PREPARATION AND QUALITY EVALUATION OF COCONUT MILK INCORPORATED FROZEN YOGHURT

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Preparation and Quality Evaluation of Coconut Milk Incorporated Frozen Yoghurt

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 Frozen Yoghurt*** presented by **Roshan Bokhim Limbu** has been accepted as the partial fulfillment of the requirements for the **B. Tech. degree in Food Technology.**

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Abstract

Nine coconut frozen yoghurt formulas with varied ratios of coconut milk and milk were made in the lab, using coconut milk and milk ranging from 0% to 50% and 50% to 100%, respectively with the goal to study the effects of coconut milk and milk on the quality of frozen yoghurt. The frozen yoghurt recipe was created with the help of a Design Expert (a statistical software). Panelists were employed for sensory evaluations of the samples acceptability. For all samples, melting rates and overruns were determined, and the data was subjected to response surface methodology to investigate the effect of formulation on physical quality.

Sensory study revealed that frozen yoghurt containing 25% coconut milk and 75% milk had significantly better ($p<0.05$) quality. Changes in coconut milk and milk had a significant ($p<0.05$) impact on taste, body, aftertaste and overall acceptability in most of the formulations, while aroma and color were not affected. According to the results of the response study, the optimal formulation was 20.795% coconut milk, 79.205% milk. The response surface plot revealed that coconut milk and milk had both positive effect on overrun. During the melting rate investigation, it was discovered that when the amount of coconut milk was increased, the melting rate of frozen yoghurt decreased at first but later showed upward trend. The software anticipated an overrun of 47.585% and a melting rate of 0.443 g per 5 min for the above-mentioned formulation of 20.795% coconut milk, 79.205% milk. As a result, coconut frozen yoghurt can be made with milk and coconut milk with sensory, physical, and chemical properties identical to regular 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

Frozen yoghurt is a mixture of ice-cream and yoghurt which has a yoghurt flavor with an ice-cream texture (Milani and Koocheki, 2011). It is a complex fermented frozen dairy dessert that combines the physical characteristics of ice-cream with the sensory and nutritional properties of fermented milk products (Soukoulis and Tzia, 2008). It can be regarded as a healthy alternative to ice-cream for people suffering from obesity, cardiovascular diseases with a reduced risk of obesity, coronary heart diseases and lactose intolerance due its low fat content (3.5-6%) and reduced lactose concentration, which depends on the kind and duration of fermentative step (A. Y. Tamime and Robinson, 2007). In addition, frozen yoghurt is expected to present acceptable quality of flavor, body, texture and cooling effect, viscosity, whipping ability and freezing properties of dairy frozen desserts (Chandan, 1997).

When consumers began to favor low acidic foods over high acidic foods in the late 1970s, frozen yoghurt was born. Consumers are interested in frozen yoghurt as a snack because it is a low-fat alternative to yoghurt and because the live cultures in the yoghurt have probiotic benefits (Dissanayaka *et al.*, 2019).

Coconut is a wonder fruit which provides the consumer with both a refreshing drink from its water and energy from its kernel (Siriphanich *et al.*, 2011). Coconut milk is a milky fluid obtained by manual or mechanical extraction of fresh coconut (*Cocos nucifera* L) kernel with or without addition of water. Coconut milk frozen yoghurt may be an excellent alternative to those who suffer from lactose intolerance and benefit others as well (Perera and Perera, 2021). Coconut milk is nutritionally rich in dietary protein, energy, calcium, and fat such as myristic acid, oleic acid, lauric acid, linoleic acid, palmitic acid, and capric acid (Belewu and Belewu, 2007). It is also a rich source of vitamins and minerals (Nieuwentus and Nieuwelink, 2002).

1.2 Statement of the problem

Milk, our very first food, is surrounded with emotional, cultural, and religious importance. We are habituated since childhood to think of milk as “nature's most perfect food.” Milk and dairy products have long been acknowledged as an important constituent of a balanced diet. In addition, evidence of health benefits of milk products allied with the presence of specific components or bacteria are progressively gaining established scientific credibility. It is, therefore, logical that among the best-known examples of functional foods are fermented milks and yogurts containing probiotic bacteria (Nagpal *et al.*, 2012). The rising problems of lactose intolerance, milk allergies, environmental concerns, and other problems due to diets rich in cholesterol are leading toward a growing demand for dairy alternatives. (Bharti *et al.*, 2021).

Plant milk is presented as a healthy, sustainable, and animal-welfare-friendly alternative to milk. Derived from the water extraction of legumes, nuts, or cereals, plant milk is completely free from animal-based ingredients. Plant milk is similar in appearance and taste to conventional milk and is used for the same purposes. The available plant milk products on the market vary with respect to their nutrients, and it is common practice to add vitamins, minerals, and proteins to them. The scarcity of fresh bovine milk supply in developing countries perhaps leads to the development of alternative milk from various sources (Bharti *et al.*, 2021).

The coconut milk is a liquid obtained from the results of the extraction of coconut fruit flesh has been grated with or without the addition of water. Coconut milk is a perishable product at room temperature because it contains water, fat, protein and other organic components (Pangan *et al.*, 2015). One of the suitable solutions for problem resolution is the processing of fresh coconut milk dairy products.

1.3 Objectives

1.3.1 General objective

The general objective of the dissertation work was to develop frozen yoghurt, flavored with coconut milk and to evaluate the effects of coconut milk and milk on the final product.

1.3.2 Specific objectives

The specific objectives of the work were

- To prepare coconut milk frozen yoghurt.
- To analyze the frozen yoghurt for its proximate composition.
- To assess the sensory attributes of fruit flavored frozen yoghurt.
- To compare consumer acceptance towards varying level of coconut milk in frozen yoghurt.

1.4 Significance of the study

Frozen yoghurt is a frozen dessert characterized by having the texture properties of ice-cream combined with the acidic taste of yoghurt. Its process consists of mixing all ingredients to make natural stirred yoghurt with stabilizers/ emulsifiers and sugar, then freezing the mix in a conventional frozen yoghurt freezer. Popularity of frozen yoghurt has increased and continues to grow, making it one of the most frequently consumed frozen desserts around the world. Frozen yoghurt's attractiveness to consumers include providing a low fat replacement for frozen yoghurt and the probiotic benefits of the live cultures present in the yoghurt (Tamime and Robinson, 2007).

Coconut milk is found to be rich in calcium. The milk is reported to be high in minerals and vitamin content (Nieuwentus and Nieuwelink, 2002). Contrary to widely held opinion, the coconut provides nutritious sources 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).

Addition of fruit juice into frozen yoghurt may increase its beneficial and nutritional effects on the host. Also, it may increase the consumer's attraction towards the frozen yoghurt. In many cases, the plain frozen yoghurt is served by adding various toppings made from fruits. But incorporation of a fruit pulp into the frozen yoghurt will be a new approach for adding flavors to the frozen yoghurt. Consuming symbiotic foods that contain prebiotics (fibers) and probiotics (lactic acid bacteria) would offer added nutritional benefits that can help boost overall health and well-being. The use of coconut milk in various food industries, such as confectionaries, bakeries, biscuits and frozen yoghurt, to enhance flavor and taste of food products is being practiced worldwide. Researchers in the Philippines have develop the new product using coconut milk. Among the products, flavored milk beverages, soft cheese and low-fat fruit frozen dairy items (Seow and Gwee, 1997).

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 frozen yoghurt making it attractive to consumers. Therefore coconut milk can be added to develop frozen yoghurt to get more benefits.

1.5 Limitations of the study

During the work the limitations found were

- Shelf life of the product could not studied due to lack of required storage conditions.
- • Rheological properties of prepared frozen yoghurt could not be determined due to lack of instruments.

