend was cooled.

Slip melting point of fat blend was determined by the following mentioned procedure. (See fig.3.1)

3.2.2. Estimating slip melting point

Glass beaker was filled with water at 25 °C. And placed on the water bath

Around 1 mm high fat column was inserted in to the capillary tube without trapping air within the fat column by inserting capillary tube in the fat

Capillary tube was tied with the thermometer by the thread so as to fat column remains in the middle of the mercury bulb.

Thermometer was dipped in the water filled beaker and held immobile by using the stand (see fig.3.1)

Water bath was switched on and water was stirred until the fat column start to ascend along the capillary tube.

At the moment fat column starts to ascend along the capillary tube, thermometer reading was taken.

Above procedure was repeated to palm oil and palm kernel oil.

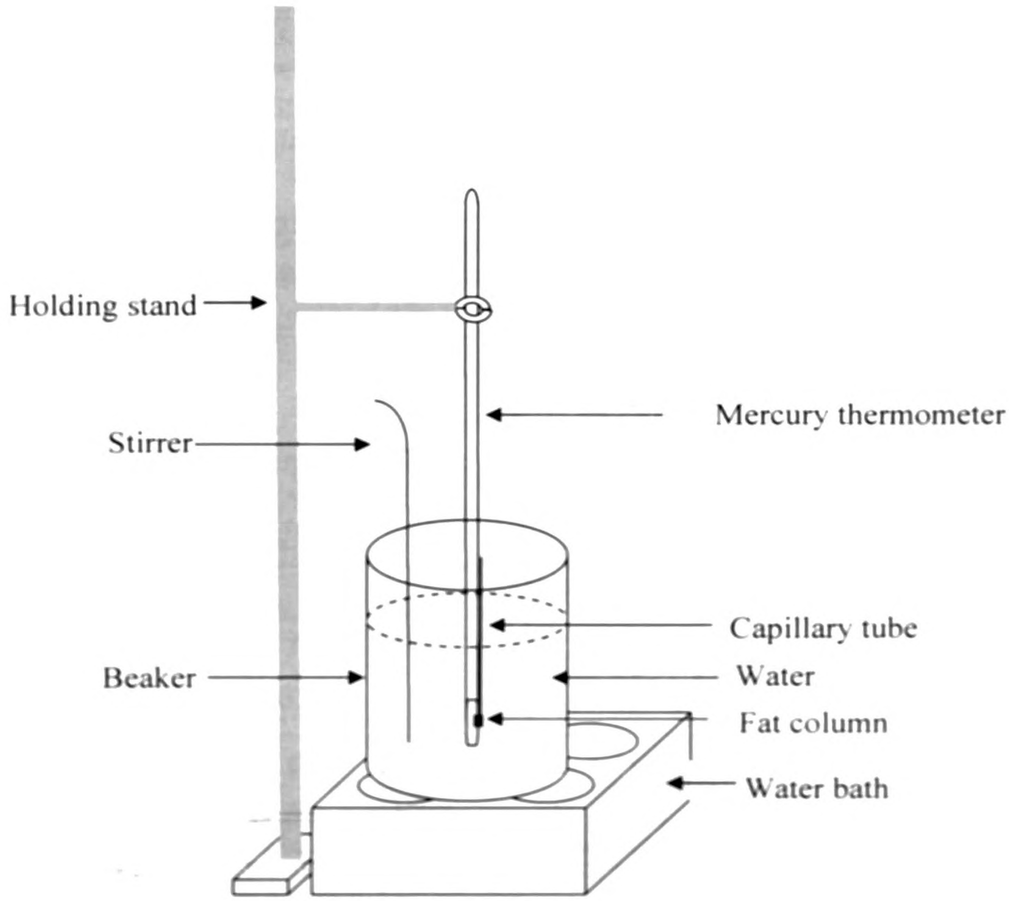

Fig.3.1 Estimation of slip melting point of fat

3.2.3. Sample preparation for the determination of melting resistance

According to the following recipes samples were prepared by the procedure motioned under procedure 3.2.6

All the ingredients weights were to prepare 1500 ml of vanilla ice cream mix.

Ice cream mix Recipe for sample with fat blend (palm kernel oil and raw milk)

Table 3.1 Ice cream mix Recipe for sample with fat blend

Ingredient	Percentage(Wt/Wt)
Raw Milk (L.R=1.024,Fat=3.9% ,TS=7.57%)	68.89
Solids-Not-Fat	5.81
Sugar	15.3
Emulsifier/stabilizer	0.38
Water	3.6
Fat	6.36
Total solids	35.5

Table 3.2 Ice cream mix Recipe for sample with palm kernel oil

Ingredient	Percentage(Wt/Wt)
Fat(Palm kernel oil)	9.0
Solids-Not-Fat	10.8
Sugar	15.3
Emulsifier/stabilizer	0.38
Water	64.45
Total solids	35.5

Table 3.3 Ice cream mix Recipe for sample with palm oil

Ingredient	Percentage(Wt/Wt)
Fat(Palm oil)	9.0
Solids-Not-Fat	10.8
Sugar	15.3
Emulsifier/stabilizer	0.38
Water	64.45
Total solids	35.5

