PREPARATION AND QUALITY EVALUATION OF COCONUT MILK INCORPORATED ICE CREAM

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A dissertation submitted to the Department of Food Technology, Central Campus of Technology, Tribhuvan University, in partial fulfillment of the requirements for the degree of B. Tech. in Food Technology

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Approval Letter

This *dissertation* entitled *Preparation and Quality Evaluation of Coconut Milk Incorporated Ice Cream* presented by Subash Sigdel has been accepted as a partial fulfilment of the requirement for the B.Tech in Food Technology.

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Abstract

Coconut ice cream is a vegan friendly frozen dessert prepared by using coconut milk as the major ingredient. The aim of this research was to develop the formulation for coconut milk incorporated ice cream and to study the effect of coconut milk and milk solid not fat (MSNF) on ice cream quality. Design expert was employed for formulating the recipe of ice cream. The obtained 9 formulations of coconut ice cream with varying levels of coconut milk and MSNF were prepared in lab, where the range of coconut milk and MSNF used were 0-100% and 10-12% respectively. The samples were subjected to sensory evaluation for consumer acceptability. The melting rates and overrun of ice cream were determined for all samples and the data subjected to response surface methodology to study the effect of formulation on physical quality.

From sensory evaluation, 50% coconut milk and 10% MSNF were found to be significantly best ($p<0.05$). In most of the formulations, taste, color, body and overall acceptability were significantly affected ($p<0.05$) by variation in coconut milk and MSNF while aroma, taste and aftertaste were not affected greatly. From response study, 62.602% coconut milk and 10% MSNF was found to be the optimized formulation. Response surface plot showed that coconut milk had an overall positive and MSNF had a negative effect on the overrun. During the study of melting rate, it was observed that the rate decreased on increasing coconut milk and MSNF, thus improving the quality of ice cream. An overrun of 48.623% and melting rate of 0.578 g per 5 min was predicted by the software for the above-mentioned formulation of 62.602% coconut milk and 10% MSNF. Hence coconut ice cream can be prepared using milk and coconut milk with sensory, physical and chemical qualities similar to that of plain ice cream.

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List of Abbreviations

Abbreviations	Full form
ANOVA	Analysis of variance
DDC	Dairy Development Corporation
DOE	Design of experiments
FDA	Food and Drug Administration
IS	Indian Standard
MSNF	Milk solid not fat
RSM	Response surface methodology
SMP	Skim milk powder
SNF	Solid not fat

Part I

Introduction

1.1 General introduction

Ice cream can be defined as a frozen dairy product comprising of milk fat, air, water, Sweeteners, stabilizers, emulsifiers, and flavors prepared by pasteurizing and homogenizing the mix before freezing. Other ingredients such as fruits, nuts, egg products, and edible flavors. Ice cream can be defined as a frozen dairy product comprising of milk fat, air, water, may also be added. It is a composite material with the main ingredients providing the required sensory properties to the product as ice gives cooling, air gives softness, fat provides creaminess, sugar gives sweetness and flavor enhances its taste(Clarke, 2004; Marshall *et al*., 2003).

Dairy product prepared by pasteurization, homogenization, aeration and freezing that has been maintained at uniform consistency is called ice cream. It is cheap, healthy, nutritious and palatable product. Composition of ice cream is comprised of sugar, fat, emulsifiers, stabilizers, water, egg and eggs products, corn syrup, dextrose and flavors. It is a three-phase network consisting on air, solid and liquid in final product. Liquid phase contains ice crystals in embedded form and air cells in dispersed form. Milk proteins, soluble and insoluble salts, fat particles, stabilizers and sugars are also present in liquid phase. So it is a very complex physiochemical food system. Ice cream is categorized in dairy frozen desserts in which frozen confections, water ice, sherbet, frozen custard, parevine like products, ice milk and mellorine are included. According to U.S standards, ice cream must be consisted of not $< 20\%$ MSNF and 10% fat from milk while when flavors added in bulk than there should be 16% MSNF and 8% fat. Stabilizers should not be $> 0.5\%$ (Syed *et al.*, 2018).

Coconut (*Cocus nucifera* L.) is one of the oldest fruits in the world and is confined to seacoast in the humid tropics. It has been estimated that 25% of the world’s output of coconut is consumed as coconut milk (Gwee, 1998). Coconut milk is being used by confectionaries, bakeries, biscuit and ice cream industries worldwide to enhance flavor and taste of various products (Persley, 1992). Coconut milk was found to be rich in calcium. The milk was reported to be high in minerals and vitamin content (Nieuwentus and Nieuwelink, 2002).

Contrary to widely held opinion, the coconut provides nutritious source of meat, juice, milk and oil. It is classified as a "functional food" because it provides many health benefits beyond its nutritional content, due to its fiber and oil content (Sanful, 2009). The oil is known to contribute to improved insulin secretion and the utilization of blood glucose; reduce symptoms associated with malabsorption syndrome and cystic fibrosis; help to relieve symptoms associated with crohn's disease; ulcerative colitis and stomach ulcers; improve the utilization of essential fatty acids and protect them from oxidation (Seow and Gwee, 1997).

1.2 Statement of the problem

Ice cream is a popular dessert a consumer associated with absolute enjoyment. While taste is a major factor affecting choice for food products, people now days are concern about nutrition and healthiness as well (Lin, 2012). Today, consumption of ice cream is increasing rapidly but its high cost has prohibited ice cream consumption by vulnerable section of the society. Therefore need to reduce the cost of ice cream, which would be possible only when milk is replaced by cheap and nutritious non-convectional ingredients (Sutar *et al.*, 2010).

Coconut milk is valued mainly for its characteristic nutty flavor and for its nutritional content. It has been reported that 25% of the world's output of coconut is consumed as coconut milk (Seow and Gwee, 1997). There is a growing demand for coconut milk and is now being used in ice cream, ices, confectionaries etc. Coconut milk-based ice cream is ideal for people who are vegans and it is a cholesterol free product. However, it has not yet been prepared on a large scale (Jayasundera and Fernando, 2014).

1.3 Objectives

1.3.1 General objectives

The general objective of the thesis work is to prepare ice cream using coconut milk and to conduct its quality evaluation.

1.3.2 Specific objectives

- To prepare varying level coconut milk incorporated ice cream.
- To study the effect of coconut milk and MSNF on overrun and melting rate of ice-cream using response surface methodology and optimize the formulation accordingly.

- To study the physico-chemical properties of plain and coconut milk incorporated ice cream.

1.4 Significance of the study

Frozen dairy desserts are characterized by containing milk solids and being consumed in the frozen state. Within the frozen dairy dessert category, ice cream is the most widely consumed product by the general population, so it can be considered as an ideal vehicle to deliver functional ingredients to consumers. The ice cream industry is very progressive with many new formulation trends some of which are ‘reduced’ or ‘no’ claims for fat, use of nutritionally functional additives or flavors showing added nutritional functionality (Goff and Hartel, 2013).

Coconut is highly nutritious and rich in fiber, vitamins, and minerals. The saturated fat content in coconut milk has been shown to be a good saturated fat, easily metabolized to give the body quick energy. The principal fatty acid in coconut milk is lauric acid, which is the same fatty acid found in abundance in mothers' milk and is known to promote normal brain development and contribute to healthy bones. Coconut also has important anti-carcinogenic and anti-pathogenic properties (Ishiaq and Odeyemi, 2012).

In the rapidly changing socio-economic scenario, novel ways of value addition are essential. Incorporation of functional ingredients like fibers, proteins, hydrocolloids, herbs and vegetable oils will help to increase the yield and decrease the calorific value of ice cream making it attractive to consumers.

1.5 Limitations

- Shelf life of the product could not be studied due to lack of required storage conditions.
- Rheological properties of prepared ice cream could not be determined.

Part II

Literature review

2.1 History and development of ice cream

Ice cream- in various parts of its history has been called 'ices', 'iced cream' and 'cream', began its ascent to worldwide dessert fame as a luxury food that only upper crust could afford. As ice cream travelled through history, it evolved from a food identified with an opulent lifestyle into a mainstream consumer sensation. Ice cream was initially formulated in Europe, principally in Italy, and travelled across the Atlantic to America but no any definite description exists, except that snow and ice were used to cool and possibly to freeze sweet desserts. The history of ice cream begins not with the familiar concoction of cream, sugar and flavors but with chilled non-dairy drinks that date back to the ancient Romans and Greeks (Weiss, 2011).

The first wholesale ice cream industry in the US was established in 1851 by Jacob Fussel in Baltimore, Maryland. The introduction of pasteurizer, homogenizer, improved freezers and other processing equipments accompanied a slow growth in the industry until after 1900. Ice cream soda was introduced in 1879, ice cream cone in 1904 and Eskimo pie in 1921. Ice cream was recognized as an essential food by 1920 and has been unusually popular since then (Arbuckle, 1986).

2.2 Production and consumption of ice cream

The history of frozen desserts shows that great efforts have been made to produce these products which was first consumed by the elite of society but today's offerings cater also to the masses, with prices of products varying by as much as a factor of 10 for equivalent volumes. Ice cream production has increased rapidly in recent years (Chhetri, 2016).

Global production of ice cream was 15.3 billion liters in 2006 and rise to 16.3 billion liters in 2010. By country, US was the largest producer at 4.4 billion liters followed by China at 2.9 billion liters, Japan at 0.9 billion liters, Germany at 0.65 billion liters and Italy at 0.6 billion liters (Goff and Hartel, 2013) and Global per capita consumption of ice cream and related products as of 2010 is shown in Table 2.1.

Table 2.1 per capita consumption of ice cream in selected countries

Country	Liters/capita
Australia	17.9
New Zealand	15.8
USA	14.2
Finland	12.5
Canada	10.5

Source: Euromonitor International (2011)

2.3 Classification of ice cream and related products

Within the ice cream category, there are numerous variations of formula, ingredients (both dairy and non-dairy), flavors, methods of freezing, sizes, shapes and other variables that make possible the creation of wide variety of products some of which are described as follows (Goff and Hartel, 2013; Jana *et al.*, 2016):

1. Plain ice cream: An ice cream in which total amount of color and flavoring ingredients is less than 5% of the unfrozen ice cream volume.

2. Chocolate: Ice cream flavored with cocoa or chocolate, usually with higher sugar content. Other variants of chocolate frozen product include chocobar, chocolate frosties, chocochips.

3. Fruit: Fruit ice cream is made by adding various fruits at the time of freezing with or without additional fruit flavoring or color.

4. Nut: Ice cream containing nut meats like almonds, pistachio or walnuts.

5. Ice milk: A product similar to ice cream containing 2-7% fat and 12-15% MSNF, sweetened, flavored and frozen like ice cream.

6. Ices: Made of fruit juices, sugar and stabilizer with or without additional fruits, color, and flavor and frozen to the consistency of ice cream.

7. Sherbet: A product made of fruit juices, sugar, stabilizer and milk products.

8. Sorbet: A product similar to ices but has high sugar and fruit juice content, stabilizer and egg white are also added and has overrun of 20% or less.

9. Mousse: Ice cream containing whipped cream, sugar, color and flavoring and frozen without further agitation.

10. Bisque: It is made by the addition of grape, nuts, macaroons, sponge cake or other bakery products with appropriate flavorings.

11. Custards: Ice cream cooked to custard before freezing. It contains whole egg or egg yolk in such a proportion that the total egg yolk solids should not be less than1.4% of the weight of finished frozen custard.

12. Cassata: It is made in a round mould, hinged so that it may be filled with ice cream and other frozen products, it is frozen for several hours and turned out of the mould.

13. Variegated or rippled ice cream: Variegated ice cream is produced by injecting 10% of a prepared base into ice cream.

14. Novelties: These include special combinations of ice cream with flavor, confections and fancy molded items, usually produced by either extrusion or molding.

15. Puddings: Ice cream containing a generous amount of mixed fruits, nut meats and raisins, with or without spices, liquor or eggs.

16. Fanciful-name ice cream: These do not contain a single characterizing flavor but the flavor is due to the mixture of several flavoring ingredients.

17. New York or Philadelphia: A plain vanilla ice cream with extra color for Philadelphia and extra fat and eggs for New York ice cream.

18. Rainbow ice cream: It is prepared by carefully mixing six or more different colored ice creams as they are drawn from the freezers to give a rainbow colored effect when the product is hardened.

19. Fancy moulded ice cream: It is moulded in fancy shapes and composed either of one or a combination of colors and flavors.

20. Mellorine: A product similar to ice cream in which the butter fat has been replaced by a suitable vegetable fat or animal fat.

21. Soft-serve ice cream: It is a frozen dessert that is similar to, but softer than ice cream. These are sold as drawn from the freezer without hardening. Its warmer temperature allows the taste buds to detect more flavors.

22. Gelato: Italian-style ice cream that is typically lower in fat (4-8%) and overrun (25-60%) but higher in sugar (up to 25%, including corn syrups) than regular formulations that tend to keep it more soft and pliable.

23. Maras or Turkish ice cream: It is distinguished by a much more elastic texture from the presence of salep, flour made from an orchid root, and mastic, a resin that imparts chewiness.

24. Aufait: Two or more layers of ice cream with pectinized fruits or preserves spread thinly between the layers so as to give a marbled appearance.

25. Spumoni: A combination of vanilla ice cream, chocolate mousse, cherries and whipped cream combined with fruits arranged in a spumoni cup and hardened.