Part II

Literature review

2.1 Frozen yoghurt

Frozen yoghurt is a refreshing, tangy dessert that combines the flavors and textures of ice cream and sherbet. Frozen yoghurt is a relatively new-comer in the dessert market. The history of frozen desserts dates back thousands of years to Asia where water ices were first made. Although Roman literature describes how the Emperor Nero was treated to exotic fruit juices and wines chilled with mountain snow, it was not until the 13th century that Marco Polo introduced Asian water ices to Italy. The popularity of these frozen desserts spread throughout Europe and within a few centuries, European colonists introduced frozen yoghurt in the U.S (Afzal *et al.*, 2022).

Technological improvements throughout the 1800s simplified the process of making frozen desserts. The first hand-freezer was patented in 1848. Shortly thereafter the first wholesale frozen yoghurt manufacturing company in the U.S. was created by Jacob Fussell of Baltimore. By the turn of the century pasteurization machines and homogenizers were developed, which improved the healthfulness and texture of frozen yoghurt. The manufacturing process was simplified further with the invention of the direct expansion freezer and the continuous freezing process. Low-temperature refrigerators developed in the 1940s expanded the frozen dessert industry into new markets, leading to the creation of carry-home packages. Finally, in the late 1960s and 1970s, high-tech, high-volume processing machinery allowed the industry to flourish (Afzal *et al.*, 2022).

Dessert makers had long experimented with a variety of frozen yoghurt flavors and styles. In the 1970s, frozen yoghurt's entry into the dessert market was a distinct failure consumers complained that it tasted too much like yoghurt. Despite the initial reaction, manufacturers reformulated and refined their frozen yoghurt recipes, and the increasingly health-conscious populace of the 1980s finally took to the low-calorie dessert with a vengeance. Frozen yoghurt was soon available in a variety of flavors throughout the U.S. It proved to be just as versatile as frozen yoghurt, served in cones and cups, with toppings, on crepes, waffles, and banana splits. Frozen yoghurt offered a tangier flavor than frozen yoghurt and more depth in flavor and texture than sherbet (Afzal *et al.*, 2022).

During the 1980s the frozen yoghurt market reached sales of $25 million in 1986 with triple-digit growth rates. Major frozen yoghurt manufacturers quickly jumped on the band-wagon and started producing their own brands of frozen yoghurt, recognizing that the low-calorie dessert was here to stay. By the early 1990s, frozen yoghurt captured about 10% of the total frozen dessert market with sales of $330 million on 135 million gallons (Afzal *et al.*, 2022).

2.2 Classification of frozen yoghurt

Frozen yoghurt has a ice-cream-like texture with a yoghurt flavor. It is generally prepared by mixing plain yoghurt to a frozen yoghurt mix, followed by freezing. Different varieties, such as soft, hard, and mousse-frozen yoghurts exist (Table 2.1). The temperature used during freezing varies from −6°C to – 25 °C. There are no official standards for frozen yoghurt but some countries have specified that the final product should have more than 3.25% milk fat, 8.25% non-fat milk solids, and 0.15–0.30% of titratable acidity.

Table 2.1 Classification of frozen yoghurt

Soft frozen yoghurt	Hard frozen yoghurt	Frozen yoghurt mousse
Made with a 80% yoghurt base blended with 20% fruit syrup	Made by blending of a 35% fruit syrup and stabilizers/emulsifier into a 65% yoghurt base	Made by mixing of yoghurt with a hot mousse base mixture that consists of skim milk, sugar, and stabilizers/emulsifiers

Source: Tur and Bibiloni (2016)

2.3 Frozen yoghurt health benefits

Frozen yoghurt is a dessert that combines the texture of ice cream with the nutritive and healthy properties of yoghurt (Rezaei *et al.*, 2011). Fermented products like yoghurt possess probiotic properties. According to Alfaro *et al.* (2015), probiotics can be defined as “mono or mixed cultures of live microorganisms which, when applied to animal or man, beneficially affect the host by improving the properties of the indigenous microflora”. Probiotics are recognized by generating an optimum balance in the microbial population in the digestive tract and this is associated with good nutrition and health. Bacteria related with these probiotic properties are mainly *lactobacilli* and *bifidobacteria* a notable number of microorganisms have been considered as probiotics. Probiotic bacteria have increasingly been incorporated into foods as dietary adjuncts. The most popular bacteria used for fermented dairy products such as yoghurt are *Lactobacillus bulgaricus* and *Streptococcus thermophilus*. The survival of these lactic acid bacteria (LAB) in the human intestine have been studied. The microflora, being composed mainly of *Lactobacillus* species, will occupy the surface area of the intestine. Therefore, there is a better absorption of nutrients and the secretion of lactic acid and other antimicrobial compounds would provide protection from growth of pathogens (Rybka and Kailasapathy, 1995).

2.4 Milk

Milk can be termed as an ideal or complete food for human body as it is a source of proteins, fats, sugars, vitamins and minerals. Now a days, due to recent technological developments in the dairy industry, variety of milk products have been introduced in the market with different tastes and nutritional benefits (Shukla *et al.*, 1987). Milk being perishable commodity, can be preserved either by converting into concentrate, or can be transformed into dried products or fermented products like, curd, yoghurt, acidophilus milk, etc. Yoghurt is one of the most common fermented dairy products, with widespread acceptance due to its nutritional and health benefits, which have been well documented for centuries (Dissanayaka *et al.*, 2019).

According to FAO/WHO (1977), "yoghurt is a coagulated milk product obtained by lactic acid fermentation through the action of *Lactobacillus bulgaricus* and *Streptococcus thermophillus*, from milk and milk products (pasteurized or concentrated milk) with or without optional additions (milk powder, skim milk powder, whey powder, etc.). The microorganisms in the final products must be viable and abundant". Another advantage of yoghurt is its ability to manage or prevent the growth of germs, as well as cure digestive illnesses such as constipation, diarrhea, and dysentery. Yoghurt has also been shown to have anti-carcinogenic properties (Dissanayaka *et al.*, 2019).

Frozen yoghurt is a unique dairy product with physical properties related to ice cream while nutritional and sensory characteristics are similar to fermented dairy products (Dissanayaka *et al.*, 2019). Frozen yoghurt or yoghurt ice cream is a complex of yoghurt and ice cream. This dessert combines the flavor of yoghurt and texture of ice cream (Nawal Galal *et al.*, 2019). This elaboration results in a nutritious product with a refreshing taste and storage stability significantly longer than that of yoghurt (El-Sayed *et al.*, 2017).

Frozen yoghurt can be manufactured in two ways which are either by mixing the yoghurt with an ice-cream mix or by fermenting an ice-cream mix. In the latter alternative a conventional line for production of stirred type yoghurt is used. About 4 – 6 % starter is dosed into the pipeline as the mix is pumped to the incubation tanks. The incubation time of the yoghurt mix is appreciably longer than for normal yoghurt production which is because the yoghurt mix contains much more carbohydrates than the normal yoghurt. An incubation time of 7 – 8 h is required at a sugar content of 10 – 12 % to attain the characteristic acidity of yoghurt, which generally occurs at pH 4.5. For both the alternatives, further processing will be identical with the conventional production of ice cream (Nawal Galal *et al.*, 2019).

2.5 Coconut

Coconut palms (*Cocos nucifera* L.) grow abundantly in coastal areas of all tropical countries and its wide variety of products are being applied in food and non-food products. Its nutritious nuts represent a major form of livelihood for millions of people (Van Dam *et al.*, 2004). Coconut is the only species in *Cocos* genus, within Aracaceae family, Cocoeae order (Siriphanich *et al.*, 2011). Primarily, the palms are grown for the oil-rich copra comprised inside the coconuts. In a mature coconut, the white meat (28 wt. %) is surrounded by a hard protective shell (12 wt. %) and a thick husk (35 wt. %) (Thampan, 1981). This husk surrounding the large seed is constitutes of 30 wt. % fibre and 70 wt. % pith material. The coarse fibres are traditionally extracted by various retting and decortication procedures from the husk for the production of ropes and yarns, mats, brushes and padding of mattresses (Kirby, 1963). Especially, Southern India and Sri Lanka have a long standing tradition and are the major production areas of a wide range of diversified coir products (Van Dam *et al.*, 2004).