3.2.4. Procedure for ice cream samples preparation

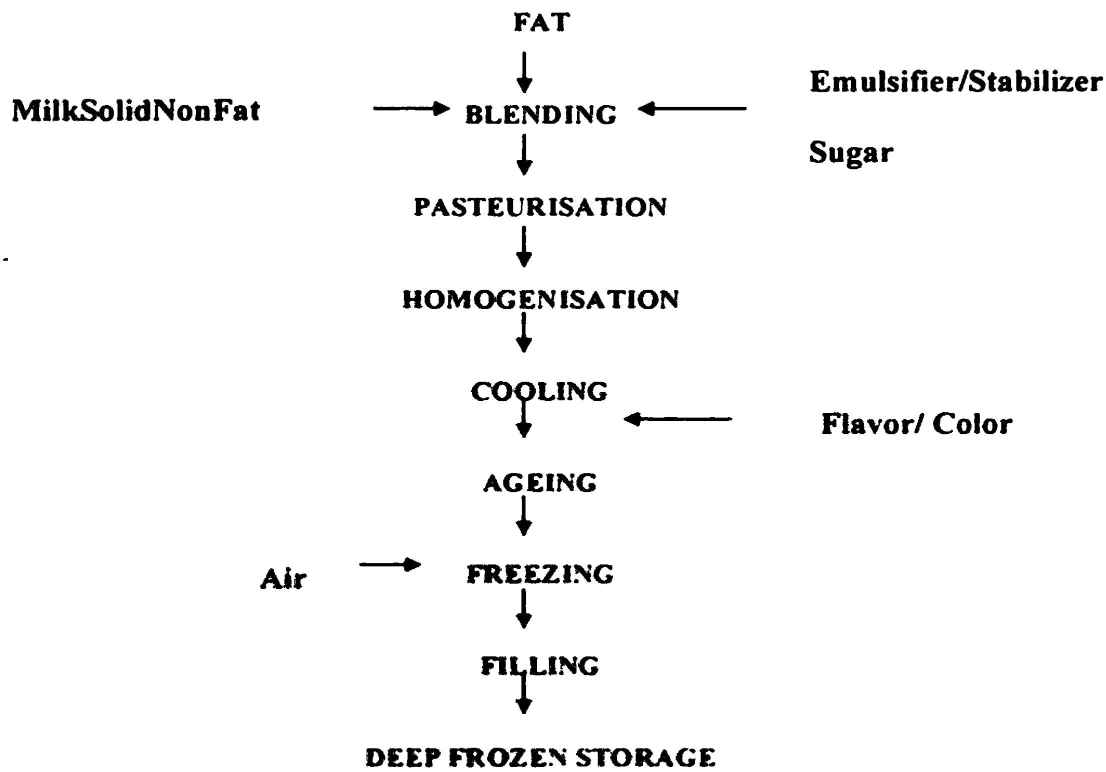

Fig.3.2 process flow chart of ice cream sample preparation

In the preparation of ice cream mix completely with vegetable fat (palm oil and palm kernel oil), first the ingredients were weighed according to the recipe. Fat was melted in a stainless steel tank by heating to 90 °C. Heated water to 85 °C was pumped into the mixing vat.(heated water in the mixing vat was circulated through the feeding cone and returns to the mixing vat. during feeding, ingredients were added to this circulating hot water.)Weighed skimmed milk powder was put through the feeding cone into circulating water .during feeding the ingredients; melted fat was transferred to the mixing vat. Weighed sugar was added to the circulating mix. While feeding sugar, emulsifier/stabilizer and whey powder was mixed with sugar.

Once mixing was completed, the ice cream mix was moved to the pasturiser .in the pasturiser, ice cream mix was subjected to 83 °C for 20 sec time temperature combination. Ice cream mix subjected to homogenizer and mix was homogenized under 2000 psi. Homogenized mix was sent to aging vat and aged for 6 hours at 4.2 °C.

Aged mix was sent to the freezer and ice cream was drawn out from the freezer to plastic containers. Temperature of ice cream at the moment of drawing from the freezer was -7.2 °C.

During preparing the samples with raw milk, first measured volume of raw milk (preheated) was transferred to the mixing vat. Melted vegetable fat pumped into the mixing vat. Weighed skimmed milk powder was put through the feeding cone into circulating mix (milk, water and fat).then the other ingredients were added to the mix as mentioned in the preparation of ice cream mix completely with vegetable fat. Upon mixing

The ice cream mix was transferred to the pasturiser following the homogenizer. Pasteurization and homogenization conditions were sans as previous. Homogenized mix was transferred to the aging vat and aged for 6 hours at 4.2 °C.

Aged mix was sent to the freezer and ice cream was drawn out from the freezer to plastic containers. Temperature of ice cream at the moment of drawing from the freezer was -7.2 °C.

3.2.5. Obtaining samples with different overruns.

The amount of air incorporated in to the ice cream in the freezer was altered to prepare samples with 100%, 110%, 120% and 140% overruns.

3.2.6 Determining melting resistance

Wire mesh was held straight above the electronic balance with the aid of holding stand (see figure 3.2)

Plastic container was placed on the electronic scale and scale was started.

Ice cream cube (6 cm±0.5 cm, length 3 cm ±0.5 cm, width, and 3.5 ±0.5 cm height) was cut with a knife and weighed.

Weighed sample was placed on the wire mesh so as to collect the drip losses into the plastic container placed on the scale and stop watch was started

The plastic container was placed on the scale collect and weighs the drip losses

Scale reading was recorded every other two minutes for a period of 74 minutes

Above procedure was repeated with four samples from each overrun of three fat varieties.

A Graph was plotted with time vs. melted ice cream weight.

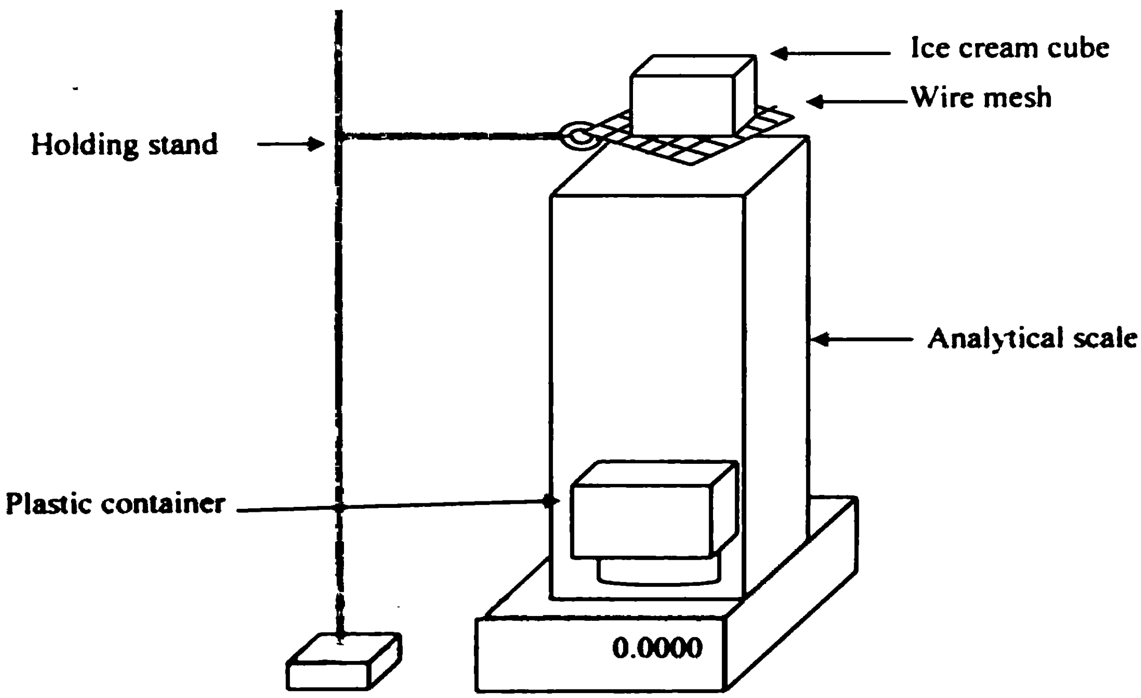

Fig.3.3 Apparatus setting for determination of melting resistance

3.2.7 Evaluation of Sensory appeal to determine the acceptance of three ice creams

Sensory evaluation was done with 20 semi trained panelists from Ceylon Cold Stores PLC. Preference test was carried out at Ceylon Cold Stores PLC using 20 semi trained panelists to assess the preference of 3 samples. Three samples were coded as three digits number (See App. II). Coded samples, ballot papers and water glasses were given for each and every panelist. Results were analyzed with Kruskal-Wallis non parametric test using computer aided Statistical Analysis package (MINITAB 14).