Source: Goff and Hartel (2013); Jana *et al.* (2016)

2.4 Composition of ice cream

An ice cream mix is the unfrozen blend of the ingredients and mix formulations are defined as percentages of constituents which can be combined in varying proportions within acceptable ranges. The composition of ice cream varies in different localities and markets consideration being given to legal requirements, quality of product desired, raw materials available, plant equipment and processes, trade demand, competition and cost. Table 2.2 summarizes ranges in composition among commercial ice creams. The milk fat content of ice cream may vary from less than 1 to 20%, depending upon such factors as regulations, expected characteristics and price. As the fat content is increased, MSNF (milk solid not fat) must be reduced so as to avoid ‘sandiness’ which means crystallization of lactose in finished product (Marshall *et al.*, 2003).

Table 2.2 Approximate composition (%) of commercial ice cream

Ice cream	Milk fat	Milk SNF	Sugar	Stabilizer and emulsifier	Total solids
Non-fat	>0.7	12-14	18-22	1.0	35-37
Low-fat	2-4	12-14	18-21	0.8	35-38
Light	5-6	11-12	18-20	0.5	35-38
Reduced fat	7-9	10-11	18-19	0.4	36-39
Economy	10-11	10-11	14-17	0.3	35-37
Trade brand	11-12	10-11	14-17	0.3	37-39
Deluxe	13-14	8-9	13-17	0.3	39-40
Premium	14-16	7-8	13-17	0.3	40-41
Super premium	17-20	6-8	16-17	0.2	42-44

Source: Marshall *et al.* (2003)

2.5 Standards of ice cream

Today, there are many choices in ice cream to cater a wide variety of consumer tastes and standards of identity as well as specification are set so that consumers will get a consistent product, no matter what brand or type they buy. The Indian Standard (IS) and Dairy Development Corporation (DDC) specification for ice cream are shown in Table 2.3 and Table 2.4 respectively.

Table 2.3 IS specification of ice cream

Characteristics	Requirement
Weight (g/L) (min)	525
Total solid (% wt.) (min)	36.0
Milk fat (% wt.) (min)	10
Acidity (%lactic acid)	0.25
Sucrose (% wt.) (max)	15.0
Stabilizer/emulsifier (%wt.) (max)	0.5
Standard plate count (/g)	Not more than 2,50,000
Coliform count (/g)	Not more than 90
Phosphatase test	Negative

Source: Chhetri (2016)

Table 2.4 DDC specification of ice cream

Characteristics	Requirement
SNF (%wt.) (min)	11.5
Total solid (% wt.) (min)	36.0
Milk fat (% wt.) (min)	10
Acidity (%lactic acid)	0.25
Sucrose (% wt.) (max)	15.0
Stabilizer/emulsifier (%wt.) (max)	0.5
Overrun (%) (max)	90
Standard plate count(/g)	Not more than 2,50,000
Coliform count(/g)	Less than 100
Phosphatase test	Negative

Source: DDC (2005)

2.6 Ingredients of ice cream

Following are the ingredients utilized for the manufacture of ice cream.

- Fat
- Milk solid not fat (MSNF)
- Sweeteners
- Emulsifiers
- Stabilizers
- Flavors
- Colors
- Water

2.6.1 Fat

Milk fat is comprised mainly of triglycerides which are in turn composed of three fatty acids and glycerol, connected through ester linkages. The fat content of commercial ice cream is usually 10-12%. The best source of fat is fresh cream, other sources are frozen cream, butter, butter oil and condensed milk blends. Milk fat is an ingredient of major importance in ice cream and the use of correct percentage is essential not only to balance the mix properly but also to satisfy legal standards (Arbuckle, 1986).

The fat content is an indicator of the perceived quality and/or value of the ice cream. Interest in milk fat is centered on its nutritional and functional attributes. Studies have shown that the fat component increases the richness of flavor, is a good carrier and synergist for added flavor compounds, produces a characteristic smooth texture by lubricating the palate, helps to give body and aids in producing desirable melting properties. It also affects the textural attributes such as firmness and ice crystal perception. As a result of emulsifier action, air incorporation and ice crystallization during freezing of ice cream, the fat emulsion in the mix will partially coalesce or destabilize and this partial churning is necessary to set up the structure and texture in the ice cream (Koeferli *et al.*, 1996; Marshall *et al.*, 2003).

Fat is thought to have a unique functionality that enables it to react with flavor compounds and to have a specific pattern of flavor release in mouth that no fat replacer can provide. Ohmes *et al.* (1998) states that milk fat affects the flavor of ice cream by contributing its own richness and creaminess, by contributing flavors acquired through hydrolysis, oxidation or processing and by modifying the perception of flavorful substances in the product. Fat carries the fat-soluble flavors into the mouth where they volatilize prior to sensory reception in the olfactory system. When there is not enough fat to carry the flavors, they are rapidly volatilized in the mouth and then quickly disappear from the perceived flavor profile.

Prindiville *et al.* (1999) showed that within the range of 0.5% to 6%, fat increased the creamy characteristic, stability of texture and flavor during storage of ice cream while the low-fat and non-fat ice creams were most adversely affected by heat-shock treatment and showed the greatest changes in iciness, smoothness and mouthcoating.

2.6.2 Milk solid not fat

Milk solid not fat or serum solids contain the lactose, casein, whey protein, minerals, vitamins, acids and enzymes of milk or milk products from which they were derived. The MSNF content can vary from 6% to 14% or more but Sommer (1951) has recommended that the MSNF should be no more than 15.6-18.5%, above which lactose crystallization and sandiness may become an issue. MSNF may be added in the form of skim milk, skim milk powder, sweetened condensed skim milk or whey powder. MSNF is high in food value, is inexpensive and while not adding much to the flavor of ice cream, does enhance its palatability. Its key components are proteins which contribute to the nutritional requirement as well as whipping characteristics. In addition, these have good functional properties some of which are as follows:

- Cause a decrease in coldness, ice crystal and melting rate perception while increase in creaminess and mouthcoating.
- Enhance texture, aid in giving body and chew resistance to the finished product.
- Allow an increasing overrun without the characteristic snowy or flaky textures associated with higher overruns (Arbuckle, 1986; Chhetri, 2016; Jana *et al.*, 2016; Marshall *et al.,* 2003).

2.6.3 Sweeteners

The constituents having a sweet taste are sweeteners which are important for the structural and sensorial characteristics of ice cream as well as its storage stability. The total amount of sugar may vary from 12-20% while14-16% seems more desirable. Very low sugar results in a flat taste while higher sugar contents produce undesirable sweetness. The main functions of sweeteners are:

- It increases the acceptance of product, not only by making it sweeter but by enhancing the pleasing creamy flavor and delicate fruit flavors.
- Sugars are used as a cheap source of total solids.
- It increases the viscosity of the mix.
- It improves the body and texture of ice cream and aids to the smooth consistency provided the sugar content does not exceed 16% above which, the ice cream tends to become too soft or chewy.

- These sugars, being in solution, depress the freezing point of the mix which results in desirable soft, scoopable and chewable characteristics in the frozen product and also in lower temperatures required for proper hardening.

Sucrose was the only sweetener used in ice cream for many years. Now, other sugars like fructose, glucose syrup, corn syrups and many good sugar blends are commercially available. Blends of sucrose and medium- or high-conversion corn solids have also been used advantageously. Saccharine, sucralose, aspartame, acesulfame-k are commonly used non-nutritive sweeteners in ice cream (Arbuckle, 1986; Asghar *et al.*, 2013; Fuangpaiboon and Kijroongrojana, 2013; Khuenpet *et al.*, 2015; Marshall *et al.*, 2003).

2.6.4 Stabilizers and emulsifiers

Stabilizers, frequently referred to as hydrocolloids, are a group of water-soluble or water-dispersible biopolymers commonly used in ice cream formulation (Clarke, 2004). Their primary purposes are as follows:

- Due to their high water holding capacity, stabilizers produce smoothness in body and texture, provide uniformity and shape retention during melting.
- They increase viscosity of the product, retard ice and lactose crystal growth during hardening and storage.
- Carrageenan is mostly used to stabilize the protein in the mix to prevent wheying off (phase separation).
- They create stable foam with easy cutoff and stiffness at the barrel freezer for packaging and slow down moisture migration from product to the package or air.
- Stabilizers improve creaminess and reduce wateriness (a sensory property that has been applied when the sample melts unusually quickly into an uncharacteristically thin, water-like fluid).
- Their ability to form cryogels on heat shock during storage results in a cryoprotective effect on ice cream.
- Stabilizers prevent coarsening of texture under temperature fluctuations in retail cabinets and give desired resistance to melting (Bahramparvar and Tehrani, 2011; Marshall *et al.*, 2003).

Stabilizers are one such ingredient, which, in spite of low level in formulation impart specific and important functions to the finished product. The amount used may be in the range 0-0.5% depending upon the solid content of the mix. Stabilizers extensively used in frozen dairy foods include proteins (gelatin), plant exudates (tragacanth gums), seed gums (locust bean gum), microbial gums (xanthan), seaweed extracts (carrageenan), pectin and cellulosics (sodium carboxymethylcellulose) (Arbuckle, 1986; Goff and Hartel, 2013)

An emulsifier is a surface active agent that produces a stable suspension between two liquids that do not mix naturally. These promote fat destabilization by lowering the fat/water interfacial tension in the mix, resulting in protein displacement from the fat globule surface. This reduces the stability of fat globule allowing partial coalescence during whipping and freezing process and leads to the formation of structure of fat in the frozen product that contributes greatly to texture and meltdown properties. Emulsifiers are sometimes integrated with stabilizers in proprietary blends but have different actions and functions some of which are as follows:

- Produce a drier and stiff ice cream to facilitate molding and fancy extrusion.
- Promote nucleation in fat during aging, thus reducing aging time.
- Improve whipping quality of the mix due to their function at air interface resulting in reduced air cell sizes and homogeneous distribution of air in ice cream
- Increase resistance to development of coarse/icy textures and shrinkage.
- Produce a product with good stand up properties and melt resistance (Marshall *et al.*, 2003).

Egg yolk solids are widely used as emulsifiers as they improve fat structure formation and whipping ability due to presence of phospholipids and lecithin-protein complexes. Ice cream emulsifiers are of two types: the mono- and di-glycerides of fat forming fatty acids and sorbitan esters. Typical concentrations in use are 0.1-0.2% (Arbuckle, 1986).

Rinaldi *et al.* (2014) showed that ice cream samples with coconut phospholipids as emulsifiers exhibited highest values for hardness, greatest resistance to melt, high fat destabilization and intermediate overrun values. The destabilized fats were reported to stabilize the air cells and to trap the aqueous phase in ice cream, preventing drainage upon meltdown.

However beneficial, excess use of stabilizers may lead to undesirable results like excess chewiness, soggy or heavy body while high emulsifier content may increase the potential for churning of fat.

2.6.5 Flavor

Flavor is the most important aesthetic attribute of food and ice cream is no exception. Flavor is a sensory response that has three components: olfaction (smell), gustation (taste) and tactual (mouthfeel). Generally compounds that impart tastes can be detected at level of 0.01-0.5% (Kilara and Chandan, 2008)

The flavor of ice cream is the result of blending flavors of all the ingredients, some of which may not be pronounced enough to be recognizable, although each contributes to the final effect. Type and intensity are two major flavor characteristics. Mild and delicate flavors are easily blended and tend not to become tiresome even when intense while harsh flavors soon become tiresome even in low concentrations (Marshall *et al.*, 2003).

Flavor is important in influencing consumer acceptance. Defects may arise if there is too much or too little flavoring, unnatural or atypical flavoring. While eating ice cream, the melting of ice and fat leads to collapse of air cell which in turn releases flavor volatiles. These volatiles traverse the palette and enter the olfactory membrane. An ice cream mix is processed to obtain a neutral flavored base which has the ability to acquire any characterizing flavor added to it. The most popular flavors are vanilla, chocolate, fruits, nuts, bakery goods, ripples and confectionary items (Kilara and Chandan, 2008).

The International Dairy Foods Association developed the following guidelines for labeling standards of FDA for ice cream flavors.

- Category I: Contains pure flavor extract and no artificial flavor e.g., vanilla ice cream
- Category II: Contains both natural and synthetic flavor but natural predominates in quantity e.g., vanilla flavored ice cream
- Category III: Flavored exclusively with artificial flavor or a combination in which artificial predominates over natural e.g., artificially flavored vanilla ice cream (Goff and Hartel, 2013).

Flavorings are available as liquids, syrups, semisolids and solids. Liquid flavorings are added to the mix just prior to freezing, fruits, nuts and other solid or semisolid flavorings are added immediately after freezing whereas ripples are added just prior to packaging. In addition to the added flavoring, temperature consumption, pH, fat content, sweetness level and process variables affect the overall flavor of ice cream. While vanilla flavor becomes more pronounced as serving temperature is increased from -14.4 to -7.8°C, 17% sugar is found to be optimum for most desirable fruit flavor. Usually frozen desserts are liked best when served below -12°C (Marshall *et al.*, 2003).

2.6.6 Color

Ice cream color should be delicate and attractive that suggests or is readily associated with its flavor. Both "certified" (within the Food and Drug Cosmetic Act) and "exempt from certification" (natural) colors are approved by the U.S. Food and Drug Administration for use in ice cream (Marshall *et al.*, 2003).

The color of ice cream has a significant influence on the consumers' perception of its flavor and quality. Colors are added to ice cream to give color to products that would otherwise be virtually colorless, to reinforce colors that are already present and to ensure uniformity of color between batches (Clarke, 2004)

The color of frozen desserts must have both the desired hue or shade and the proper intensity because an inappropriate hue gives the impression of artificiality. If color is lacking, it may seem like too little flavoring has been added and if the intensity is too high, the product may appear to be artificially flavored even when it is not (Goff and Hartel, 2013).