The fruit of the coconut is a fibrous drupe. Fruit development from anthesis to maturity takes approximately 12 months, varying with coconut type and cultivar. A mature fruit is about 1–2 kg in weight, a significant reduction from 3–4 kg at its maximum weight at around 9 months, 15–20 cm in diameter and 20–30 cm long, with a variation of fruit shapes, from round to elongated but mostly ovoid to oblong and triangular fruit (Siriphanich *et al.*, 2011).

The coconut palm is now grown mainly by smallholders but was once the major perennial plantation oil crop widely cultivated in the humid tropics. 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 (Chan and Elevitch, 2006).

The actual percentage of domestic consumption of coconut in Asian and Pacific Coconut Community (APCC) countries was around 64% in 2001. Coconut is mainly an oil crop, particularly rich (48%) in lauric acid (Perera *et al.*, 2009). 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 *et al.*, 1990).

2.5.1 Varieties

The classification of coconut has been highly non-standardized, resulting in different authors in different countries using different terminology of coconut. However, the major classification of coconut is based on stature and breeding behavior which groups coconut broadly into two groups or types: tall (also termed typical) and dwarf (also termed nana) (Perera *et al.*, 2009). The major differences between tall and dwarf coconuts are given in Table 2.2.

Table 2.2 Contrasting features of tall and dwarf coconuts

Characteristics	Tall (typical)	Dwarf (nana)
Stature	Tall (about 20–30 m)	Short (about 10–15 m)
Bole formation at base of stem	Yes	No
Time till flowering	6–8 years	3–4 years
Economic life span	Long (about 80–100 years)	Short (about 40 years)
Bearing nature	Continuous	Seasonal
Nuts/palm/year	Average 40	Average 80–100
Copra amount and quality	200 g/nut, good quality	80–100 g/nut, poor quality
Growing conditions	Variable	Sensitive to climate changes
Breeding habit	Out-breeding	In-breeding

Source: Van Dam *et al.* (2004)

2.5.2 Coconut meat

Coconut meat is the white flesh inside a coconut. Coconuts are the large seeds of coconut palms which grow in tropical climates. Their brown, fibrous husks conceal the meat inside. As the oil and milk from this fruit have become increasingly popular, many people may wonder how to use coconut meat and whether it offers health benefits (Lin and Wilkens, 1970).

2.5.3 Coconut fat

Coconut oil is produced by crushing copra, the dried kernel, which contains about 60-65% of the oil. The oil has the natural sweet taste of coconut and contains 92% of saturated fatty acids (in the form of triglycerides), most of them (about 70%) are lower chain saturated fatty acids known as medium chain fatty acids (MCFAs). MCFAs are not common to different vegetable oils with lauric acid at 45-56%. Various fractions of coconut oil have medium chain triglycerides and are excellent solvent for flavors, essences, emulsifiers, etc. These fatty acids are used in the preparation of emulsifiers, as drugs and also in cosmetics. Its metabolism is different from that of the normal vegetable oils containing long chain fatty acids. Hence, it cannot be generalized as an oil similar in properties to that of a 92% long chain saturated fatty acids containing oil/fat. More studies are required to prove the good effects of coconut oil, medium chain triglycerides (MCT) and the fatty acids on humans especially on the ill effects on cardiovascular and other diseases (Krishna *et al.*, 2010).

2.5.4 Coconut milk

Coconut milk is a milky white oil-in-water emulsion. It is obtained from extraction of coconut flesh with or without added water. It contains fat, water, carbohydrate, protein, and ash with the major components being water and fat (Tansakul and Chaisawang, 2006).

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 (Banzon, 1990). Standard Task Force of APCC (1994) term “coconut water” should exclusively to natural aqueous liquid endosperm of drupe of *Cocos nucifera* L while the term “coconut milk” should refers to aqueous product essentially free from fibres, extracted from solid coconut endosperm, but optionally include some coconut water (Seow and Gwee, 1997).

Coconut milk is the word used to describe the liquid obtained from the mechanical or manually press of the coconut meat usually with or without added water. The composition of coconut milk depends on the amount of water used for the extraction, affecting significantly moisture and fat content. Coconut milk exhibits a highest antioxidant activity with significant differences among goat and cow's milk. Coconut milk contains fat, water, carbohydrate, protein, and ash with the major components being water and fat which is shown in table 2.3. Regular coconut milk is higher in fat and calories than cow's milk. It is rich in proteins such as albumin, globulin, prolamin and gluten. Emulsifying agents help in increasing stability of food emulsions; examples of such are phospholipids, cephalin and lecithin which have been found in coconut milk. However, it is recognized that the product which is highly susceptible to chemical and biochemical spoilage such as lipid oxidation (Alyaqoubi *et al.*, 2015).

Many factors enter into the quality and composition variations of coconut milk. The agronomic conditions, varietal difference, cultural practices, maturity of the nut, processing ,etc. affect the quality and composition of milk prepared from the coconut kernel. The sorting of the nuts to eliminate the spoiled kernels, treatment given to the nut before and during the shelling operation, the grating or communication process, the pressing operation and the method used in refining the extracted coconut milk are significant (Alyaqoubi *et al.*, 2015).

It would be expected that the chemical composition of coconut milk as reported in the literature, would show wide variation because of the differences in varieties, geographical location, maturity of nut, method of extraction and the degree of dilution with water or liquid endosperm (Cancel, 1979).

Table 2.3 Composition of coconut milk

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

Carbohydrate	2.81

Source : Ahuja *et al.* (2012)

2.5.5 Coconut protein

Apart from oil, coconuts also contain proteins with moderately well-balanced amino acid profile in term of nutritive value. For protein content in coconut skim milk, 75% is accounted for globulin, whereas the remaining (25%) is albumin (Patil, 2018).

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 2.4.

Table 2.4 Distribution of protein in defatted coconut meal

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

Source: Patil and Benjakul (2017)

2.5.6 Nutritional and medicinal importance of coconut milk

Some of the most important benefits of coconut milk are:

1. 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.
2. Lauric acid can also be helpful in maintaining the elasticity of the blood vessels and in keeping them clean, which can lower the risk for conditions like, atherosclerosis and heart disease.
3. 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.
4. 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.
5. 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.
6. Coconut milk health benefits are mentioned in traditional medicine for the human body. It is also used for treatment of mouth ulcer.
7. Coconut is a dairy free alternative to those who are lactose intolerant and are also allergic to animal milk.
8. Coconut milk is good for the health of skin and hair. Many cosmetic giants use it as a base in products for skin and hair.
9. Coconut milk is applied to the scalp to have dandruff free hair and condition hair naturally.
10. Coconut milk is a reservoir of antioxidants. Antioxidants help the body fight aging, low vision and low bone density.
11. Coconut milk also aids in digestion and is also used as a laxative. It can also be a remedy for urinary and kidney problems.
12. Coconut milk is an excellent source of Vitamin E. It helps in nourishment of the skin.
13. 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.
14. 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).

2.6 Mix ingredients

To manufacture frozen yoghurt of highest quality, it is essential to have ingredients of excellent quality, a mix that is formulated and balanced to provide proper function of each component, and excellent processing, freezing and hardening processes. However selection of ingredients is without the doubts the important task in the success of production of frozen yoghurt (Goff and Hartel, 2013).