CHAPTER 04

RESULTS AND DISCUSSION

4.1 Result of slip melting point of three fat varieties

Table 4.1 Slip melting points of three fat varieties

Fat variety	Slip melting point (°C)
Palm oil	37
Palm kernel oil	34
Fat blend	35.5

Slip melting points of three fat varieties were different. Slip melting point determines by several factors while the main determinant is solid fat content of the fat. Lower slip melting indicates low solid fat content.

The iodine number is a measure of the unsaturated fatty acids present in fats. High iodine number indicates high amount of unsaturated fatty acids of a fat.

The higher melting temperature is mainly related to the higher contents long-chain fatty acids. long saturated chain fatty acid increase the melting point of fat while unsaturated fatty acids present in fat decreases the melting point of fat(Charley and Weaver 1998).Namely palmitic C16:0 and stearic C18:0, and lower contents of unsaturated long-chain fatty acids.(Qingzhe Jin et al). Palm oil contains 48% of C16 fatty acid (palmitic) and 51 % of C18 fatty acids(38% oleic,9% linoleic,4% stearic).palm kernel oil contains 8% of C16 (palmitic) and 17% of C18 fatty acids(13% oliec, 2% linoleic,2% stearic).butter constitutes 27% of C16 fatty acide(26% palmitic,1% palmitoleic) and 48% of C18 fatty acids(29% oleic,15% stearic,2% linoleic,2% linolenic).since long chain increase the melting point of fat.

Comparing to palm oil and palm kernel oil, lower amount of Long chain 8% of C16 (palmitic) and 17% of C18 fatty acids contain in palm kernel oil causes the lower slip melting which is 34°c

Lower amounts long chain fatty acids cause the lower slip melting point of palm kernel oil and low degree of unsaturation also affects the low slip melting point of palm kernel oil.

Among three fat varieties palm oil showed the highest slip melting point of 37 °C. Palm oil constitutes 48% of C16 and 51% of C18 fatty acids which is the highest among three fat varieties.
Iodine value (51) indicates higher unsaturation. Since the main reason for elevated melting point is long chain saturated fatty acids, palm oil has the gad the highest slip melting point.

Fat blend was a mixture of milk fat and palm kernel oil (27% milk fat and71%).milk fat (butter) contains 27% of C16 fatty acids and 48% of C18 fatty acids. thus slip melting point of fat blend is a combination of the long chain saturated fatty acids .this combination gave the slip melting point (35.5 °C) for fat blend during determination of slip melting point.