Most ice cream flavors require addition of at least a small amount of color. Yellow color is added to vanilla ice cream to give it the golden shade of cream while in fruit ice creams, the usual amount of fruit added is insufficient to impart adequate color. The only exception is chocolate ice cream which does not need added color as highly alkalized cocoa imparts high color at the used concentration. Most colors are of synthetic origin. While Annatto color is the most used exempt color in ice cream, several other natural colorings have also emerged such as anthocyanins (red-purple), chlorophyll and chlorophylline (green-yellow), caramel (brown) and carotenoid (saffron). Colorants permitted for use in ice cream are Erythrosine, Allura Red, Green S, Sunset Yellow, Indigo Carmine, Tatrazine and Brilliant Blue (Jana *et al.*, 2016).

2.6.7 Water

Water is an important constituent of ice cream. It is a continuous phase in which all the other solute components are dissolved or dispersed. Water in ice cream is present as a liquid, a solid or a mixture of the two physical states. Water varies in pH, alkalinity and hardness, but unless any of these parameters are extreme, water does not need to be chemically treated.

Ice cream mix requires a source of water to standardize the content of fat and MSNF. Water used must be of high quality, potable and free of contamination. In some cases, it might be necessary to chlorinate the water for bacteriological reasons. It may be a common practice to use fluid milk as a source of water. When water is used to balance the mix, a larger portion of dry or concentrated skim milk is used to supply MSNF (Chhetri, 2016).

2.7 Defects of ice cream

Defects are caused by defective ingredients, manufacturing errors and unbalanced mix. In ice cream, defects result from faults in flavor, body and texture, melting characteristics, color and packaging (Arbuckle, 1986).

- Flavor defects: It arises from poor quality ingredients, improper flavoring, serving temperature and sweetness. Flavor defects includes following:
  - High and low flavor result due to excess and low amount of flavor respectively.
  - Cooked flavor is due to overheating the mix and bitter due to inferior products.
  - Acid flavor is the result of presence of excessive amount of lactic acid.
  - Unnatural flavor indicates presence of a flavor not typical to ice cream.
  - Metallic flavor is caused by copper contamination or bacterial action.
  - Salty flavor may be due to too high MSNF in the mix.
  - Oxidized flavor results when old or stale ingredients are used.

- Body and texture defects: Body refers to firmness while texture refers to fine structure of ice cream. Sources are improper mix composition, process and storage conditions.
  - Crumbly body lacks cohesion, breaks apart easily and is associated with low
  - TS content, insufficient stabilization and excessive overrun.
  - Soggy body is dense and wet in appearance; it is due to low overrun, excess
  - stabilizer or hand packaging after hardening the ice cream.
  - Weak body lacks firmness or chewiness and is accompanied by rapid melting.
  - Buttery texture refers to presence of large lumps of butterfat.
  - Coarse or icy texture indicates non-uniform or large sized ice crystals.
  - Fluffy texture is detected by presence of large air cells and open texture.
  - Sandy texture refers to sand like roughness in melted ice cream.
- Melting quality: Melted ice cream should show characteristics similar to the original mix. However, several defects in melting quality may be noted.
  - Foamy meltdown results due to large air cells and high amount of egg solids.
  - Curdy meltdown includes dull scum like surface on the melted ice cream.
  - Curdled meltdown indicates high acidity or instability of milk protein.
  - Does not melt includes shape retention by ice cream when warmed, slow
  - melting and is accompanied by body defects like soggy, doughy and sticky.
  - Wheying off is noted by appearance of bluish fluid leaking from ice cream.
- Color and appearance defects: This includes excessive color, unnatural color, gray or dull appearance and non-uniform color in ice cream.
- Shrinkage: This refers to ice cream pulling away from the walls of container and results from loss of discrete air bubbles as they coalesce forming continuous channels and eventually lead to collapse of the product itself into the channels (Goff and Hartel, 2013; Jana *et al.*, 2016).

2.8 Manufacture of ice cream

The first step in making ice cream is to mix the ingredients in a tank, equipped with devices to heat the contents, in proportions calculated on the basis of formula used. The liquid ingredients are poured first and the tank put to heat (Acharya, 2006).

2.8.1 Pasteurization of the mix

The objectives of pasteurizing the mix is to kill pathogenic and spoilage microorganisms, dissolve the ingredients, inactivate lipase enzymes and to decrease its susceptibility to auto-oxidation (Walstra *et al.*, 2006). Pasteurization can be carried out in 3 different ways:

- Batch process (68-70°C for 30 min)
- High Temperature Pasteurization (70-85°C for 2-20 s)
- Ultra-High Temperature Process (100-130°C for 1-40 s)

2.8.2 Homogenization of the mix

The main purpose of homogenization is to obtain a more uniform and stable emulsion so as to give sufficiently fine and smooth texture but excess homogenization may lead to highly viscous mix which should be avoided. The homogenization pressure should be adapted to the fat content, pasteurization intensity and the mix composition mix (Walstra *et al.*, 2006).

2.8.3 Ageing of the mix

The mix is aged at 0-2°C for 4-24 h for allowing the stabilizers to swell, fat globules to crystallize before freezing and emulsifiers to displace protein from fat globules. Ageing is generally done for producing a mix with better physical properties (Walstra *et al.*, 2006).

2.8.4 Freezing of the mix

Freezing implies cooling the mix to a few degrees below zero. During the freezing, small ice crystals are formed due to the vigorous beating and rapid cooling. Simultaneous beating of air and ice formation should take place because beating in of air after the bulk of water is frozen becomes impossible and late freezing of water leads to insufficient churning of fat globules (Acharya, 2006; Walstra *et al.*, 2006).

2.8.5 Hardening

The mix leaves the freezer at -3.5 to -7°C and packaging in cups allows better shape retention during hardening. The hardening process serves to adjust the temperature of ice cream to such a level as to retain its shape and to give it sufficient shelf life with respect to its chemical and enzymatic reactions and physical structure as well (Walstra *et al.*, 2006).

2.9 Melting properties of ice cream

Meltdown of ice cream is an empirical parameter that measures its ability to resist melting when exposed to warm temperatures for a period of time. It is a measure that reflects thermal conductivity, heat capacity and microstructure as well as indicates the effect of changing the formulation on the properties of ice cream (Clarke, 2004).

The melting rate of ice cream is influenced by amount of air incorporated, nature of ice crystals and network of fat globules formed during freezing. Lower melting rate relates to the sustainability of the ice cream's shape, which is typically evaluated as a good quality ice cream (Pon *et al.*, 2015). Muse and Hartel (2004) found that increased levels of destabilized fat contributed to slower melting rates. A greater extent of destabilized fat increases the resistance to flow of serum phase as ice melts which leads to slower meltdown. Ice cream with high consistency coefficients also has a greater resistance to flow. Sakurai *et al.* (1996) showed that ice creams with lower overruns had faster melting rates. This was attributed to a reduced rate of heat transfer due to a larger volume of air.

2.10 Overrun of ice cream

Air is an important component of ice cream that affects the physical and sensory properties as well as its storage stability. Overrun is defined as the volume of ice cream obtained in excess of the volume of mix. The presence of air in mix gives an agreeable light texture to the final product (Yuksel, 2015). The increased volume is composed of air incorporated during the freezing process. The amount of air which should be incorporated depends on composition of mix and the way it is processed and regulated so as to give that percent overrun which will give proper body, texture and palatability to the ice cream. Variation in emulsifier content and freezing temperature also influences overrun development in ice cream (Tong *et al.*, 1983).

The overrun attainable at the freezer depends on type of ingredients used in the mix, sharpness of scrapper blades, speed of dasher, volume of refrigerant passing over freezing chamber and temperature of refrigerant. The incorporation of air gives smoother, more velvety texture to the ice cream. The amount of air incorporated influences the sensory attributes of ice cream. If a lower amount of air is applied, the resulting ice cream is dense, heavy and colder eating. If higher amount of air is used, the ice cream becomes light and fluffy. Among the mix components, emulsifier is important for structure formation, air cell distribution and stability of the formed air cells (Ludvigsen, 2011).

Pon *et al.* (2015) found that the average ice cream overrun was lower than the general literature value. This may be due to inconsistency during whipping process which is caused by limitation of the equipment. Studies have also found that it is difficult to obtain higher overrun values by a batch type freezer.

2.11 Coconut

2.11.1 Description and development

The coconut (*Cocos nucifera* L.) is a member of the family Arecaceae (palm family). It is the only accepted species in the genus *Cocos*, and is a large palm, growing up to 30 m tall, with pinnate leaves 4-6 m long and pinnae 60-90 m long which old leaves break away cleanly, leaving the trunk smooth. The term coconut can refer to the entire coconut palm, the seed, or the fruit, which is not a botanical nut (Afodunrinbi and Onyeukwu, 2000). The coconut palm is found throughout the tropics, where it is interwoven into the lives of the local people. It is particularly important in the low island of the pacific where, in the absence of land-based natural resources it provides almost all the necessities of life-food, drink, oil, medicine, fiber, timber, thatch, mats, fuel and domestic utensils. For good reason, it has been called the “tree of heaven” and ‘tree of life”. Today it remains an important economic and subsistence crop in many small pacific island states Banzon (1990).

The coconut’s name is a bit of misnomer, since it is botanically classified as a drupe and not a nut. It is the largest seed known (Banzon, 1990)

Production of coconut

2.11.2 Varieties

Varieties and characteristics of coconut shown in the Table 2.5

Table 2.5 Varieties and characteristics of coconut

Variety	Characteristics
Tall	Thick stem with swollen base (bole). Later flowering (5–6 year from out planting). Little or no overlapping of male and female phases of an inflorescence encouraging out- crossing.
Dwarf	Slender stem with short internodes. Bole slight or absent. Early flowering (3 year from out planting). Considerable overlapping of male and female phases of an inflorescence resulting in self-pollination

Source: Romney (1997)

2.11.3 Coconut meat

Coconut meat is the edible white meat of a coconut; often shredded for use in cakes and curries. It contains essential mineral salts particularly magnesium, calcium and phosphorus which are of great importance to the musculoskeletal system. Though present in small amounts (32 mg/100 g of magnesium) in coconut meat, the Magnesium content surpasses that of all animal-based foods including meat, fish, milk and eggs (Pamplona-Roger, 2007).

2.11.4 Coconut fat

All fat and oils are composed of molecules called fatty acids. These are two methods of classifying fatty acids. The first is based on saturation; there are saturated fats, monounsaturated fats, and polyunsaturated fats. The other system of classification is based on molecular size or length of the carbon chain within each fatty acids. In this system there are short chain fatty acid (SCFA), medium chain fatty acids (MCFA), and long chain fatty acids (LCFA) (Thompson *et al* 1961)

Coconut oil is composed predominately of medium-chain fatty acids (MCFA), also known as medium-chain triglycerides (MCT). The size of the fatty acid is important because the human body responds to and metabolizes each fatty acid differently depending on its size. So, the physiological effects of MCFA in coconut oil are distinctly different from those of LCFA more commonly found in our foods. The saturated fatty acids in coconut oil are predominately medium-chain fatty acids. Both the saturated and unsaturated fat found in meat, milk, eggs, and plants (including almost all vegetable oils are composed of LCFA. MCFA are very different from LCFA. They do not have a negative effect on cholesterol and help to protect against heart disease. MCFA help to lower the risk of both atherosclerosis and heart disease. It is primarily due to the MCFA in coconut oil that makes it so special and so beneficial. There are only a very few good dietary sources of MCFA. The best sources of MCFA are coconut and palm kernel oils (Pamplona-Roger, 2007)

2.11.5 Coconut milk

Coconut milk should not be confused with coconut water, although some studies have used the two terms interchangeably. The aqueous part of the coconut endosperm is termed coconut water, whereas coconut milk, also known as "*santan"* in Malaysia and Indonesia, and *"gata"* in the Philippines, refers to the liquid products obtained by grating the solid endosperm, with or without addition of water. Coconut milk is usually used as food ingredient in various traditional cooking recipes, while coconut water is served directly as a beverage to quench thirst (Banzon, 1990).

Coconut milk is the term used to designate the liquid obtained by the manual or mechanical extraction of grated coconut meat with or without added water. The term coconut milk and coconut cream are used interchangeably. But coconut milk refers to the milky fluid, freshly extracted from the coconut kernel with or without added water, and coconut cream refer to the high fat cream like material obtained from the coconut milk by either gravity separation or centrifugation (Banzon, 1990).

Maturity of the coconut greatly affects the yield of coconut milk. Mature brown husked coconuts with no protruding sprouts produce higher yields of milk. Coconut milk is generally produced from mature nuts of 12 months in age. At this stage, the meat is hard and thick, with a typical composition of as follows: 50% moisture, 34% oil, 3.5% protein, 3% fiber, 2.2% ash and 7.3% carbohydrates (Banzon, 1990).

Composition of coconut milk is shown in the Table 2.6

Table 2.6 composition of coconut milk

Components	Value (%)
Moisture	72.88
Ash	1.7
Protein	2.02
Fat	5
Acidity (as % citric acid)	0.13
Carbohydrate	2.81

Source: USDA (2012)

2.11.6 Coconut protein

Coconut proteins are generally classified according to their solubility and amino acid composition. The predominant proteins in coconut endosperm or kernel are classified as globulin (salt-soluble) and albumin (water-soluble), which account for 40% and 21% of total protein, respectively. Globulin fraction of coconut has a high level of charged amino acids. Those are aspartic acid, glutamic acid, arginine, and lysine (Kwon et al., 1996; Patil and Benjakul, 2017). The albumin fraction has higher proportions of amino acids with polar side chains. The relative proportion of each protein fraction affects the functional properties and the nutritional quality. The differences in maturation stage, fertilizer, climate, starting material, and so on, also result in varying proportion of various proteins in coconut meat (Patil and Benjakul, 2017). Distribution of proteins in defatted coconut meal, classified based on solubility, is shown in Table 2.7.