Formulations can be derived from a number of different starting points. Details and suggested formulas are detailed on the formulations page, but turning the formulation into a recipe depends on the ingredients used to supply the components, and it is then necessary to do a mix calculation to determine the required ingredients based on the formula. Ice milk and light frozen yoghurts are very similar to the composition of frozen yoghurt but in the case of ice milk in Canada, for example, it must contain between 3% and 5% milk fat by legal definition (Goff and Hartel, 2013).

The ingredients to supply the desired components are chosen on the basis of availability, cost, and desired quality. Following paragraphs examine the ingredients in more detail.

2.6.1 Milk fat

Milk fat contributes significantly to the rich, full, creamy flavor and to the smooth texture of frozen yoghurt. Part of flavor contribution comes from the short chain, volatile fatty acids that are part of triglycerides of milk fat (Goff and Hartel, 2013). Triglycerides, which are made up of three fatty acids and glycerol and are linked together by ester bonds, make up the majority of milk fat. Fresh cream is the best source of fat; other options include frozen cream, butter, and lard (Arbuckle, 2013).

Cream is the best source of milk if free from rancidity and lipid oxidation, it provides the best of all fat-based ingredients. It is a liquid, which facilitate the ease of handling. However it expensive compared to other fat sources. Cream like milk supports the growth of bacteria, so it should be stored at 4°C or less. Unsalted butter of the good quality can be an important source of milk fat for frozen desserts. It is comparatively less expensive than cream, can be transported at lower cost and can be stored at 4°C or lower, for several weeks to months with a little loss of quality and is nearly always available (Goff and Hartel, 2013).

In dairy products, dairy fat contains unique functional and flavor components. The buttery, creamy and ‘rich’ flavor of milk fat results from several odorants such as fatty acids, lactones, and carbonyl compounds. Moreover, milk fat reacts with sugars and proteins, yielding sugary and caramel texture (Koeferli *et al.*, 1996). Ohmes *et al.* (1998) states that milk fat affects the flavor of frozen yoghurt 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.

The nutritional and functional properties of milk fat have piqued people's interest. According to studies, fat contributes to flavor richness, acts as a carrier and synergist for added flavor components, generates a smooth texture by lubricating the palate, helps to give body, and aids in the production of optimal melting qualities. It also has an impact on textural properties including hardness and ice crystal perception. The fat emulsion in the mix will partially agglomerate or destabilize as a result of emulsifier activity, air inclusion, and ice crystallization during frozen yoghurt freezing, and this partial churning is required to build up the structure and texture in the frozen yoghurt (Marshall *et al.*, 2003). The trapped water, which creates an oil-water emulsion with the interaction of stabilizers and emulsifiers during whipping, is one probable method for milk fat supplying crucial structure and texture to the product (Hyde and Rothwell, 1973).

A experiment revealed that fat increased the creamy characteristic, texture stability, and flavor during storage of frozen yoghurt in the range of 0.5 to 6%, whereas low-fat and non-fat frozen yoghurts were the most adversely affected by heat-shock treatment and showed the greatest changes in iciness, smoothness, and mouth coating (Prindiville *et al.*, 1999).

2.6.2 MSNF

MSNF is the solids of skim milk, and consists of protein (36.7%), milk sugar (lactose: 55.5%), and minerals (7.8%). It is high in food value, inexpensive and enhance palatability. The lactose adds slightly to the sweet taste, and the minerals adds slightly salty taste, which rounds out the flavors of finished product. The protein in MSNF provide compact and smooth body (Arbuckle, 2013).

MSNF contributes significantly to flavors and texture of frozen product. It gives body and smooth texture through emulsification of fat, foam formation and stability of air bubble, and viscosity enhancement in unfrozen phase (Goff and Hartel, 2013). MSNF content can vary from 6% to 14% or more but Sommer (1946) has recommended that the MSNF should be no more than 15.6-18.5%, above which lactose crystallization and sandiness may become an issue.

The most commonly used MSNF sources and their composition are shown in the Table 2.5

Table 2.5 Typical composition of MSNF Sources

Ingredients	Constituents (%)					
	Fat	Casein	Whey	Lactose	Ash	water
Skimmed Milk	0.1	2.5	0.8	4.8	0.8	91.0
SMP	1.0	27.7	9.3	52.0	7.0	3.0
Whey Powder	1.0	-	13.0	73.0	9.0	4.0
Whey Protein Concentrate	2.0	-	35.0	51.0	7.0	5.0

Source: Jana *et al.* (2016)

Major functional properties of MSNF are:

- It gives body,takes part in texture formation and gives smooth consisitency.
- It improve the mix ability to absorbs air andacts partly as a stabilizers.
- It influences the freezing point depression in the mix , mainly by the content of lactose and minerals.
- 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, 2013).

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 (Goff and Hartel, 2013).

2.6.3 Sweeteners

A sweet frozen yoghurt is usually desired by the consumer. As a result, sweetening agents are added to frozen yoghurt mix at a rate of usually 12 - 16% by weight (Goff and Hartel, 2013). In frozen yoghurt production, different sugars such as glucose, fructose, sucrose and sugar alcohols are used, but sucrose is the main sweetener. It imparts flavor. Lactose is not used as sugar source in frozen yoghurt industry, because lactose can cause sandiness in frozen yoghurt under some conditions (Lee and White, 1991).

Corn syrup secured a firmer and chewier body to the frozen yoghurt and is an economic source of solids. An enzymatic hydrolysis and isomerization procedure convert glucose to fructose, a sweeter carbohydrate, in corn syrups, yielding a high fructose corn syrup (HFCS), which can be used as sucrose replacement. However, these HFCS blends reduce the freezing point, producing a very soft frozen yoghurt at usual conditions of storage and dipping at home. Fructose, a naturally occurring hexose, is a component of honey and many fruits. Fructose is sweeter, more soluble, and less glucogenic than glucose or sucrose. Therefore, it has been recommended as a replacement for diabetic patients and obese subjects (Hallfrisch, 1990). Conforti (1994) produced vanilla frozen yoghurt with different sugars and found that melting times of frozen yoghurt samples ranged from 1,504 s to 1,742 s. It was found that the corn sweetener blend addition decreased the melting times in comparison to sucrose. But panelists preferred the frozen yoghurt samples with sucrose compared to corn sweetener blend. Ozdemir *et al.* (2003) found that the use of HFCS instead of sucrose decreased the viscosity and overrun ratio.

The main functions of sweeteners are:

- Sugars are used as a cheap source of total solids.
- It increases the viscosity of the mix.
- It improve the texture and enhance the flavors.
- These sugars, being in resolution, depress the melting point of the combination which ends up in fascinating soft, scoopable and tender characteristics within the frozen product and also in lower temperatures needed for correct hardening (Arbuckle, 2013).

2.6.4 Stabilizers and emulsifiers

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 frozen yoghurt. This results in many functional benefits and also extends the shelf life by limiting ice recrystallization during storage. Without the stabilizers, the frozen yoghurt would become coarse and icy very quickly due to the migration of free water and the growth of exiting ice crystals (Goff and Hartel, 2013).

A good stabilizer should be nontoxic, readily disperse in the mix, not produce excessive viscosity or separation or foam in the mix, not clog strainers and filters, provide frozen yoghurt with desirable meltdown, be economical, and not impart off flavor to the mix. The amount and kind of stabilizer required in frozen yoghurt depend on its properties, mix composition, and ingredients used; processing times, temperatures, and pressures; storage temperature and time; and many other factors. Usually 0.1–0.5% stabilizer is utilized in the mix (Bahramparvar and Mazaheri Tehrani, 2011).

The stabilizing ingredients most used in frozen dairy foods are guar gum, locust bean gum (carob bean gum), CMC, sodium and propylene glycol alginates, xanthan gum, gelatin and carrageenan. Pectin is useful in combination with the gums in sherbet and ices (Moeenfard and Tehrani, 2008).