4.2. Result of melting of an ice cream samples produced wit three fat varieties for four overruns

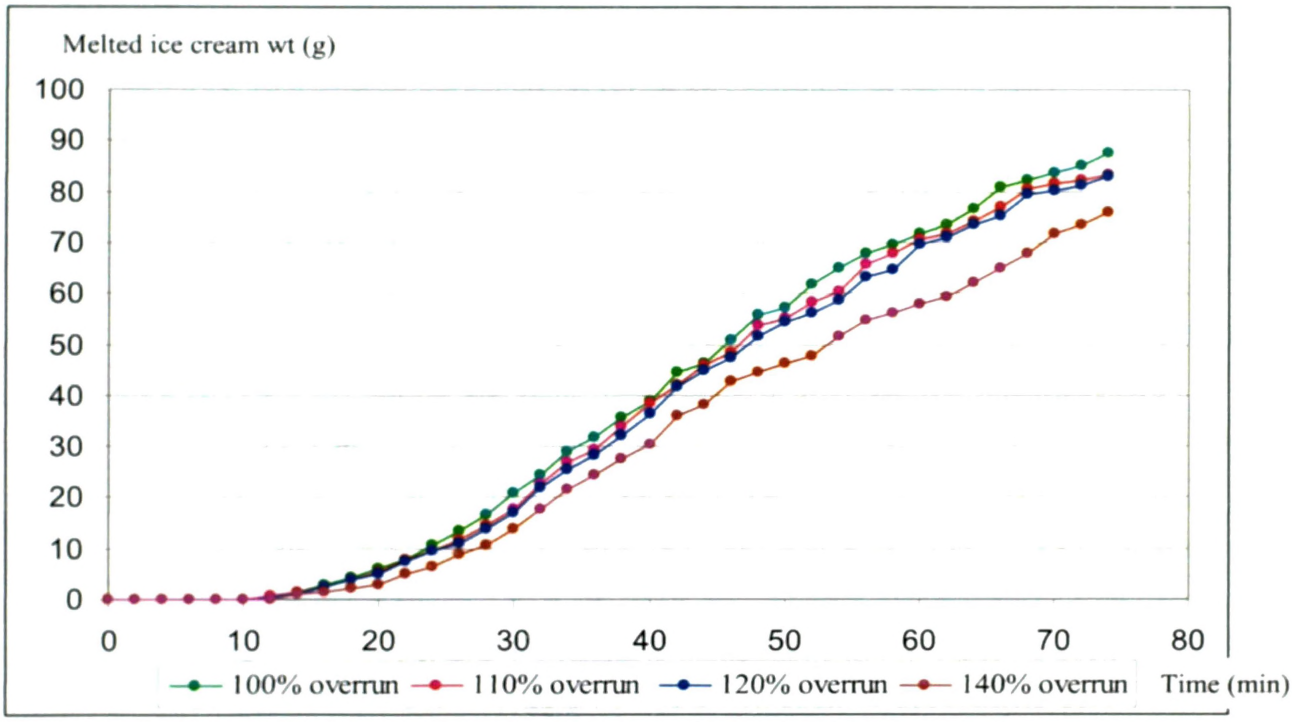

Fig.4.1 Melting curve of palm oil samples for four overruns

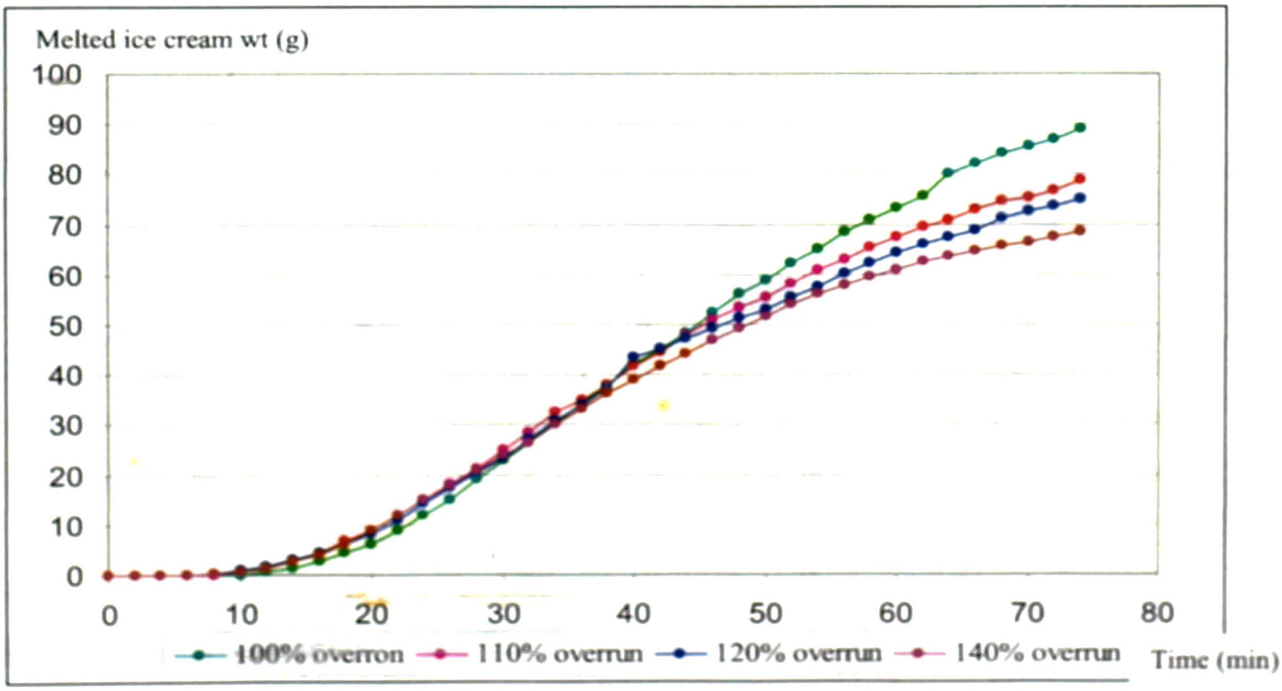

Fig. 4.2 Melting curves of palm kernel oil for four overruns

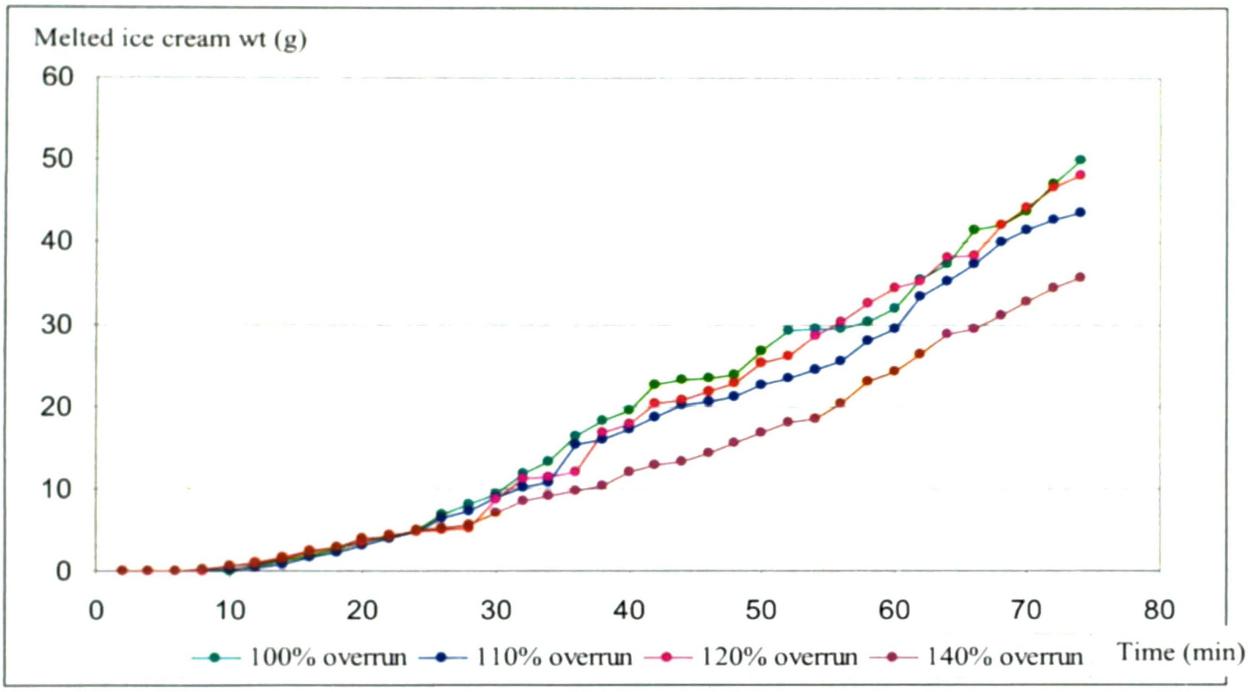

Fig. 4.3 Melting curves of fat blend for four overruns

Fat has a greater influence in developing the ice cream structure by forming fat a network within the ice cream through the process of partial coalescence of fat develops of a continuous internal fat network or matrix structure in the product. During melting of ice cream at a particular overrun, ice cream structure is gradually destroyed. it starts by melting he ice crystals within the ice cream consequently the fat network is damaged by increasing the crystalline fat content and in the end of melting, the ice cream transforms to a liquid. The principle reason for ice cream melting is the temperature at which the ice cream is served.

In above graph, when the melting rate has been reduced with the increasing overrun. High overrun impart the ice cream an improved insulation. This insulation reduces the heat penetration into the ice cream thus reduce the melting rate.

In the beginning up to 10 min, ice cream at all the four overruns shows no melting. Initially the ice cream was at -20 °C. It takes several minutes to increase the temperature of ice cream to start its melting. After 10 min, melting was increased with a decreasing rate. Once the outer layers of ice cream melted, air bubbles present within the ice cream insulate the heat penetration into the ice cream. This causes the melting with decreasing rate.

Initially the ice cream sample was 6 cm x3 cm x3cm in size. During melting, the surface area/volume of ice cream is increased. This increased surface area/volume ratio increase the amount of heat penetrated into the gradually melting the ice cream sample. This causes the increase of melting with the time.