Table 2.7 Distribution of protein in defatted coconut meal

Protein	Extraction solvents	Proportion (%)
Albumin	Water	19
Globulin	Nacl (1-0.5M)	36
Prolamin	Isopropyl alcohol (70%)	2
Glutelin-1	Glacial acetic acid (50%)	10
Glutelin-2	NaOH (0.1M)	4
Unextractable protein	Residue	-

Source: Patil and Benjakul (2017)

2.11.7 Nutritional and medicinal importance of coconut milk

Some of the most important benefits of coconut milk

- A major part of the fats found in coconut milk is lauric acid, which has been found to exhibit antibacterial, antifungal and antiviral properties. This fatty acid can boost the immune system and its disease fighting ability.
- Lauric acid can also be helpful in maintaining the elasticity of the blood vessels and in in keeping them clean, which can lower the risk for conditions like, atherosclerosis and heart disease.
- Coconut milk also contains several antioxidant compounds, which can provide protection against the harmful free radicals and their damaging effects on the body cells and tissues.
- Coconut milk can improve the health of the digestive system and promote digestion. It can relieve the symptoms of stomach ulcer and acid reflux disease as well.

- Coconut milk can give about 22% of the recommended daily allowance of iron. With such a high level of iron, it can help to treat anemia caused by iron deficiency.
- Coconut milk health benefits are mentioned in traditional medicine for the human body. It is also used for treatment of mouth ulcer.
- Coconut is a dairy free alternative to those who are lactose intolerant and are also allergic to animal milk. This milk is also nut free, soy free and gluten free.
- It is known to relieve the symptoms of sore throat.
- It is good for the health of your skin and hair. Many cosmetic giants use it as a base in products for skin and hair.
- Apply coconut milk to the scalp to have dandruff free hair and condition your hair naturally.
- Coconut milk is a reservoir of antioxidants. Antioxidants help the body fight aging, low vison and low bone density.
- It also aids in digestion and is also used as a laxative. It can also be a remedy for urinary and kidney problems.
- Coconut milk is an excellent source of Vitamin E. it helps in nourishment of the skin.
- The saturated fat content in coconut is made up of short and medium chain fatty acids. These fatty acids are quickly converted into energy instead of storing as fat in the body.
- The medium chain fatty acids present in coconut milk are full of lauric acid. Lauric acid is antifungal, antiviral and antimicrobial. Lauric acid present in coconut milk helps to keep the arteries of the heart clean and healthy (Banzon, 1990).

Part III

Materials and methods

3.1 Materials

The materials collected for the formulation of coconut milk incorporated ice cream were as follows:

3.1.1 Milk

standard milk was collected from DDC, Dharan. Fat and SNF were tested, which were found to be 3.0% and 8.0% respectively.

3.1.2 Cream

Fresh cream was bought from DDC, Dharan. Fat and SNF were found to be 70% and 2.2% respectively.

3.1.3 Milk solid not fat

Skim milk powder was used as the source of MSNF and it was bought from the local market of Dharan. According to the label of packet, it contained 94% SNF.

3.1.4 Sweetener

Sugar was used as a sweetener. It was bought from the local market of Dharan.

3.1.5 Mixed stabilizer/emulsifier

Mixed stabilizer/emulsifier containing di-glycerides, gelatin and carrageenan was used. The product name of mixed stabilizer/emulsifier was ICO Caragel. It was also bought from local market of Dharan. It can be used in range of 0.3-0.5%.

3.1.6 Coconut

Coconut was collected from the local market of dharan.

3.1.7 Containers

Plastic cup as ice cream packaging materials were bought from the market of Dharan. The size of cup was 50 ml and plain in design.

3.1.8 Equipment and chemicals

The following equipment and chemicals used were available in campus. The list of chemicals used for the analysis is shown in Table 3.1 and the list of equipment is shown in Table 3.2.

Table 3.1 List of chemicals used

Sodium hydroxide (NaOH)
Hydrochloric acid (HCl)
Sulphuric acid (H_2SO_4)
40% Formaldehyde
Fuchsin solution

Table 3.2 List of equipments used

Heating arrangement	Soxhlet apparatus
Electric balance	Hot air oven
Centrifuge	Grinding apparatus
Thermometer	Stainless steel vessels
Ice cream batch freezer	Whatman filter paper
Plastic cup and spoon	Kjeldahl digestion and distillation set

Titration apparatus	Refrigerator
Muffle furnace	Gerber butyrometer

3.2 Methods

3.2.1 Preparation of coconut milk

The coconut will be de-husked. The de-husked nut will be cracked open into halves. The split nuts will be de-shelled to separate the coconut meat (kernel). Coconut meat will be washed and comminuted using an electric blender with water. This will be pressed through a muslin cloth and strained to obtain coconut milk.

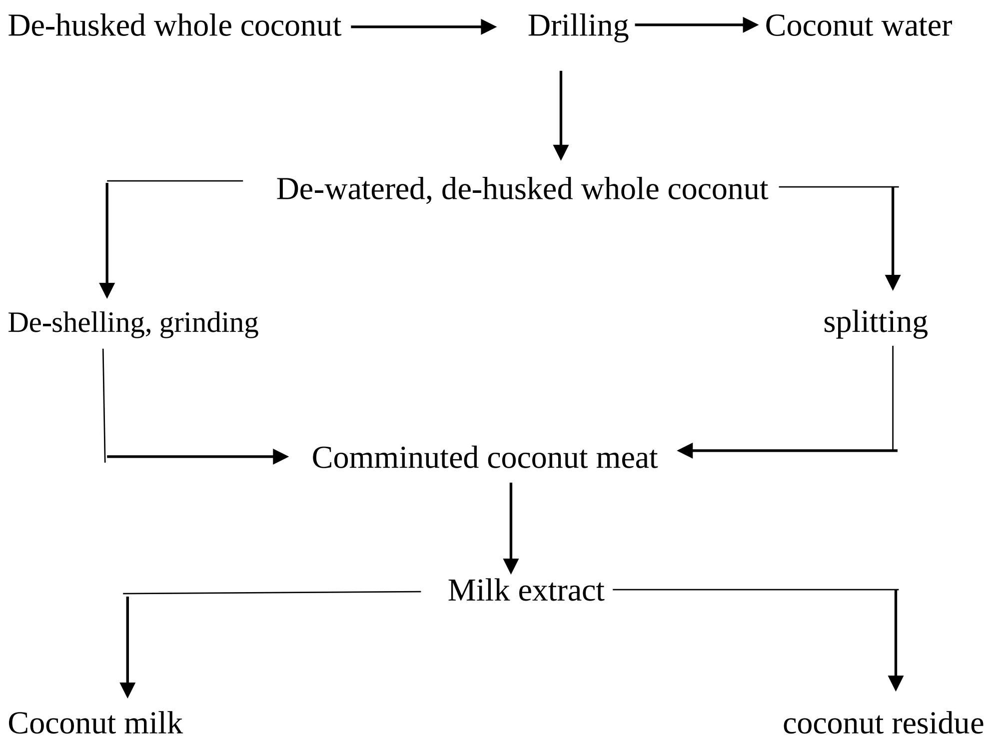

Fig. 3.1 Preparation of coconut milk

Source: Tamrakar (2017)

3.2.2 Formulation of ice cream using experimental design

Response surface methodology (RSM) is a collection of statistical and mathematical techniques for developing and optimizing products and processes. It is useful in a situation where several input variables have potential influence on some performance measures or quality characteristics. RSM initiates from design of experiments (DOE) to determine the factors' values for conducting the experiments and collecting data which are then used to develop an empirical model that relates the process response to the factors (Zhen *et al.*, 2013)

RSM was adopted in the experimental design and a three-level, two-factor optimal(costume) was employed. The independent variables selected for the experiment were: coconut milk content and MSNF content. Response variables were overrun and melting rate. The three levels of the process variables were coded as -1, 0 and 1 and the values of variables at three levels are given in Table 3.3.

Table 3.3 Values of independent variables at three levels of optimal design

Independent variables	Uncoded	Levels in coded form		
		-1	0	1
Coconut milk (%)	A	0	50	100
MSNF (%)	B	10	11	12

The upper limit and the lower limit of the ingredients were set as above since there are no any standard values for coconut milk content to be used in ice cream mentioned in literature. The effect was studied within the above range of the ingredients. The MSNF content in ice cream should be in the range of 10-12% as given by Acharya (2006). Table 3.4 and 3.5 tabulate the experimental design in coded form for response surface analysis and experimental combinations for at actual levels for response surface analysis respectively.

Table 3.4 Experimental combinations at actual levels for response surface analysis

S.N.	A: Coconut milk	B: MSNF
1	0	10
2	50	10
3	100	10
4	0	11
5	50	11
6	100	11
7	0	12
8	50	12
9	100	12

The work was carried out for the preparation of standard quality of different varieties of ice cream with different proportion of milk, coconut milk and MSNF. The input variation range in design experiment was 0-100% for coconut milk and 10-12% for MSNF.

3.2.3 Method of coconut milk incorporated ice cream preparation

Coconut milk incorporated ice cream will be prepared by heating the coconut milk to 90°C for 1-2 s. Calculated amount of sugar, stabilizer and SMP will be added during the pasteurization of the mix. It will be homogenized when hot, and then cooled to room temperature; flavor will be added to it and then aged for 6 h in chilling temperature. The aged mix will be subjected to a freezer until consistent texture will be obtained.

Fig. 3.2 shows the detail method of preparation of coconut milk incorporated ice cream.

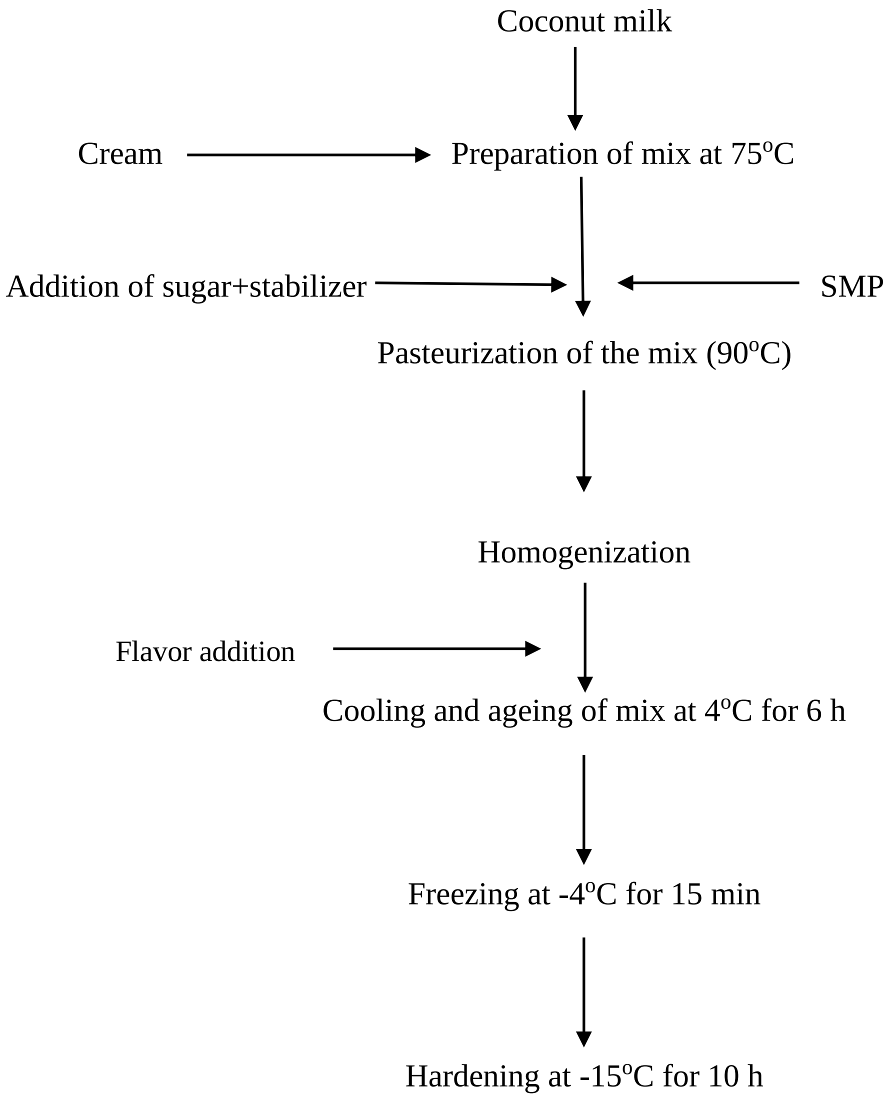

Fig. 3.2 Method of preparation of coconut milk incorporated ice cream

Source: Jayasundera and Fernando (2014)

3.2.3.1 Preparation of the mix

Ice cream mix will be prepared by transferring liquid ingredients such as milk and/or coconut milk according to the formulation and cream in a vat. The mixture will be then heated with continuous stirring. The dry ingredients like milk powder will be mixed with little amount of warm milk and will be stirred so as to avoid lumpiness and will be added to the vat. After the temperature of mix reached 50°C, sugar mixed with stabilizer will be sprinkled on the surface and agitation will be continued for proper suspension to avoid uneven consistency.

The recipe formulation for coconut milk and MSNF was done according to the combination given in Table 3.4 keeping other ingredients constant.

3.2.3.2 Pasteurization of the mix

The mix will be batch pasteurized at 90^{o}C for 1-2 s.