The functions of stabilizers are as follows:

- The stabilizers also prevent the air bubbles from collapsing and promote good flavor release and holds flavoring compounds in dispersion (Guinard *et al.*, 1994).

- It cools uniformly and allows easy incorporation of air into the mix.
- It provides superior heat-shock resistance.
- It does not produce any taste or flavor-masking properties to the mix.
- It forms a cryo-gel, which can be effective in cryo-protection (Bahramparvar and Mazaheri Tehrani, 2011).
- 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 frozen yoghurt 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 frozen yoghurt during storage: To prevent lactose crystal growth and retard or reduce ice crystal growth during storage (see also the discussion on frozen yoghurt 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 frozen yoghurt at the time of consumption: To provide some body and mouthfeel without being gummy, and to promote good flavor release (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 (Marshall *et al.*, 2003).

The emulsifiers in frozen yoghurt aid in developing the appropriate fat structure and air distribution necessary for the smooth eating and good meltdown characteristics desired in frozen yoghurt. Since each molecule of an emulsifier contains a hydrophilic portion and a hydrophobic 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 original frozen yoghurt emulsifier was egg yolk, which was used in most of the original recipes. Today, two emulsifiers predominate most frozen yoghurt formulations:

1. Mono-and di-glycerides: derived from the partial hydrolysis of fats or oils of animal or vegetable origin.
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 (Goff and Hartel, 2013).

Usually, blends of stabilizer and emulsifier designed to function best in full fat, low fat, or nonfat frozen yoghurts are used (Baer *et al.*, 1999). Emulsifiers are sometimes integrated with stabilizers in proprietary blends but have different actions and functions some of which are as follows:

- Emulsifiers have the ability to reduce surface tension at the interface of two normally immiscible phases, which will then mix and form an emulsion (Baer *et al.*, 1999).
- Emulsifiers are also effective in destabilizing the fat emulsion during the freezing of an frozen yoghurt milk (Adziezak, 1988).
- 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 frozen yoghurt(Baer *et al.*, 1997).
- 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).

2.6.5 Starter culture

A starter culture is a product that contains a high concentration of lactic acid bacteria. In order to activate the acidification process in milk, Starter cultures are typically produced in special starter culture laboratories are available, but they can also be cultured and propagated in dairy farms (Gandhi, 2006).

Streptococcus thermophillus and *Lactobacillus delbrueckii* subsp. *bulgaricus* are used as important starter microorganisms in the production of yoghurt and some cheeses. Because both bacteria can grow on their own in milk, this indirect positive interaction is known as protocooperation (Fredrickson, 1977). Although they can grow independently, the rate of acid production is much higher when the two organisms are grown together than when the two organisms are grown separately. *S. thermophilus* grows more quickly and emits both acid and carbon dioxide. The formate and carbon dioxide produced stimulate the growth of *L. bulgaricus*. *L. bulgaricus'* proteolytic activity, on the other hand, generates stimulatory peptides and amino acids for use by *S. thermophilus* (Desai *et al.*, 1994). This positive relationship frequently promotes bacterial growth and the production of lactic acid and aromatic compounds. Lactic acid production lowers pH, rendering the product unsuitable for the growth of spoilage or pathogenic microorganisms (Donkor *et al.*, 2007b).

These microorganisms are ultimately responsible for the flavor and texture of yoghurt. Because of the pH drop, the yoghurt mixture coagulates during fermentation. The streptococci are responsible for the yoghurt mix's initial pH drop to around 5.0. Lactobacilli are to blame for a further drop to pH 4.0. Fermentation products that contribute to flavor include lactic acid, acetaldehyde, acetic acid, and diacetyl (Chandan and Shahani, 1995).

2.6.6 Flavors

Flavor is generally considered the most important characteristic of frozen yoghurt. It is easily confused with taste, which includes the "feel sensation" of body and texture as well as the true flavor. The flavor of frozen yoghurt is the result of blending the flavors of all the ingredients, some of which may not be sufficiently pronounced to be recognizable, although each contributes to the final effect (Marshall *et al.*, 2003). The most important aesthetic attribute of food is flavor, and frozen yoghurt is no exception. Flavor is a three-part sensory response that includes olfaction (smell), gustation (taste), and tactual (mouthfeel). In general, compounds that impart flavors can be detected at levels as low as 0.01-0.5 % (Boltong *et al.*, 2012).

The two important characteristics of flavor are type and intensity. Generally the delicate flavors are easily blended and tend not to be objectionable at high concentrations. Harsh flavors tend to be objectionable, even at low concentrations. In any case flavors should be only intense enough to be recognized easily and to present a delicate, pleasing taste (Marshall *et al.*, 2003).

Federal Standards of Identity divide flavoring materials and the labels of frozen desserts into three categories:

• Industry category I: Pure extracts and flavors

• Industry category II: Pure extracts and flavors that dominate over synthetic components

• Industry category III: Artificial flavor that predominates over natural flavor components (Marshall *et al.*, 2003)

Flavorings are available as liquids, syrups, semisolids and solids. Liquid flavorings, such as vanilla, are added to the mix just prior to freezing. Flavorings of naturally and chemically produced origins are available mainly in mixtures for the proper flavoring of foods. Natural flavorings useful in frozen desserts derive from citrus and non-citrus fruits, tropical fruit, sugar-free fruit, botanicals, spices, cocoa and chocolate, coffee, natural flavorings from vanilla beans, and nuts. The Code of Federal Regulations, , defines "natural flavor" or "natural flavoring" as the essential oil, oleoresin, essence or extractive, protein hydrolysate, distillate, or any product of roasting, heating or enzymolysis that contains the flavoring constituents derived from a series of materials, which it then lists. The synthetic flavorings include aromatic chemicals and artificial flavors. Liqueur flavorings include alcohol, whiskey and distilled beverages, fruit brandy distillate, brandy flavor essence, and fruit liqueurs (Marshall *et al.*, 2003).

Preferences for sweetness level in vanilla frozen yoghurt range from 15 to 19% as sugar. A professional panel that studied the use of fruit concentrates and essences in frozen yoghurt found that 17% sugar was optimum for the most desirable fruit flavor (Arbuckle *et al*., 1961). When the sugar content was over 17%, the fruit flavors tended to be submerged by the excess sweetness. Sweetening at the sucrose equivalencies of 15% for plain frozen yoghurts and 17-18% for bulky flavors of frozen yoghurt usually results in optimal acceptance (Arbuckle *et al*., 1961).

2.6.7 Colors

Frozen Yoghurt should have a delicate, attractive color that suggests or is closely associated with its flavor. Almost all are slightly colored to give them the shade of the natural product. 15% fruit produces only a slight effect on color (Jana *et al.*, 2016). However, most suppliers would include some color in the fruit to save the processor time,i.e., solid pack strawberries include color. Most colors are of synthetic origin must be approved (Goff and Hartel, 2013).

The Food and Drug Administration has approved both "certified" (within the Food and Drug Cosmetic Act) and "exempt from certification" (natural) colors for use in frozen yoghurt (Marshall *et al.*, 2003). Colors are used in frozen yoghurt to create appeal. If used to excess they indicate cheapness. The choice of shade is dictated by flavor, i.e., red for strawberry, light green for mint, purple for grape, etc. Colors are added to frozen yoghurt to add color to otherwise colorless products, to reinforce colors that are already present, and to ensure color consistency between batches (Clarke, 2004).

Table 2.6 The list of permitted colorings by FSSAI for use in frozen yoghurt

Colorant	Color hue imparted
Erythrosine	Red
Allura red	Red
Caramel	Brown
Green S	Green
Sunset Yellow	Orange
Tartrazine	Yellow
Indigo Carmine	Indigo
Brilliant Blue	Blue
Black PN	Black

Source**:** Jana *et al.* (2016)

Several natural colorings have emerged due to negative health impact of the permitted synthetic colorants in frozen yoghurt. However, these have not got wide acceptance due to problems in stability of the colorants. Some examples of natural colorants that has been tried in frozen yoghurt and frozen desserts is depicted in Table-2.7.