4.3. Comparison of melting of same overrun of three samples produced with fat varieties

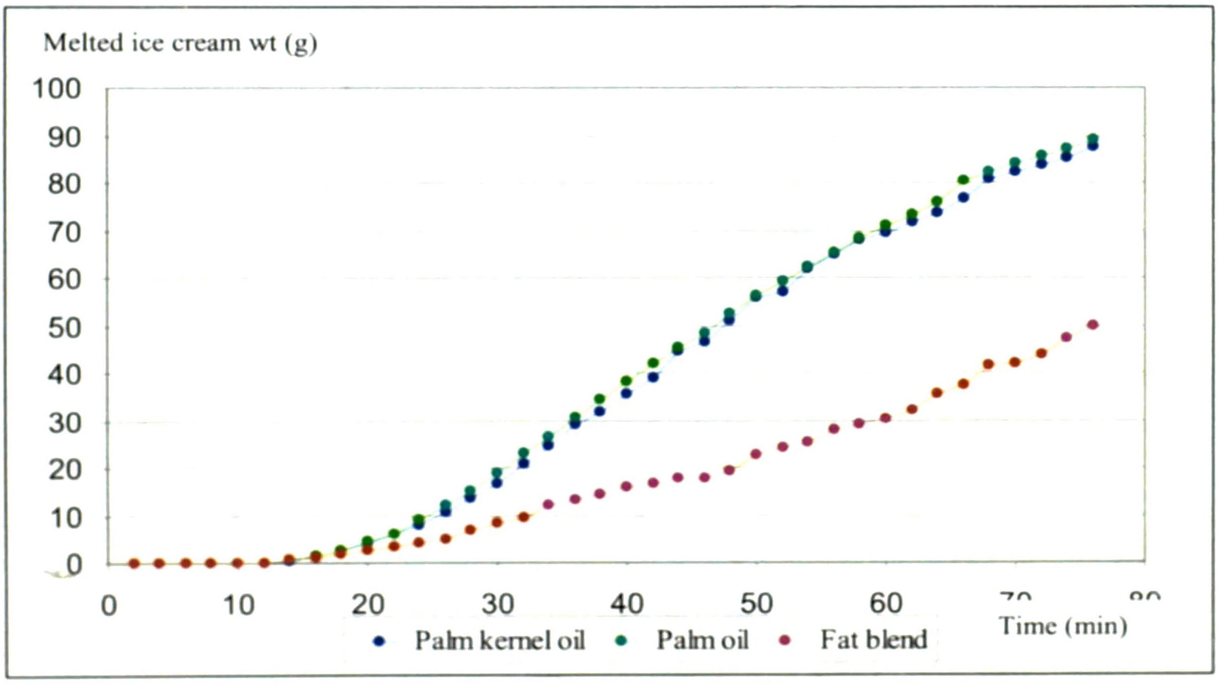

Fig. 4.4 Melting curves of three ice cream samples produced with three fat varieties at 100% overrun

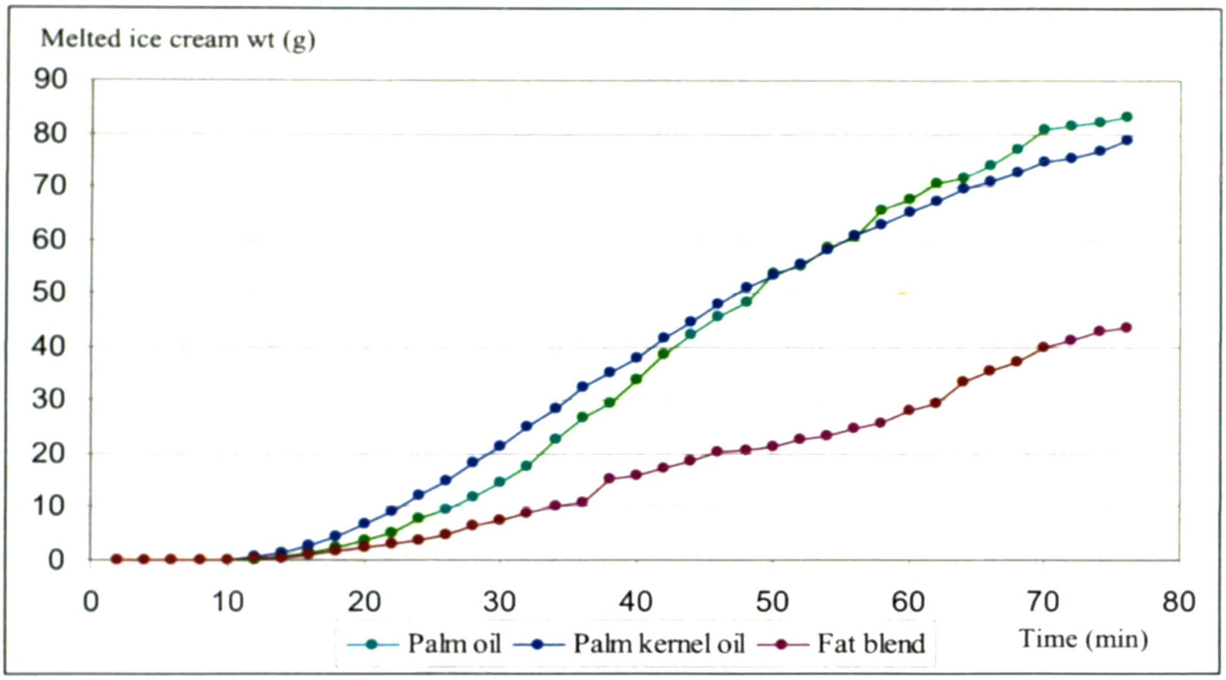

Fig. 4.5 Melting curves of three ice cream samples produced with three fat varieties at 110% overrun