3.2.3.3 Homogenizing of the mix

The mix will be homogenized at a temperature in between 65-80^{o}C so as to avoid clumping of fat globules and excessive viscosity at lower temperature in a stirrer. It will be done for emulsion stability.

3.2.3.4 Ageing of the mix

The mix will be aged for about 6 h in order to develop the proper stable emulsion.

3.2.3.5 Freezing of the mix

Freezing of the cooled mix will be done in an ice cream freezer for about 15 min. the mix will be introduced into a cylinder containing a dasher. Air will be incorporated during the freezing process.

3.2.3.6 Hardening and packaging

The bulk of ice cream from the freezer will be withdrawn and poured into small plastic cups and will be frozen into deep freeze at -10 to -15^{o}C for 10 h.

3.3 Experimental Procedure

3.3.1 Sensory evaluation

The ice cream samples, the best one in terms of sensory quality was determined. For sensory evaluation, hedonic rating method was used as described by (Ranganna, 2000). The panelist members consisted of students and teachers of CCT, Hattisar. The data were subjected to statistical analysis and the scores given by the panelists were analyzed by Two-way analysis of variance (ANOVA) no blocking at 5% level of significance using statistical software GENSTAT Release (version 12.1) developed by Lawes Agricultural Trust (1995). The calculated mean values of each sensory parameter were compared with value in the LSD at 5% level of significance to determine whether the samples were significantly different from each other and also to determine which one is superior among them. The parameters taken for sensory analysis were aroma, taste, color, body, aftertaste and overall acceptance. The sensory card is presented in the Appendix A.

3.3.2 Statistical analysis of responses

The responses overrun and melting rate for different experimental combinations were related to the coded variables (xi, i = 1 and 2), by a polynomial equation as given below:

$$Y = \beta o + \beta 1x1 + \beta 2x2 + \beta 11x12 + \beta 22x22 + \beta 12x1x2 + \varepsilon$$

The coefficients of the polynomial were represented by βo (constant), $\beta 1$, $\beta 2$ (linear effects), $\beta 11$, $\beta 22$ (quadratic effects), $\beta 12$ (interaction effect) and ε (random error). A second order quadratic model was employed to correlate the independent process variables. The second order polynomial coefficient for each term of equation was determined through multiple regression analysis using design expert. Data were fitted to the selected models and the statistical significance of the terms was examined by analysis of variance for each response. The adequacy of the model was tested considering R^2 (coefficient of determination of the amount of variation around the mean explained by the model), adjusted R^2 (a measure of the amount of variation around the mean explained by the model adjusted for the number of terms in the model), predicted R^2 (a measure of good the model predicts a model value) and Fischer's F test. Coefficient of determination R^2 is a measure of degree of fit as it is the ratio of explained variation to the total variation. When R^2 approaches to unity, a better empirical model fits the actual data. The smaller the value of R^2, the less relevance the dependent variables in the model have in explaining the behavior variation. Then the effect of predictors on the response was interpreted using the models.

The analysis of variance (ANOVA) tables were generated and the significance of all terms in the polynomial equation was judged statistically by computing the F-value at 5% level of significance. Design expert version 12.0 was used for this purpose.

3.3.3 Chemical and physical analysis of raw materials, final product

3.3.3.1 Parameter analyzed

The milk, cream and SMP were analyzed for fat content, SNF content and acidity. In addition of these, protein content was also determined for coconut milk and milk. The final ice cream was analyzed for its overrun, total solid, fat content, lactose, protein, total ash, melting rate and acidity.

- Overrun: Percentage overrun of ice cream was determined by the gravimetric method given in National Dairy Development Board (2001). Initial weight of the empty ice cream cup was taken as W; weight of ice cream cup with mix was taken as W_1. The cup was emptied and filled with ice cream after freezing and weighed as W_2. Result was expressed by following formula:

$$\% \text{ Overrun} = \frac{(W_1\text{-}W_2)}{(W_1\text{-}W)} \times 100$$

• Total solid: Total solid content was determined by using the gravimetric method as (National Dairy Development Board, 2001). The initial weight of an empty petridish was taken as W. 2 g of ice cream sample was taken and weighed as W1. It was then heated in a water bath until it appeared dry and then placed in hot air oven at a temperature of 100°C for 3 hrs. The dried sample was then cooled in desiccator and weighed again as W2. Result was expressed by the following formula:

$$\% \text{ Total solid} = \frac{(W_2\text{-}W)}{(W_1\text{-}W)} \times 100$$

• Fat: The fat content of ice cream was determined by Gerber method. 5ml melted ice cream sample was taken in an ice cream butyrometer. 10 ml Gerber sulfuric acid and 1 ml amyl alcohol was added to it. This was centrifuged for 5 min at 1200 rpm and allowed to stand for some time. After immersing in water bath for 5 min, the fat content was noted.

• Lactose: Percentage lactose of the final ice cream was determined by Lane and Enyon method as in Handbook of Analysis and Quality Control of Fruits and Vegetable Product (Kilara and Chandan, 2008).

• Protein: Percentage protein in ice cream was determined by formal titration method as described in Handbook of Analysis and Quality Control of Fruits and Vegetable Product by Muse and Hartel (2004).

• Total ash: Total ash of the ice cream was determined by Gravimetric method as described by Ranganna (2000).

• Melting rate: The melting rate was determined as given in Ice Cream. The meltdown was quantified by determining the mass that drips from the product 48 through a mesh screen as a function of time when the product is allowed to melt while being held at a selected temperature (Goff and Hartel, 2013).

• Acidity: The acidity of ice cream was determined as lactic acid by titration with standardized alkali solution as given in Handbook of Analysis and Quality Control of Fruits and Vegetable Product (Ranganna, 2000).

Part IV

Results and discussion

This work was carried out for the preparation of standard quality of different varieties of ice cream with different proportions of coconut milk and MSNF. As ice cream is a product widely favored and consumed by the general population, coconut ice cream as a functional food was chosen as a vehicle to deliver the functional ingredients in this study. At first, the major raw materials were subjected for proximate analysis.

4.1 Proximate composition

Milk and coconut milk were analyzed for proximate components whereas cream and SMP were analyzed for fat and solid not fat (SNF). The results of analysis of milk and coconut milk in wet basis are tabulated in Table 4.1 and that of cream and SMP in Table 4.2.

Table 4.1 Proximate composition of milk and coconut milk

Components	Milk (% wb)	Coconut milk (% wb)
Moisture	88.3±0.85	86.2±1.1
Protein	2.9±0.3	3.1±0.4
Fat	2.95±0.22	7.5±0.3
Ash	0.6±0.1	1±0.05
Carbohydrate	4.5±0.6	2.2±0.08

Table 4.2 Analysis of cream and SMP

Components	Cream (% wb)	SMP (% wb)
Fat	75	0.5
SNF	3.2	95

*the values in the table are mean of triplicate ± standard deviation

4.2 Sensory analysis of coconut milk ice cream

Sensory analysis of coconut milk ice cream was performed with the aid of ten semi-trained panelists evaluating aroma, taste, color, body, aftertaste and overall acceptability of prepared coconut ice cream. 9 samples were subjected to sensory analysis. They are alphabetically coded as given in Table 4.3.

Table 4.3 Sample formulation in coded form

S.N.	Coconut milk	MSNF
A	0	10
B	50	10
C	100	10
D	0	11
E	50	11
F	100	11
G	0	12
H	50	12
I	100	12

Sensory scores obtained from 10 panelists using 9-point hedonic rating scale (9= like extremely, 1= dislike extremely) for different coconut ice cream formulations were statistically analyzed. From the statistical analysis ($p<0.05$), products were found significantly different in terms of all sensory parameters.

4.2.1 Effect on formulation on aroma

The mean sensory score ± standard deviation for aroma of nine samples A, B, C, D, E, F, G, H and I were found to be 7.1±0.74, 7.7±0.48, 7.2±0.63, 7.3±0.48, 7.5±0.84, 6.9±0.73, 7.6±0.70, 6.6±0.52 and 7.3±0.67 respectively. The statistical analysis showed that there is significant effect ($p<0.05$) of coconut milk variation on aroma at 5% level of significance. The mean score was found to be highest for sample B which was significantly difference from samples A, C, F, H and I but not from D, E and G.

The mean score for samples with average coconut milk and lower MSNF were found to have higher values while slightly lower values were obtained for control G. This showed that average coconut milk content was preferred than complete coconut milk ice cream. Soler (2005) observed similar results where flavor of ice cream with average coconut milk content was preferred. However, MSNF seemed to have no or very less effect on aroma of ice cream as samples with highest and lowest MSNF contents acquired similar scores.

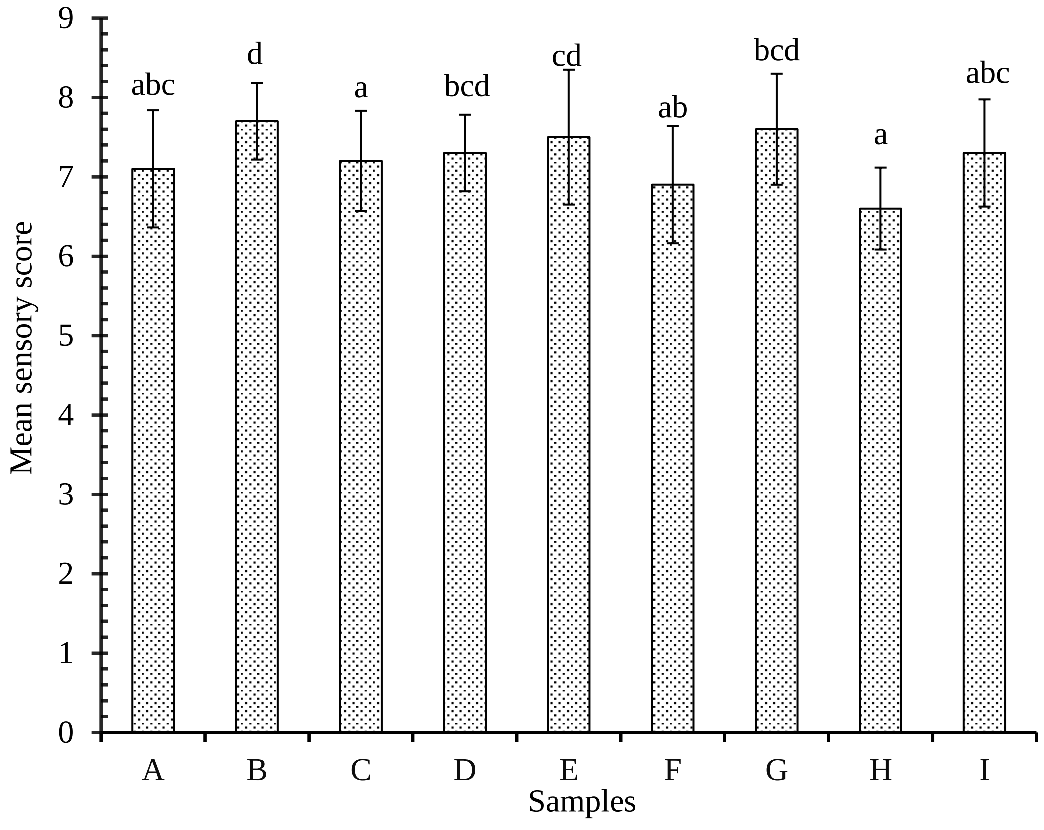

Fig. 4.1 Mean sensory scores for aroma of coconut ice cream

Fig. 4.1 represents the mean sensory scores for aroma of coconut ice cream. Values on top of the bars bearing similar superscript are not significantly different at 5% level of significance. Vertical error bars represent ± standard deviation of scores given by panelists. Samples A, B, C, D, E, F, G, H and I represent sample formulations as given in Table 4.3.

4.2.2 Effect of formulation on taste

The mean sensory scores for taste of samples A, B, C, D, E, F, G, H and I were found to be 7.1±0.57, 8.2±0.42, 7.2±0.79, 7.6±70, 7.5±0.53, 7.5±0.97, 7.7±0.48, 7. ±0.94 and 7.3±0.48 respectively. The mean score was found to be highest for sample B and was similar to control G. samples A&B, A&G, B&C, B&D, B&E, B&F, B&H, B&I, D&H, and G&H were found to be significantly different.

The mean score for sample with half coconut milk and half milk were found to be higher while slightly lower values were obtained for sample D and G. This showed that average coconut milk was more preferred than complete coconut milk ice cream. Results of other researches were similar with the findings of this work where coconut ice cream claimed the highest score for taste (Reilly, 2017).