Table 2.7 Natural colorants used in frozen yoghurt

Colorant	Natural source	Color hue imparted
Annato	*Bixa orellana*	Yellow
Betanin	Beet root	Red
Curcumin	Turmeric	Yellow
Paprika	Paprika leaves	Pale yellow
Carotenoid	Saffron	Saffron
Anthocyanin	Grapes	Red

Source: Jana *et al.* (2016)

2.6.8 Water

Mostly ignored but very influential component present in frozen yoghurt are air and water. Water maintains the continuous phase in frozen yoghurt either by adding as solid or liquid form. Products from dairy origin also contribute water contents. Water provided from supply source must be purified while it is expected that water of milk source has been cleaned already during its passage and excretion from mammary glands (Qamar Abbas Syed, 2018). Water is an important constituent of frozen yoghurt. It is a continuous phase in which all the other solute components are dissolved or dispersed. Water in frozen yoghurt 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 (Chhetri, 2016).

Water is the solvent for the continuous phase. In frozen yoghurt, it is present both as a liquid and a solid, as it will not completely freeze due to the effect of the added solutes on freezing point depression. The solid: liquid ratio, as dictated by solute concentration and temperature, greatly affects the firmness of the frozen yoghurt. Water in the frozen yoghurt mix comes from fluid dairy products and syrups or from added water (Marshall *et al.*, 2003).

The function of water are as follows:

- Act as solvent
- Provides liquid medium (Qamar Abbas Syed, 2018)

2.7 Defects

An acceptable frozen yoghurt at the time of serving should resemble yoghurt being smooth bodied, pleasant flavor and refreshing. The stabilizers should be one which is compatible with acidic nature of yoghurt mix.

Frozen yoghurt makes heavy demands of stabilizers and only few of them are suitable for fermented dairy products. Most vegetable stabilizers react with milk protein and form a gritty structure which results in syneresis. A normal ice-cream stabilizers cannot be used for frozen yoghurt. Gelatin based stabilizers will handle and perform well during culturing process and sometimes carrageenan modified gums mixture may also be suitable.

The general criteria used in sensory evaluation of frozen yoghurt are comparable to those of sherbets or low fat ice cream. “Chalkiness” may sometimes be observed in the mouthfeel of frozen yoghurt, this is quite possible due to dehydration of protein by the combined action of heat and acidity. The absolute level of product sweetness and acidity, as well as balance between sweetness and acidity, in association of the given flavors, are important consideration for frozen yoghurt.

The defects related to various aspect in frozen yoghurt are given below

Culture-related aspect

1. Acetaldehydes
2. Bitter
3. Too high acid
4. Too low acid

Dairy ingredients related

1. Lacks freshness
2. Rancid
3. Salty
4. Oxidised (Dudhrejiya, 2017)

2.8 Manufacture of frozen yoghurt

The method for the preparation of frozen yoghurt involve blending of yoghurt with ice cream mix, before freezing, to get a frozen yoghurt dessert having excellent sensory attributes.

2.8.1 Yoghurt production

Yoghurt process and formulation variations are as numerous as the number of manufacturers. The finished yoghurt will vary in regard to body and texture, depending upon the type of ingredients, processing, starter cultures, flavor, and packaging that is used. The processing of yoghurts can be broken down into the following steps: blending, pasteurization, homogenization, culturing and cooling, packaging and storage. Each is extremely important in the process, and strict attention to detail must be taken (Tribby, 2008). The basic steps for yoghurt production are as follows:

2.8.1.1 Milk procurement

Milk intended for yoghurt production must be of the highest bacteriological quality. It should have low content of bacteria and substances which may impede the development of the yoghurt culture. Milk should not contain antibiotics, bacteriophages, residues of CIP solution or sterilizing agents. The milk must be very carefully analyzed at the dairy.

2.8.1.2 Standardization and mix preparation

In most yoghurt formulation, standardization of milk fat and SNF contents is done to bring uniformity in the product quality. When the milk arrives at the plant, its composition is modified before it is used to make yoghurt. This standardization process typically involves reducing the fat content and increasing the total solids. The fat content is reduced by using centrifugation to separate fat from milk. For stirred yoghurt manufacture, the solids content of the milk is usually increased to about 16% with 1-5% being fat and 11-14% solids-not-fat (SNF). This is accomplished either by evaporating off some of the water, or adding concentrated milk or milk powder, other ingredients. Increasing the solids content improves the nutritional value of the yoghurt, makes it easier to produce a firmer yoghurt and improves the stability of the milk substance is fermented until it becomes yoghurt. Fruits and flavorings are added to the yoghurt before packaging the yoghurt by reducing the tendency for it to separate on storage. Yoghurt mix should have a minimum SNF of 12% to increase the viscosity and also to increase the resistance to "wheying off". After the solids composition is adjusted, stabilizers are added and the milk is pasteurized (Tribby, 2008).

2.8.1.3 Homogenization

Yoghurt mix homogenization aids in hydration of stabilizers, and the interaction of stabilizers with milk proteins. In the manufacture of yoghurt and other dairy products, it is common to homogenize mixes at approximately 63°C (145°F), with a total pressure of between 7 and 10 MPa (1000 and 1500 psi) in the 1st stage and 3 MPa (500 psi) in the 2nd stage. Different types of homogenizers may be used but the same pressure conditions are applied. Homogenization is done to reduce fat globule size, so that it helps to produce smooth texture, increases viscosity of yoghurt, and prevent creaming during incubation (Tribby, 2008).

2.8.1.4 Pasteurization

Pasteurization of yoghurt mixes can be accomplished by several different methods. As with any other dairy product, the purpose for pasteurization is to heat treat milk to eliminate pathogenic bacteria. In addition, it is very important to denature the proteins to attain the highest level of functionality from the milk proteins. Pasteurization also aids in the hydration of the stabilizers and dry ingredients that were added during blending, as well as adding a pleasant cooked flavor. The three main types of pasteurization are low temperature long time (LTLT) , i.e., 63°C for 30 min, high temperature short time (HTST), i.e., 72-75°C for 15 s, and ultra-high temperature (UHT) ,i.e., 125-138°C for 2–4 s (North and Park, 1927).

2.8.1.5 Cooling

After pasteurization and homogenization, the yoghurt mix is cooled to the optimum setting temperature. The milk is cooled to 42-45°C, which is the optimum temperature for the activity of yoghurt starter culture.

2.8.1.6 Starter addition

The yoghurt starter consists of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* in the ratio of 1:1. The symbiotic relationship between two organisms, at a given ratio is synergistic. Although they can grow independently, the rate of acid production is much higher when used together than either of the two organisms grows individually. The symbiosis is responsible for typical yoghurt flavor and texture (Donkor *et al.*, 2007).

2.8.1.7 Incubation

After addition of the culture, the cup-set yoghurt is moved to the incubation room where it will be left until the pH reaches pH 4.4–4.6. At isoelectric pH (4.7) of casein, the colloidal casein micelles collapse, thereby precipitating into curd. This usually takes yoghurt between 5 and 6 h depending upon regional differences and variations in solids levels, and heat treatments. Product should be checked for pH after 3 h of ripening. The best temperature for yoghurt production is 43°C, with an incubation time of 2.5 to 3.5 h (Tamime and Robinson, 1999).

2.8.1.8 Cooling and storage

When the coagulum is well set and optimum pH (typically 4.5) is reached, it is time to start cooling. The product is cooled to 18-20°C within 30-45 min. Final cooling is normally down to 5°C, which takes place in the cool store, where the products are held to await distribution.