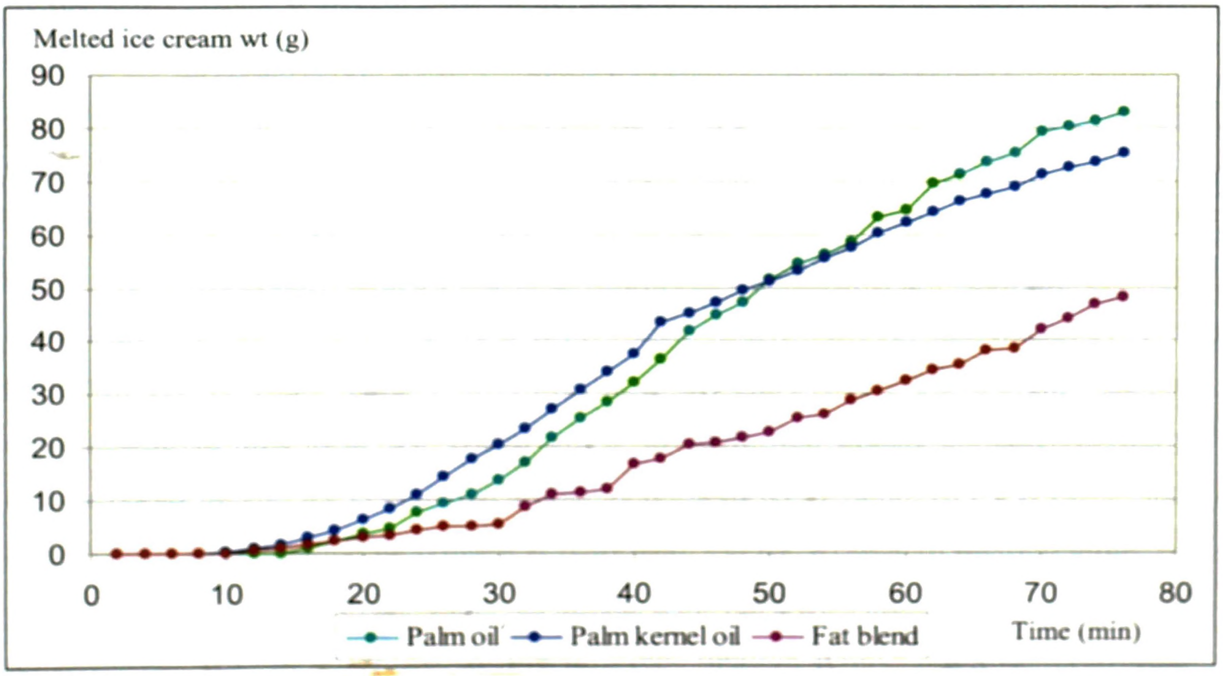

Fig. 4.6 Melting curves of three ice cream samples produced with three fat varieties at 120% overrun

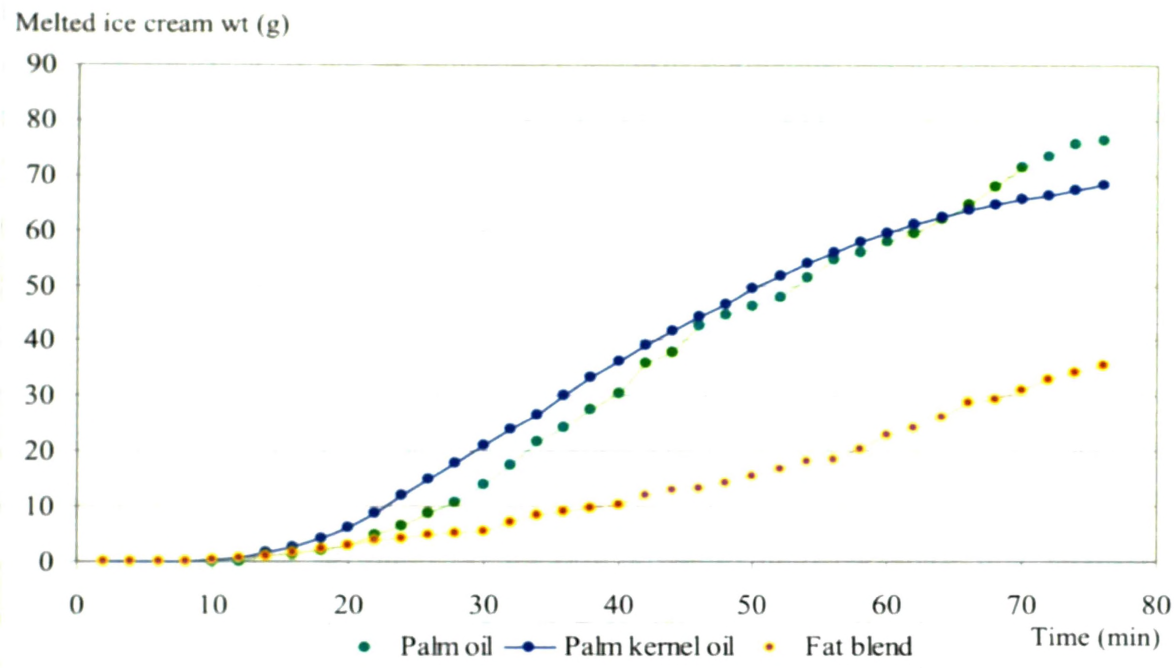

Fig. 4.7 Melting curves of three ice cream samples produced with three fat varieties at 140% overrun

In the comparison of melting of three samples, at 100%.110%, 120% and 140% overruns, sample produced with fat blend showed the lowest and the palm oil shows the highest melting while sample produced with fat blend showed the lowest melting rate throughout 74 min.

Ice cream has a depressed freezing point due to the constituents present in the ice cream mix. At the serving temperature, temperature gradient does exist between the ice cream and surrounding ambient temperature. Since the ambient temperature is high that the ice cream temperature, heat from the surrounding transfer into the ice cream. Due to this heat ice cream starts to melt. Ice cream contains partially coalascenced fat and ice crystals. With the increase of temperature of ice crystals start to melt and the crystalline fat content is increased. Fat has a range of melting point. At a particular temperature fat starts to melts and complete the melting at another temperature. This is attributed by the different melting temperatures of individual fatty acids. Within that range a fat has a mixture of liquid and crystalline fat. Higher melting point of fat gives slower melting rate. Thus sample produced with the palm oil which had slip melting point of 37°C had the highest melting resistance in the beginning of melting.

Sample produced with palm kernel oil had the lowest melting résistance, and the sample produced with the fat blend had the lowest melting resistance. In this case solid fat: liquid fat ratio of fat is to be considered. according to the table butter has 32% of solid fat at 10°C and 12% of solid fat at 21°C.palm kernel oil has 49% of solid fat at 10°C and 33% of solid fat at 21°C.fat blend contains higher amount of long chain saturated fatty acids than palm kernel oil but crystalline fat to liquid fat ratio is lower than palm kernel oil and palm oil. During melting sample produced with fat blend showed a significant event, which was the melted ice cream was being attached to the down side of the ice cream cube. Melted weight did not dripped to the container as it happen with other two samples produced with palm oil and palm kernel oil. Considering the solid fat index of fat this is not explainable since that increased melting resistance was given by a combined action of two fat varieties.

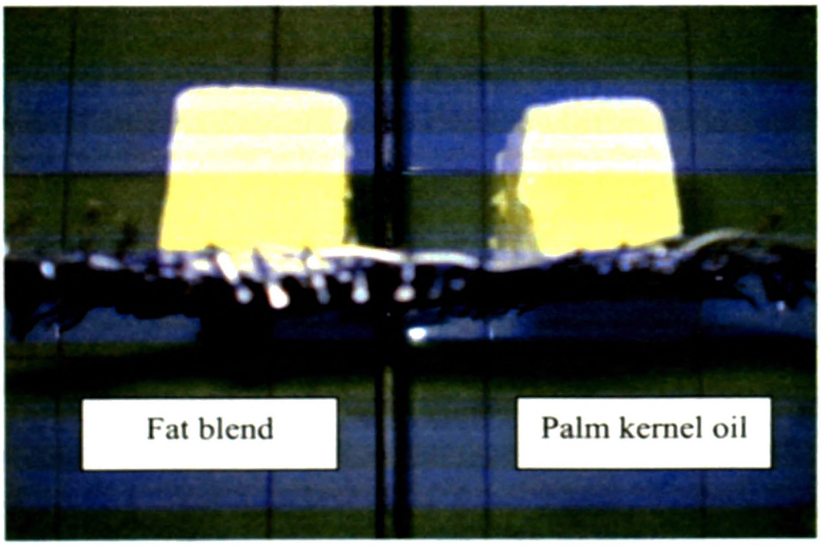

Fig.4.8 initial stage of melting of sample produced with fat blend.