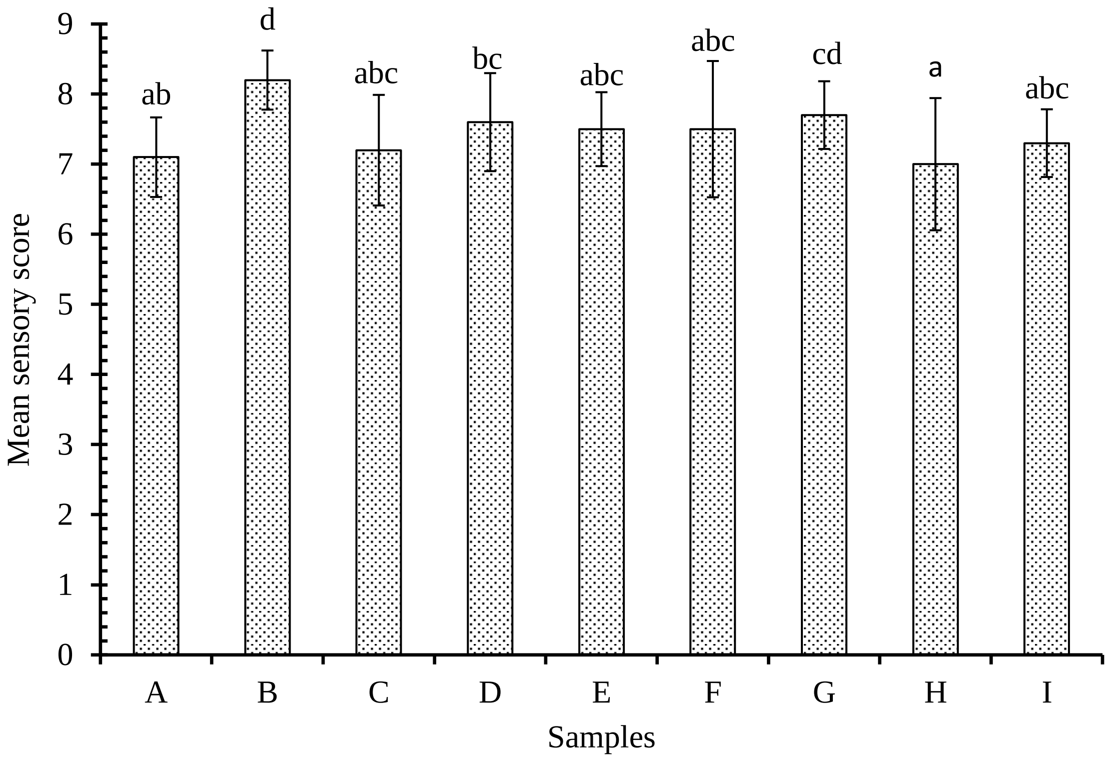

Fig. 4.2 Mean sensory scores for taste of coconut ice cream

Fig.4.2 represents the mean sensory scores for taste of coconut ice cream. Values on top of the bars bearing similar superscript are not significantly different at 5% level of significance. Vertical error bars represent ± standard deviation of scores given by panelists.

4.2.3 Effect of formulation on Color

The mean sensory scores for color of samples A, B, C, D, E, F, G, H and I were found to be 7.6±.52, 7.5±0.53, 6.5±0.53, 7.7±0.67, 6.9±0.32, 6.5±0.53, 7.5±0.71, 6.9±1.1 and 7.0±0.9 respectively. The mean score was found to be highest for sampe D which was significantly different from samples C, E, F, H and I. samples B and control G obtained the same mean score while slightly more was for control A. samples C, E, F, H and I were almost similar with least mean score. Which indicate average and complete coconut milk gave same coor effect. While samples with same MSNF showed decreasing scores with increasing in coconut milkcontent which indicate that panelists preferred the white milk color.

MSNF content did not seem to have any effect on color of ice cream as there was no definite pattern in the mean score with increasing MSNF content. Aboulfazli *et al.* (2014) found similar result where score decrease with increasing coconut milk content.

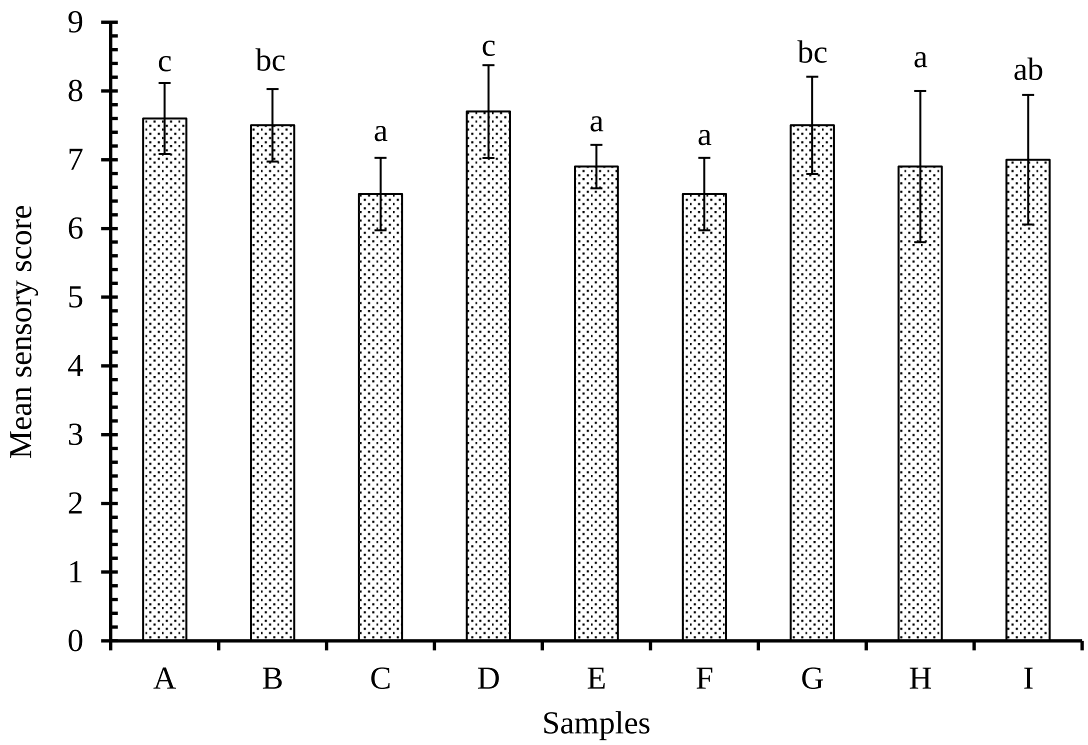

Fig. 4.3 Mean sensory score for color of coconut milk ice cream

Fig. 4.3 represents the mean sensory scores for color of coconut ice cream. Values on top of the bars bearing similar superscript are not significantly different at 5% level of significance. Vertical error bars represent ± standard deviation of scores given by panelists.

4.2.4 Effect of formulation on body

The mean sensory scores for body of samples A, B, C, D, E, F, G, H and I were found to be 7.7±0.48, 8.1±0.57, 6.8±0.42, 7.7±0.48, 7.1±0.87, 6.7±0.67, 7.5±0.53, 6.6±1.07 and 7.0±0.67 respectively. The mean score was found to be highest for sample B and was slightly greater than the score of control A and D. Statistical analysis shows that effect of different coconut milk portion on body of product was significant.

The high score of sample B may be due to interaction between average coconut milk and low MSNF. As such MSNF may not exert much effect on the body of ice cream but coconut milk with low MNSF was found to be preferable than others. average

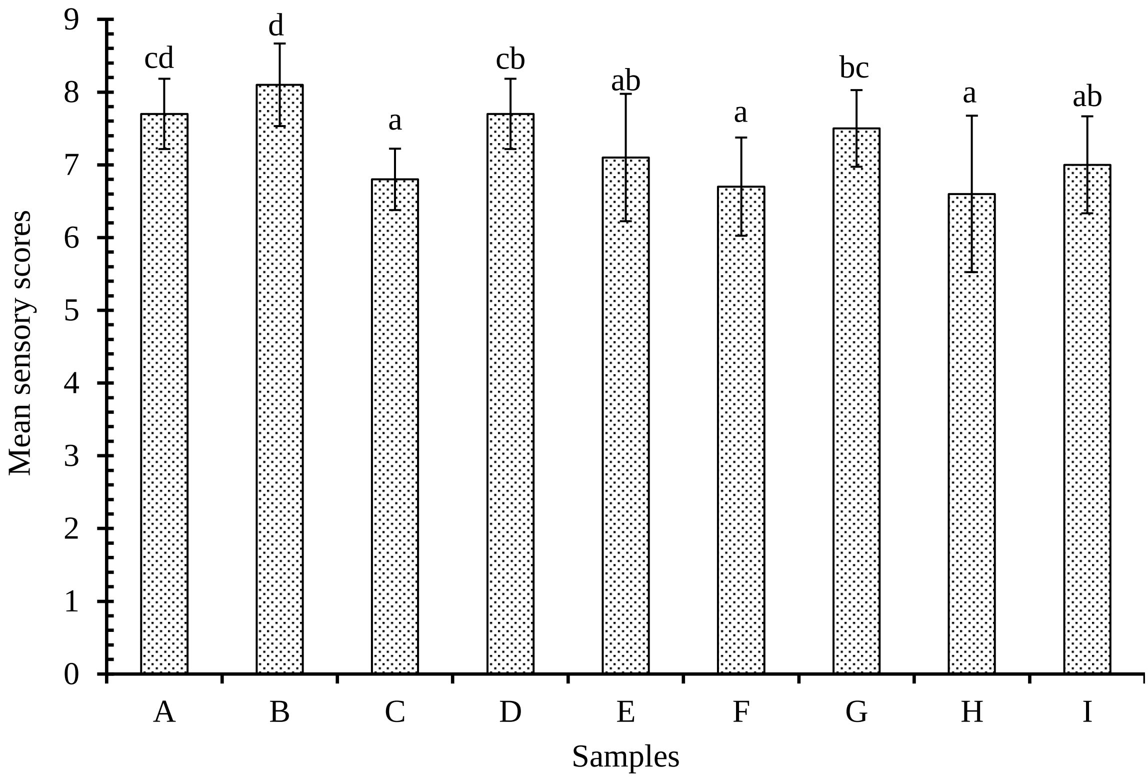

Fig. 4.4 Mean sensory scores for body of coconut milk ice cream

Fig. 4.4 represents the mean sensory scores for body of coconut ice cream. Values on top of the bars bearing similar superscript are not significantly different at 5% level of significance. Vertical error bars represent ± standard deviation of scores given by panelists.

4.2.5 Effect of formulation on aftertaste

The mean sensory scores for aftertaste of samples A, B, C, D, E, F, G, H and I were found to be 7.1±0.57, 7.8±0.63, 6.9±0.57, 7.5±0.71, 7.6±0.52, 7.0±0.47, 7.5±0.53, 6.7±0.67 and 7.2±0.63 respectively. Statistical analysis shows that the effect of different coconut milk portion on aftertaste of the product was significant ($p<0.05$). which is shown in Fig. 4.5.

The mean sensory score for aftertaste was found to be highest for sample B. control D and control G obtained the same mean score while slightly less for control A. samples A & B, B&C, B&E, C&D, C&G and E&H were found to be significantly different in aftertaste while samples C, F, H and I were almost similar with least mean scores which showed that high coconut concentration was not preferred by the panelist for aftertaste. MSNF content did not seem to have any effect on after taste of ice cream as there was no definite pattern in the mean score with increasing MSNF content in ice cream.

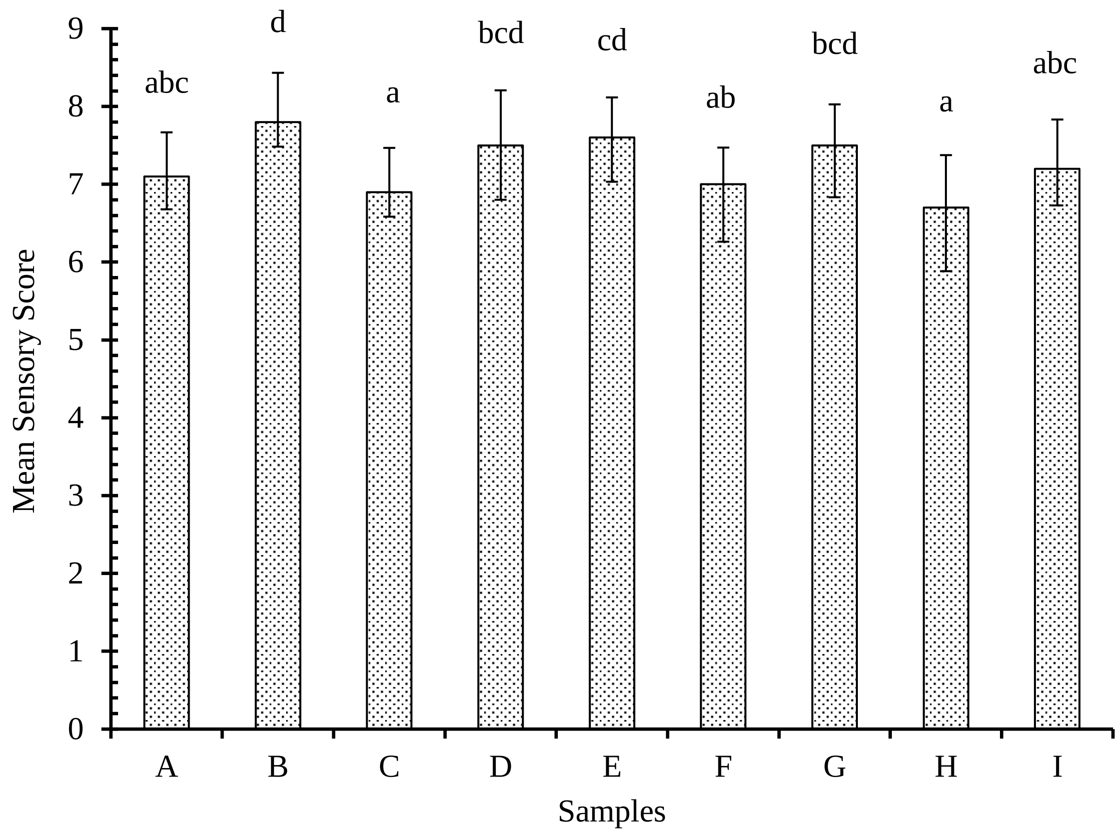

Fig. 4.5 Mean sensory scores for aftertaste of coconut milk icecream

Fig. 4.5 represents the mean sensory scores for aftertaste of coconut ice cream. Values on top of the bars bearing similar superscript are not significantly different at 5% level of significance. Vertical error bars represent ± standard deviation of scores given by panelists.