2.8.2 Preparation of ice-cream mix

2.8.2.1 Standardization of the mix

The milk is standardized with addition of various ingredients. Required amounts of sugar, butter, coconut milk are added.

2.8.2.1 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.*, 2005). 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). Advantages of pasteurization are:

- It renders the mix completely free of pathogenic bacteria.
- It dissolves and helps to blend the ingredients of the mix.
- It improves flavor.
- It improves keeping quality.
- It produces a more uniform product (Jana *et al.*, 2016)

The temperature -time combination for pasteurization of the mix as per Bureau of Indian Standards (BIS) is as follows

- For Batch method : 68.5°C for not less than 30 min
- HTST method : 80°C for not less than 25 s
- Vacreation : 90°C for not less than 1-3 s
- UHT pasteurization : 98.8 to 128.3°C for not less than 0-40 s (Jana *et al.*, 2016)

High temperature pasteurization is preferred as there is a greater bacterial kill resulting in low bacterial count in frozen yoghurt

- Better body and texture
- Better flavor
- Protection against oxidation
- Saving of stabilizer
- Saving of time, labour and space
- Increased capacity (Jana *et al.*, 2016)

2.8.2.2 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 (Walstra *et al.*, 2005). The mix is 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 µm. Two stage homogenization is usually preferred for frozen yoghurt 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:

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

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 frozen yoghurt mix. Clumping or clustering of the fat is reduced thereby producing a thinner, more rapidly whipped mix. Melt-down is also improved (Goff, 1987). Homogenization of mix is usually done at temperature ranging from 63 to 77°C. A pressure of 2000 to 2500 psi (135 to 170 kg/cm^2) with one valve or 2500 to 3000 psi (170 to 200 kg/ cm^2) on the first and 500 psi (35 kg/cm^2) on the second stage will usually give good results for an average mix (Jana *et al.*, 2016).

2.8.2.3 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.*, 2005).

The changes that occurs during ageing are

- Hydration of milk proteins
- Crystallization of fats
- Absorption of water by any added hydrocolloids
- Viscosity is increased largely due to the previously mentioned changes.
- Ageing is substantially completed within 24 h and longer period should be avoided to control spoilage by psychrotrophs (Jana *et al.*, 2016)

The mix is then aged for at least 4 h and usually overnight. 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 (Goff and Hartel, 2013).

2.8.3 Mixing ice-cream mix and yoghurt

Prepared yoghurt and ice-cream mixture are mixed well (75% yoghurt and 25% ice-cream (w/w)). The final mixture is homogenized for 5 min in constant stirring (Airani, 2007) **.**

2.8.4 Freezing

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).

Frozen yoghurt mix is frozen in single-batch machines or in continuous freezers. In general, both machines utilize a cylindrical chamber with double wall which acts as a jacket to contain the refrigerant. On the axis of the cylinder, a rotating dasher and scraper keep the mix thoroughly agitated and remove the ice from the refrigerated wall. Frozen yoghurt contains a considerable quantity of air, up to half of its volume. This gives the product its characteristic lightness. Without air, frozen yoghurt would be similar to a frozen ice cube. The air content is termed its overrun, which can be calculated mathematically (Jana *et al.*, 2016).

2.8.5 Hardening

The mix leaves the freezer at -3.5°C to -7°C and packaging in cups allows better shape retention during hardening. The hardening process serves to adjust the temperature of frozen yoghurt 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.*, 2005).

2.9 Melting properties

The ability of frozen yoghurt to resist melting when exposed to heated temperatures for a period of time is measured by its meltdown. It is a metric that accounts for thermal conductivity, heat capacity, and microstructure, as well as the impact of changing the frozen yoghurt's composition on its attributes (Clarke, 2004).

The amount of air in the frozen yoghurt, the type of the ice crystals, and the network of fat globules created during freezing all influence the melting rate. A lower melting rate is associated with the frozen yoghurt's ability to maintain its shape, which is often regarded as a sign of high quality (Pon *et al.*, 2015). The melt-down rate of frozen yoghurt is affected by many factors, including the amount of air incorporated, the nature of the ice crystals, and the network of fat globules formed during freezing (Muse and Hartel, 2004). Sakurai (1996) found that frozen yoghurts with low overruns melted quickly, whereas frozen yoghurts with high overruns began to melt slowly and had a good melting resistance. This slower melting rate in the frozen yoghurts with high overruns was attributed to a reduced rate of heat transfer due to a larger volume of air but may also be due to the more tortuous path through which the melting fluid must flow (Hartel *et al.*, 2004).

The rate of meltdown in frozen yoghurt must be controlled as it guides us to a good product. A meltdown range of 10-40% was considered acceptable when the product was allowed to melt at 25°C (Hartel *et al.*, 2004).

2.10 Overrun

The volume of frozen yoghurt obtained in excess of the volume of mix is known as overrun. The presence of air in the mix provides the final product a pleasant light feel (Kavaz Yuksel, 2015).

Air in frozen yoghurt provides a light texture and influences the physical properties of melt down and hardness. However, it is not just the amount of air incorporated, or overrun, but also the distribution of sizes of the air cells that influences these parameters. The manufacture of high quality frozen yoghurt requires careful control of both overrun and air cell size distribution (Sofjan and Hartel, 2004).

The amount of overrun achieved in the freezer is determined by the type of ingredients in the mix, the sharpness of the scrapper blades, the speed of the dasher, the volume of refrigerant moving through the freezing chamber, and the temperature of the refrigerant. The addition of air gives the frozen yoghurt a smoother texture. Frozen yoghurt's sensory qualities are influenced by the amount of air it contains. When less air is added to the frozen yoghurt, it becomes dense, heavy, and cooler to consume. The frozen yoghurt becomes light and fluffy when more air is added. The emulsifier is significant among the mix components for structure creation, air cell distribution, and air cell stability (Ludvigsen, 2011).

Pon *et al.* (2015) found that the average frozen yoghurt 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.

Part III

Materials and methods

3.1 Materials

The materials collected for the formulation of coconut milk incorporated frozen yoghurt were as follows:

3.1.1 Milk

Standard milk was collected from local market of Dharan. Fat and SNF were labelled as 3.0% and 8.0%, respectively.

3.1.2 Butter

Fresh butter was bought from local market of Dharan. Fat and SNF were labelled to be 80% and 3%, 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 96.5% 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 Jolly Ice-cream of Dharan. It can be used in range of 0.3-0.5%.

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3.1.6 Starter culture

Starter culture was bought from Kamdhenu dairy named lactoferm developed in biochemical research center.

3.1.7 Coconut

Coconut was collected from the local market of Dharan. The skin was mostly brown and the stem on top of the coconut was also brown.

3.1.8 Containers

Plastic cup as frozen yoghurt packaging materials were bought from the market of Dharan. The size of cup was 50 ml.

3.1.9 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 equipment used

Heating arrangement.	Soxhlet apparatus
Electric balance.	Hot air oven
Centrifuge	Grinding apparatus
Thermometer	Stainless steel vessels
Batch freezer	Plastic cup and spoon
Kjeldahl digestion and distillation set	Refrigerator
Gerber Butyrometer	Desiccator
PH meter	Muffle furnace

3.2 Method

3.2.1 Preparation of coconut milk

The obtained coconuts were dehusked and cracked opened using a machete where its water was poured into a food-grade container.