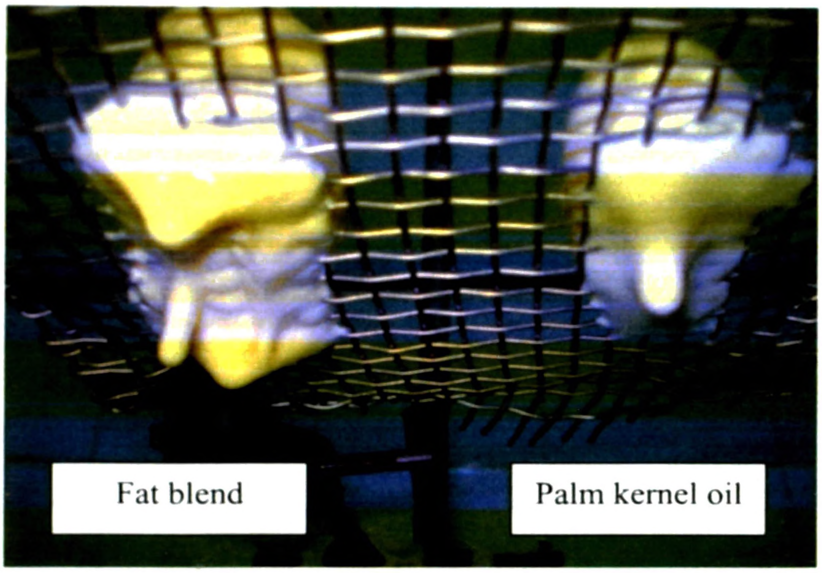

Fig.4.9 latter stage of melting of sample produced with fat blend.

At100%, 110%, 120% and 140%, initially the melting resistance of palm kernel oil was high than palm oil. Fat network within the ice cream is high with the increased amount of solid fat. Initially the melting rate of palm kernel oil was the highest due to the lower solid fat content of palm kernel oil. With the time the melting was lowered due to the increased solid fat content at that particular temperature.

Palm oil contains low amount of solid fat 34% at 10°C and 12% of solid fat at 21°C.Higher amount of solid fat increase the stabilization of partial coalescence fat network, thus improve the fat network within the ice cream. This causes the improved melting resistance in the initiation of melting of ice cream produced with palm oil.

Palm kernel oil contains 49% of solid fat at 10°C and 33% of solid fat at 21 °C. Solid fat is melted during melting of fat in the blending of ingredients. Upon melting, during aging fat starts to crystallize again. In the ice cream, the degree of partial coalescence of fat is unknown. Both palm and palm kernel oil were completely melted during blending of ingredients. Interactions of tat with other ingredients also affect the melting of ice cream since ice cream melting is not only attributed by fat melting.

4.4. Result of sensory evaluation to determine the degree of preference of three samples.

Table 4.2 statistical results of sensory evaluation.

Sensory attribute	p value
Sweetness	0.181
Evenness	0.828
Creaminess	0.000
Oiliness	0.037
Overall acceptability	0.000

4.4.1 Sweetness

P-value (0.181) indicates that there is no sufficient evidence to reject the null hypothesis. Medians of three samples were same. Statistical results prove that preference for the sweetness of three samples remains same (See. App. II).

4.4.2 Evenness

Evenness referred to the uniform appearance of ice cream. Statistical results do not provide sufficient evidence to reject null hypothesis. P-value (0.828) indicates that there is no difference in preference for evenness of thee samples (See. App. II).

4.4.3 Creaminess

Creaminess referred to the milky taste of ice cream sample. Sample produced with the fat blend had the highest creaminess according to the statistical analysis of data. P value (0.000) provides sufficient evidence to reject null hypothesis. Highest median 3 of sample produced with fat blend had the most preferred creaminess, next palm kernel oil sample and the lowest creaminess showed by the palm oil with median 1 (See. App. II).

4.4.4 Oiliness

Preference for Oiliness of three samples was different. P value (0.037) indicates that there is sufficient evidence to reject null hypothesis. With median 2, ice cream produced with palm oil, palm kernel oil had the lower preference than the sample produced with fat blend of median 3 (See. App. II).

4.4.5 Overall acceptability

P-value for the preference of overall acceptability was 0.000 provides indicates that there is sufficient evidence to reject null hypothesis, proving that three sample have different preferences for overall acceptability. Sample produced with fat blend had the highest preference with median 3.Lowest preference was given to the sample produced with palm kernel oil while sample produced with palm oil was more preferred that palm kernel oil but less that sample produced with fat blend
(See. App. II).

4.5. Result of determining the Cost effectiveness of three different ice creams at four overruns

Increased overrun yields high amount of ice cream (See App.III).It is certain that with the increased overrun, cost per ice cream liter is reduced since the amount of air present is high. Cost of bovine milk is not constant throughout the year. Thus cost per litter of ice cream is not constant at all the time. Lower the price of bovine milk, lower the cost of ice cream produced with raw milk.

Cost per litter of ice cream produced with palm kernel oil or palm oil was lower than the use of bovine milk in the manufacturing of ice cream. Use of vegetable to standardize the fat in ice cream mix and use of skimmed milk powder instead of milk solids not fat is profitable than use of raw milk, though the profit margin is low.

Increased overrun increases the profit as it is always obvious. At 100% overrun, 1500 l ice cream mix yields 3000 l of ice cream. At 110%, 1500 l ice cream mix yields 3150 l of ice cream. At 120%, 1500 l ice cream mix yields 3300 l of ice cream. At

140%. 1500 l ice cream mix yields 3600 l of ice cream (See App III).According to the Sri Lanka standards, weight of one ice cream liter must be 475 g minimum. With 140% of overrun, ice cream weight is 454 g. The maximum overrun of ice cream that can be present in the ice cream is 130 %.(see App. III)

CHAPTER 05

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Fat with higher amount of long chain saturated fatty acids has higher Slip melting point (melting point) than a fat that contains lower number of long chain saturated fatty acids.

Overrun and fat variety affect the melting resistance of fat. Higher overrun gives improved melting resistance to an ice cream due to improved insulation against heat penetration into the ice cream.