4.2.6 Effect of formulation on overall acceptance

The mean sensory score ± standard deviation for overall acceptability of nine samples A, B, C, D, E, F, G, H and I were found to be 7.2±0.42, 7.9±0.32, 6.9±0.32, 7.6±0.70, 7.1±0.57, 6.9±0.74, 7.7±0.48, 7.0±0.82 and 7.0±0.47 respectively.

The mean score was found to be highest for sample B followed by D and G. Sample B was significantly different from samples A, C, E, F, H and I. but not from sample D and G. Samples A, C, E, F, H and sample I were not significantly different in terms of overall acceptance.

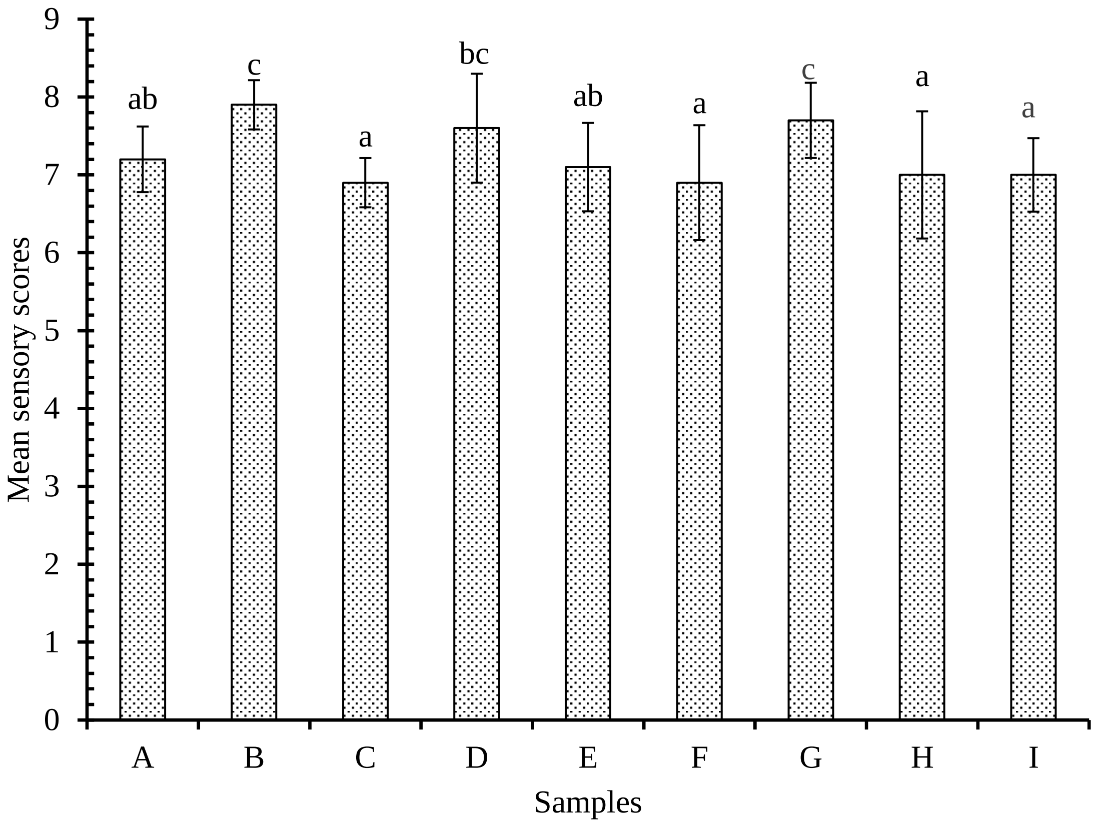

Fig. 4.6 Mean sensory score for overall acceptance of coconut milk ice cream

Fig. 4.6 represents the mean sensory scores for overall acceptance of coconut ice cream. Values on top of the bars bearing similar superscript are not significantly different at 5% level of significance. Vertical error bars represent ± standard deviation of scores given by panelists. Samples A, B, C, D, E, F, G, H and I represent sample formulations as given in Table 4.3.

Similarities of mean scores for samples B, D and G indicate that sample B represents the same overall acceptance as obtained by the controls. Also, the samples with same MSNF content showed decreasing mean scores with increasing coconut milk content.

Patel and Amin (2015) observe lower score for samples with 100% coconut milk in terms of acceptability and Soler (2005) found high score for samples with average coconut milk in terms of acceptability. The score seems to decrease with increasing MSNF content and may not exert much effect on overall acceptability.

Therefore, sample B was found to be the best in most of the parameters and overall acceptability as well. The formulation with 50% coconut milk and 10% MSNF was chosen to be the best product by sensory evaluation and obtained data interpretation. This conclusion was derived based on sensory analysis of limited number of panelist and so the experimental results should be taken with some reservation as it may differ when subjected to other populations.

4.3 Effect of different formulation on physical properties of coconut ice cream

Formulations were prepared according to the experiment design given by Design Expert and physical analyses of coconut milk incorporated ice cream were carried out. The results of physical analyses are presented in Appendix A.

4.3.1 Effect of different formulation on overrun of ice cream

The overrun of coconut milk incorporated ice cream varied from 42.85% to 50.26%. Table 4.4 and 4.5 show the coefficients of model and other statistical attributes of overrun. Regression model fitted to experimental results of overrun shows the Model F-value of 21.94, which implies the model is significant ($p<0.05$) relative to the pure error. The chance of large model F-value due to noise was only 1.2%. The lack of fit was not significant. Non-significant lack of fit is good as it means that the model fits well. The coefficient of determination R^2 also expresses the fit of model, which was found to be 0.9734, indicating that 97.34% of the variability of the response could be explained by the model. The Predicted-R^2 of 0.7464 is in reasonable agreement with the Adjusted-R^2 0.9290 of Adequate Precision of 17.593 indicates an adequate signal as it measures the signal to noise ratio and a ratio greater than 4 is desirable. Hence, this model can be used to navigate the design space. Considering all the above criteria, the model (Equation 4.1) was selected for representing the variation of overrun and for further analysis.

$$\text{Overrun} = 43.87+1.17A-0.8667B-1.11AB-0.0167A^2+3.25B^2 \ldots\ldots (4.1)$$

Where A and B are the coded values of coconut milk (%) and MSNF (%) respectively.

Table 4.4 Analysis of variance for overrun

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	38.89	5	7.78	21.94	0.0144	significant
A	8.26	1	8.26	23.31	0.0169	
B	4.51	1	4.51	12.72	0.0377	
AB	4.95	1	4.95	13.97	0.0334	
A^2	0.0006	1	0.0006	0.0016	0.9709	
B^2	21.17	1	21.17	59.73	0.0045	

*Significant at p<0.05, DF: Degree of freedom

Table 4.5 Model summary statistics for overrun

Source	Std. Dev.	R^2	Adjusted R^2	Predicted R^2	PRESS	
Linear	2.13	0.3196	0.0928	-0.5954	63.74	
2FI	2.11	0.4435	0.1096	-1.2361	89.33	
Quadratic	0.5953	0.9734	0.9290	0.7464	12.13	Suggested
Cubic	0.4183	0.9956	0.9650	0.2016	31.89	Aliased

The above quadratic equation (4.1) of overrun had significant ($P<0.05$) positive effect of coconut milk (A) at 95% confidence level. The linear term of MSNF (B) had linear positive effect on overrun of coconut milk ice cream was significant at 95% confidence level. The interaction term of coconut milk and MSNF (AB) had negative effect on overrun. Quadratic term of coconut milk (A^2) and MSNF (B^2) had significant ($p<0.05$) negative and positive quadratic effect respectively, indicating the concave shaped variation on the overrun. The interaction term of coconut milk and MSNF (AB) had a negative effect on overrun. Similar results were reported by Gohari Ardabili *et al.* (2005), where an increase in solid not fat content caused an initial increase in overrun values and then showed a falling trend. This variation can be related to the mechanism of change in viscosity. During freezing, viscosity increases steadily due to ice crystal formation caused by concentration of the unfrozen phase. Consequently, water movement from the unfrozen liquid part required for crystal formation becomes difficult leading to reduced crystallization and ice volume thus decreasing the viscosity and the overrun as well.

Santanaa *et al.* (2011) and Fuangpaiboon and Kijroongrojana (2017) were also found parallel with the results of this study as the overrun of coconut milk ice cream was positively affected by higher concentrations of coconut milk due to interaction effect which can be attributed to increased total solids content in samples with high amount of coconut milk. Response surface plot for overrun as a function of coconut milk and MSNF content in coconut milk ice cream is shown in Fig 4.7.

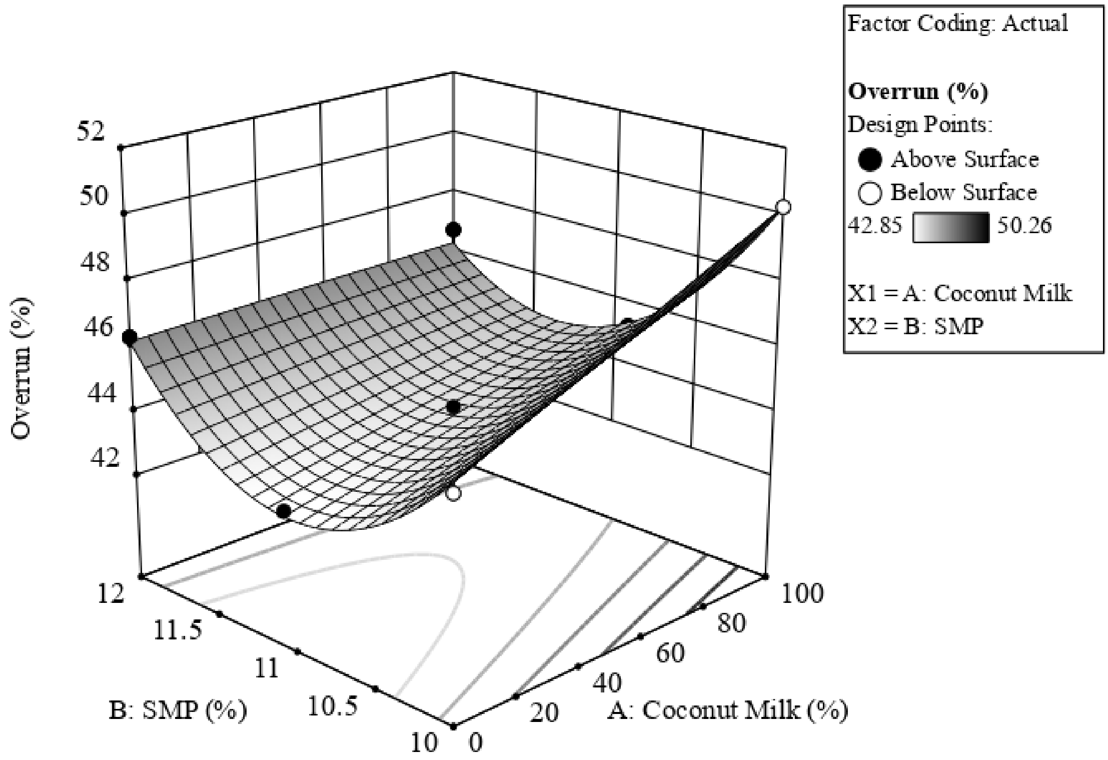

Fig. 4.7 Response surface plot for overrun as a function of coconut milk and MSNF content in coconut milk ice cream.

4.3.2 Effect of different formulation on melting rate of coconut ice cream

The Melting rate of coconut milk ice cream varied from 0.34 g to 0.84 g per 5 min. Table 4.6 and 4.7 show the coefficients of the model and other statistical attributes of melting rate. Regression model fitted to experimental results of melting rate shows the model F-value of 17.13 which implies the model is significant ($p<0.005$). There is 0.46% chance that a "Model F-value" this large could occur due to noise. The coefficient of determination R^2 was found to be 0.9114, indicating that 91.14% of the variability of the response could be explained by the model. The Predicted-R^2 was found to be 0.6581 which implies that the overall mean is a better predictor of the response than the current model. Adj-R^2 was 0.8482 and Adequate Precision of 13.576 indicated an adequate signal. Hence, this model can be used to navigate the design space.

Considering all the above criteria, the model (Equation. 4.2) was selected for representing the variation of melting rate and for further analysis.

Melting rate = 0.5667-0.80A+0.0150B-0.1825AB…… (4.2)

Where A and B are the coded values of coconut milk (%) and MSNF (%) respectively.

Table 4.6 Analysis of variance for melting rate

Source	coefficient of estimate	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.5667	0.1730	3	0.0577	17.13	0.0046	significant
A-Coconut milk	0.0800	0.0384	1	0.0384	11.41	0.0197	
B-MSNF	0.0150	0.0014	1	0.0014	0.4012	0.5543	
AB	0.1825	0.1332	1	0.1332	39.59	0.0015	
Residual		0.0168	5	0.0034			
Cor Total		0.1898	8				

*Significant at $p<0.05$, DF: Degree of freedom

Table 4.7 Model summary statistics for melting rate

Source	Std. Dev.	R^2	Adjusted R^2	Predicted R^2	PRESS	
Linear	0.1581	0.2094	-0.0541	-1.4682	0.4685	
2FI	0.0580	0.9114	0.8582	0.6281	0.0706	Suggested
Quadratic	0.0431	0.9706	0.9217	0.6425	0.0678	
Cubic	0.0050	0.9999	0.9989	0.9760	0.0046	Aliased

During the melting of ice cream, initially the exterior ice melts and diffuses into the viscous unfrozen serum phase, flowing downwards through the destabilized fat globules, air cells and ice crystals leading to the collapse of stabilized foamy structure (Silva *et al.*, 2010). In this case, negative effect is desirable since ice cream with high consistency coefficients have a greater resistance to flow and lower melting rates relate to sustainability of ice cream's shape.

The above equation (4.2) of melting rate had a highly significant negative effect on coconut milk (A) ($p>0.05$) at 95% confidence level. The linear term of MSNF (B) had significant positive effect on melting rate of coconut milk ice cream. The interaction term of coconut milk and MSNF (AB) had a negative effect on melting rate of coconut milk ice cream.

Santos and Silva (2012) reported similar results. The interaction term of coconut milk and MSNF (AB) had a negative effect on melting rate, indicating a concave shaped variation with the change in value of variables. Response surface plot for melting rate as a function of coconut milk and MSNF content in coconut milk ice cream is shown in Fig 4.8.

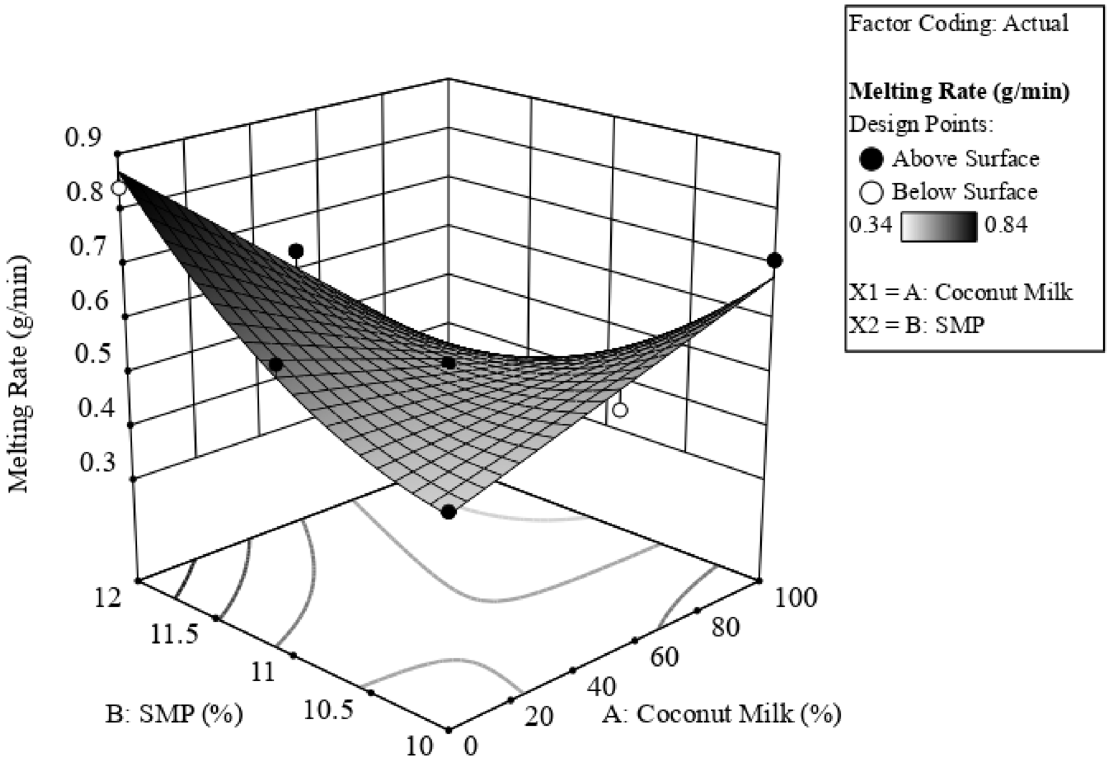

Fig. 4.8 Response surface plot for melting rate as a function of coconut milk and MSNF content in coconut milk ice cream.

4.4 Optimization study

A numerical multi-response optimization technique was applied to determine the optimum combination of coconut milk and MSNF in coconut ice cream ice cream. The assumptions were to develop a product with maximum overrun and minimum melting rate. These parameters were attempted to be maintained whereas other parameters were kept in range. Under these assumptions by Design expert, the uncoded optimum proportions of milk and solids for coconut milk ice cream preparation were 62.602% coconut milk and 10% MSNF with a desirability of 63.6%. The response predicted by the software for these optimum proportions of constituents were overrun of 48.623% and melting rate of 0.578 g per 5 minutes. Table 4.8 shows the different composition of constituents for optimization.

Table 4.8 Multi response optimization constraints of coconut milk icecream.

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Coconutmilk	is in range	0	100	1	1	3
MSNF	is in range	10	12	1	1	3
Melting Rate	minimize	0.34	0.84	1	1	3
Overrun	maximize	42.85	50.26	1	1	3

The optimized sample given by Design expert was sample (62.602% coconut milk, 10% MSNF) and from sensory analysis, sample B (50% coconut milk 10% MSNF) was found to be the best. Physical analysis and sensory evaluation are different techniques used to optimize the product and these are hard to correlate. The proximate analysis of the best product B is given in Table 4.9

Table 4.9 Proximate analysis of the best coconut milk ice cream sample (50% coconut milk and 10% MSNF)

Parameter	Result
Moisture content (%)	59.8±1.3
Total solid (%)	41.2±1
Fat (%)	11±0.3
Acidity (%)	0.26±0.06
Lactose (%)	4.5±0.08
Protein (%)	4.8±0.6
Ash content (%)	2.93±0.12
Overrun (%)	48.30±2.1
Melting rate (gm/5min)	0.54±0.15

4.5 Cost evaluation

The total cost associated with the best product was calculated and the cost of coconut milk ice cream per 100 g was NRs. 15.70, excluding labor cost, packaging cost and tax. Mass production further reduces this cost. From the cost calculation given in Appendix B, it can be seen that due to the low cost of coconut to prepare coconut milk, the cost of ice cream has been decreased. If the byproduct can be utilized from the grinded coconut then the cost can be reduced even more.

Part V

Conclusions and recommendations

5.1 Conclusions

The present work was carried out to study the recipe optimization and acceptability of coconut milk ice cream and to observe the effect of coconut milk and MSNF content on overrun and melting rate of ice cream. From the research following conclusions were made:

• From sensory analysis, coconut ice cream with 50% milk, 50% coconut milk and 10% MSNF was found best.

• From physical analysis, coconut ice cream with 62.602% coconut milk and 10% MSNF was found to be best respective of overrun and melting rate.

• Coconut milk had no significant effect on aftertaste of ice cream while many found its aroma repulsive but it had significant effect on taste, color and body of ice cream.

• Coconut milk and MSNF showed significant effect on both overrun and melting rate of ice cream with highest coconut milk content and lowest MSNF representing the optimum formulation.

• Production cost of the prepared coconut milk ice cream was reasonable, within the reach of general population and slightly lower than dairy ice cream so its commercialization could be done.

5.2 Recommendations

Based on the present study, the following recommendations have been made:

• coconut milk ice cream with not more than 50% coconut milk content can be prepared for a variety of diet requirements, catering consumer tastes as well as for improving the physicochemical properties of regular ice cream.

• Other fruit-based ice cream could be prepared and their quality studied.

Part VI

Summary

Coconut milk ice cream is a frozen product prepared by mixing, pasteurizing, homogenizing, ageing, freezing and hardening the mix using coconut milk. Coconut milk ice cream is a Britain phenomenon and is produced in Australia, New Zealand and other countries. Ice cream is a desired dessert and coconut milk being lactose free as well as nutritious, is an ideal substitute for lactose intolerant and vegans. So, the present work is conducted to study the consumer acceptance of coconut milk ice cream, its physical and chemical quality.

For the study, coconut, milk, cream and sugar were purchased from local market of Dharan and SMP was purchased from DDC, Biratnagar. Coconut milk was prepared by grinding the coconut with water in 1:1 ratio. A optimal (three level, two factor) design for two variables (coconut milk and MSNF) at three levels was designed for experimental combinations. Using coconut milk and milk, the mix was prepared as calculated in the formulation, pasteurized, homogenized, flavored, aged and subjected to freezing in an ice cream freezer.

The prepared coconut ice cream was analyzed physically, chemically and by sensory analysis. From sensory analysis, the sample with 50% coconut milk and 10% MSNF was found to be the best. It was found that coconut milk and MSNF had no effect on aroma, taste and aftertaste but had significant effect on color, body overrun and melting rate of ice cream. The product with 62.602% coconut milk and 10% MSNF was optimized to have maximum overrun and minimum melting rate. The chemical composition of the best ice cream was analyzed. Moisture content, total solid, fat, acidity, lactose, protein, ash content, overrun and melting rate of sample B were found to be 59.8%, 41.2%, 11%, 0.26%, 4.5%, 4.8%, 2.93%, 48.30% and 0.54 g/min respectively in wet basis.

It was concluded from the present study that coconut ice cream was nutritionally equivalent to dairy or plain ice cream. It was found to be slightly yellowish in color and of good coconut flavor. coconut ice cream was found to be moderately harder in texture, had higher overrun and significantly reduced melting rate than that of plain ice cream.

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Appendices

Appendix A

Sensory evaluation score sheet for ice cream

Date:

Hedonic rating test

Name of the panelist: …………………………………

Name of the product: Ice cream

Please test the following samples of Ice cream and check how much you prefer for each of the samples. Give the points for your degree of preferences for each parameter for each sample as shown below:

Judge the above characteristics on the 1-9 scale as below:

Like extremely – 9 Like Slightly – 6 Dislike moderately – 3

Like very much – 8 Neither like nor dislike -5 Dislike very much - 2

Like moderately – 7 Dislike slightly – 4 Dislike extremely – 1

Formulations / **Attributes**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Aroma									
Color									
Taste									
Body									
Aftertaste									
Overall acceptability									

Comments………………….

Signature……………………..

Appendix B

Cost calculation of the product

Ingredients	Quantity	Rate NRs	Quantity used	Rate NRs
Milk	1000 g	80	23.69 g	1.89
Coconut	1 piece	50	23.69 g	2.369
SMP	1000 g	500	5.31 g	2.655
Cream	1000 g	800	3.91 g	3.128
Sugar	1000 g	80	10.12 g	1.01
Emulsifier and stabilizer	100 g	50	0.33 g	0.165
Overhead cost	40%			4.48
Total costing				15.70 per 100gm

Appendix C

Run	Coconut milk (%)	MSNF (%)	Melting Rate(g/min)	Overrun
1	0	12	0.84	46.32
2	50	11	0.52	44.15
3	0	10	0.48	45.38
4	50	12	0.64	45.67
5	100	12	0.34	46.75
6	100	10	0.71	50.26
7	100	11	0.41	44.58
8	0	11	0.62	42.85
9	50	10	0.54	48.3

Appendix D

ANOVA for physical analysis of samples

Table D.1 Two-way ANOVA (No blocking) For aroma

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	8	9.6222	1.2028	3.62	0.001
panelist	9	11.0667	1.2296	3.70	<.001
Residual	72	23.9333	0.3324		
Total	89	44.6222			

Table D.2 Two-way ANOVA (No blocking) for taste

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	8	10.6222	1.3278	3.30	0.003
panelist	9	8.7667	0.9741	2.42	0.018
Residual	72	28.9333	0.4019		
Total	89	48.3222			

Table D.3 Two way ANOVA (No blocking) for color

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	8	17.3556	2.1694	5.86	<.001
panelist	9	11.6556	1.2951	3.50	0.001
Residual	72	26.6444	0.3701		
Total	89	55.6556			

Table D.4 Two-way ANOVA (No blocking) for body

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	8	22.0222	2.7528	6.66	<.001
panelist	9	6.8444	0.7605	1.84	0.075
Residual	72	29.7556	0.4133		
Total	89	58.6222			

Table D.5 Two-way ANOVA (No blocking) for aftertaste

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	8	10.6222	1.3278	3.64	0.001
panelist	9	2.2333	0.2481	0.68	0.724
Residual	72	26.2667	0.3648		
Total	89	39.1222			

Table D.6 Two-way ANOVA (No blocking) for overall acceptability

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	8	11.4222	1.4278	4.64	<.001
panelist	9	3.5667	0.3963	1.29	0.258
Residual	72	22.1333	0.3074		
Total	89	37.1222			

Appendix E

Summary of ANOVA of sensory of coconut milk ice cream

Sample code	Aroma	Taste	Color	Body	Aftertaste	Overall
A	7.1±0.74	7.1±0.57	7.6±.52	7.7±0.48	7.1±0.57	7.2±0.42
B	7.7±0.48	8.2±0.42	7.5±0.53	8.1±0.57	7.8±0.63	7.9±0.32
C	7.2±0.63	7.2±0.79	6.5±0.53	6.8±0.42	6.9±0.57	6.9±0.32
D	7.3±0.48	7.6±70	7.7±0.67	7.7±0.48	7.5±0.71	7.6±0.70
E	7.5±0.84	7.5±0.53	6.9±0.32	7.1±0.87	7.6±0.52	7.1±0.57
F	6.9±0.73	7.5±0.97	6.5±0.53	6.7±0.67	7.0±0.47	6.9±0.74
G	7.6±0.70	7.7±0.48	7.5±0.71	7.5±0.53	7.5±0.53	7.7±0.48
H	6.6±0.52	7.0 ±0.94	6.9±1.1	6.6±1.07	6.7±0.67	7.0±0.82
I	7.3±0.67	7.3±0.48	7.0±0.9	7.0±0.67	7.2±0.63	7.0±0.47
LSD (5%)						

Color plates

Plate 1 Sensory analysis of coconut ice cream

Plate 2 Melting apparatus of ice cream

Plate 3 Coconut ice cream samples after freezing