Sample produced with palm kernel oil the high resistance against melting at 21°C than the sample produced with palm kernel oil had the next higher melting resistance

Highest melting resistance was shown by the sample produced with fat blend. This increased resistance to melting was complicated during the study.

The method used in the determination of melting resistance is much suitable to study or compare the melting behavior of different overruns of one fat variety though not suitable in determining melting behavior of different fat varieties.

5.2 Recommendations

Interactions between milk fat and vegetable fat during preparation of fat blend are needed to be studied rather.

Method of preparation of vegetable fat needs further studies since unit operations of preparation methods affect the solid fat content of a fat such as tempering.

Effect of homogenization on partial coalescence of different fat varieties also requires further studies

Modifications of the method used in the determination of melting resistance or an improved method is to be considered to compare the melting resistance of different fat varieties.

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Appendix I

Sensory evaluation-Ballet sheet

Date..
Name...

Please evaluate the ice cram samples given for the following attributes and overall acceptability. Assign a rank value 3 for the sample you prefer most, 2 for the sample you prefer and 1 for the sample you least like. Rinse your mouth after tasting one sample before tasting the next sample.

3-Most prefer
2-Prefer
1-Slightly prefer

Sample code	142	523	309
Sweetness			
Evenness			
Creaminess			
Oiliness			
Overall Acceptability			

Comments
....
....
....
....

Thanks for your kind co-operation

Appendix II

Test hypothesis

H_0: Three samples have equal medians for sweetness

H_1: At least one sample has different median for sweetness

Kruskal-Wallis Test: Sweetners versus Sample

Kruskal-Wallis Test on Sweetners

Sample	N	Median	Ave Rank	Z
Socolate	30	2.000	39.6	-1.53
Ta.Shortening	30	2.000	45.0	-0.14
Tat Blend	30	2.500	52.0	1.66
Overall	90		45.5	

H = 3.42 DF = 2 P = 0.181

H = 3.83 DF = 2 P = 0.147 (adjusted for ties)

Decision rule

Reject Ho if p value< α

Decision

Since P value (0.181) > α, do not reject Ho. There is no difference in preference for sweetness of three samples.

Kruskal-Wallis Test: Evenness versus Sample

Test hypothesis

H_0: Three samples have equal medians for Evenness

H_1: At least one sample has different median for Evenness

Kruskal-Wallis Test on Evenness

Sample	N	Median	Ave Rank	Z
Socolate	30	[illegible]	[illegible]	[illegible].43
Ta.Shortening	30	[illegible]	46.2	[illegible]
Tat Blend	30	2.000	43.2	-0.59
Overall	90		45.5	

H = 0.38 DF = 2 P = 0.828

H = 0.42 DF = 2 P = 0.809 adjusted for ties

Decision rule

Reject Ho if p value< α

Decision

Since P value (0.828)> α, do not reject Ho. There is no difference in preference for Evenness of three samples.

Kruskal-Wallis Test: Creaminess versus Sample

Test hypothesis

H_0: Three samples have equal medians for Creaminess

H_1: At least one sample has different median for Creaminess

```
Kruskal-Wallis Test on Creaminess

Sample           N  Median  Ave Rank       Z
Socolate        30   1.000      28.3   -4.41
Ta.Shortening   30   2.000      44.1   -0.36
Tat Blend       30   3.000      64.1    4.76
Overall         90              45.5

H = 28.16  DF = 2  P = 0.000
H = 31.69  DF = 2  P = 0.000  (adjusted for ties)
```

Decision rule

Reject Ho if p value< α

Decision

Since P value (0.000)> α, reject Ho. At least one sample has different median for for creaminess of three samples.

Kruskal-Wallis Test: Oiliness versus Sample

Test hypothesis

H_o: Three samples have equal medians for Oiliness

H_1: At least one sample has different median for Oiliness

```
Kruskal-Wallis Test on Oiliness

Sample            N  Median  Ave Rank      Z
Scoolate         30   2.000      40.5  -1.28
Ta.Shortening    30   2.000      40.5  -1.28
Tat Blend        30   3.000      55.5   2.57
Overall          90              45.5

H = 6.59  DF = 2  P = 0.037
H = 7.42  DF = 2  P = 0.025  (adjusted for ties)
```

Decision rule

Reject Ho if p value< α

Decision

Since P value (0.037)> α, reject Ho. At 0.05 α levels, at least one sample has different median for oiliness of three samples.

Kruskal-Wallis Test: Overall acceptability versus Sample

Test hypothesis

H_o: Three samples have equal medians for Overall acceptability

H_1: At least one sample has different median for Overall acceptability

```
Kruskal-Wallis Test on Overall acceptability

Sample            N  Median  Ave Rank      Z
Scoolate         30   1.000      25.5  -5.14
Ta.Shortening    30   2.000      50.5   1.28
Tat Blend        30   3.000      60.5   3.85
Overall          90              45.5

H = [illegible]  DF = 2  P = 0.000
H = 3[illegible].14  DF = 2  P = 0.000  (adjusted for ties)
```

Decision rule

Reject Ho if p value< α

Decision

Since P value (0.000)> α, reject Ho. At least one sample median is different for Overall acceptability of three samples.

Appendix III

COST COMPARISON OF THREE ICE CREAMS AT DIFFERENT OVERRUNS

If cost per 1500 ice cream mix is X,

At 100% overrun

1500 l ice cream mix yields 3000 l of ice cream
Cost per litre=X/3000

At 110% overrun

1500 l ice cream mix yields 3150 l of ice cream
Cost per litre=X/3150

At 120% overrun

1500 l ice cream mix yields 3300 l of ice cream
Cost per litre=X/3300

At 140% overrun

1500 l ice cream mix yields 3600 l of ice cream
Cost per litre=X/3600

WEIGHT OF ICE CREAM WITH DIFFERENT OVERRUNS

Ice cream mix density= 1.094g/cm3

Weight of 1000 ml of ice cream mix=1094 kg

$$\text{Overrun} = \frac{\text{weight of ice cream mix-weight of ice cream}}{\text{Weight of ice cream}} \times 100$$

Weight of ice cream litre at 100% overrun

100= (1094-wt of ice cream/Wt of Ice cream)*100
=547.0 g

Weight of ice cream litre at 110% overrun

110= (1094-wt of ice cream/Wt of Ice cream)*100
=520.9 g

Weight of ice cream litre at 120% overrun

120= (1094-wt of ice cream/ Wt of Ice cream)*100
=497.2 g

Weight of ice cream litre at 140% overrun

140= (1094-wt of ice cream/ Wt of Ice cream)*100
=455.8 g

Maximum overrun(x) of ice cream to be conformed with the Ice cream weight specified by Sri Lanka standards institution

x= (1094-475/475)*100

=130%

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