The coconuts were then cracked into pieces and also de-shelled and the testa of the meat was removed as depicted and the brown skin was pulled away to reveal the white kernel. The brown skin is removed so that it does not give the extracted coconut milk a dark hue and a little unpleasant taste. Coconut meat is rich in minerals, especially calcium and magnesium, so the kernel was cleaned with deionized water. The pieces of coconut were charged into an electric blender, and heated to 55°C. It was blended and homogenized smoothly. The viscous slurry resulting from the mixture was filtered using a muslin cloth and then squeezed to extract the coconut milk into a clean bowl. The squeezed pulp was poured back into the electric blender with hot water added and the process was repeated three more times. The extracted coconut milk was pasteurized at 62.8°C for 30 - 60 min by heating it and using a thermometer to monitor its temperature before storage in a container with tight-fitting for analysis. Fig 3.1 shows the process followed for preparing coconut milk.

Matured coconut

↓

De-husking

↓

De-shelling

↓

Pairing

↓

Washing with deionized water

↓

Blending using electric blender and heated to 55°C

↓

Mixing with water in 1:1

↓

Filtering using muslin cloth

↓

Pasteurization at 62.8°C for 30-60 min

↓

Coconut milk

Fig. 3.1 Process of extraction of coconut milk

Source: (Kofi Tulashie *et al.*, 2022)

3.2.2 Preparation of yoghurt

Fresh standardized milk was heated to 60°C and homogenized about 15 min. Then sugar and gelatin were added and milk was pasteurized at 63°C for 30 min. Then the mixture was cooled to (42-45)°C and it was inoculated with 1-2% starter culture. The inoculated yoghurt mixture was then incubated at 43°C for 2.5-3.5 h until the pH reaches to 4.4-4.6. Then, they were cooled to 18-20°C and later stored at 5°C (Airani, 2007). Fig 3.2 shows the process followed for preparing yoghurt.

Standardization of milk (Solid 16%, Fat 3%, SNF 12%)

↓

Homogenization at 63 ºC and pressure 7-10 MPa 1st stage and 3 MPa 2nd stage

↓

Pasteurization 63 ºC for 30 min

↓

Cooling to incubation temperature (42-45) ºC

↓

Inoculation of starter culture (1-2% v/v) (1:1 *Streptococcus thermophilus* and *Lactobacillus bulgaricus*)

↓

Fermentation/Incubation 43 °C (Until pH reached to 4.6) for 2.5-3.5 h

↓

Cooling (18-20) °C

↓

Cold storage at 5 °C

↓

Yoghurt

Fig. 3.2 Manufacturing steps of yoghurt

Source: (Airani, 2007b)

3.2.3 Preparation of coconut milk ice-cream mix

Coconut milk was heated to 90°C for 1-2 s to make the ice-cream with coconut milk. During pasteurization, a calculated amount of sugar, stabilizer, and SMP was added. When it's hot, it was homogenized, then cooled to room temperature. After, that flavor was added and it' was aged for 6 h at room temperature. The aged mix was placed in the freezer until it reached a consistent texture.

Fig. 3.3 shows the detail method of preparation of coconut milk incorporated ice-cream

Coconut milk

↓

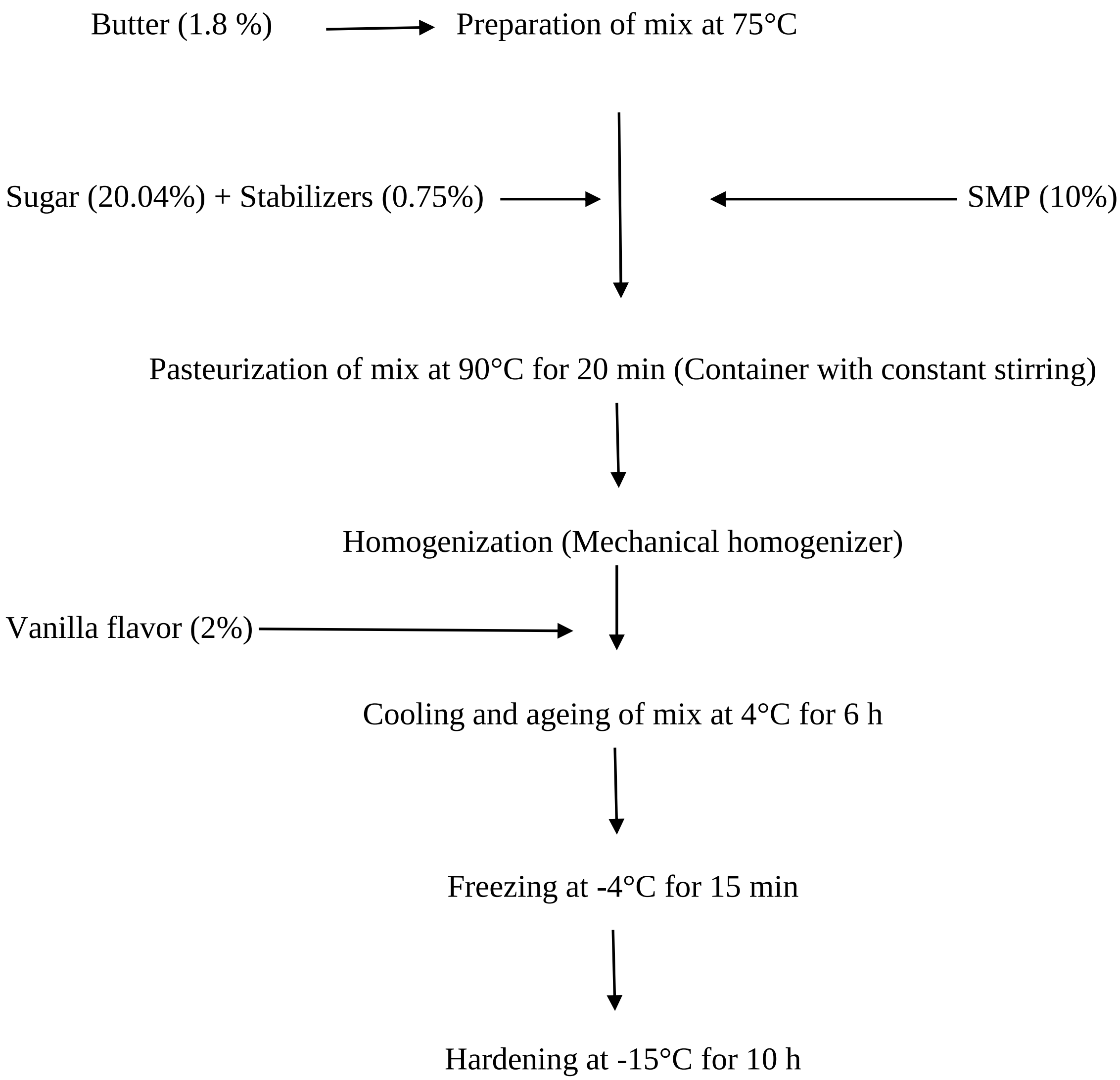

Fig. 3.3 Manufacturing steps for coconut milk ice-cream

Source: (Jayasundera and Fernando, 2014)

3.2.4 Preparation of frozen yoghurt

Method of manufacture frozen yoghurt: The method used in preparing frozen yoghurt was mentioned by (Ahmed *et al.*, 2010). Fig. 3.4 shows the processing steps for frozen yoghurt.

The required amount of milk solids not fat, gelatin and half the amount of granulated sucrose needed were dry blended, then mixed with milk.

↓

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The mixture was pasteurized at 80°C for 30 min.

↓

Cooled to 40°C.

↓

Inoculate with active yoghurt culture starter at the rate of (1-3%)

↓

Incubate for 4 h at 40°C.

↓

The yoghurt cooled to 5°C again for 24 h.

↓

Ice-cream mix was added to yoghurt mix, prior to freezing.

↓

The product was packaged in cups 45 ml in volume.

↓

Hardening held at -25 C for 24 h.

Fig. 3.4 Processing steps for coconut milk frozen yoghurt

format

Source: (Ahmed *et al.*, 2010)

Ahmed et al. (2010)

3.2.5 Experimental design

The effect of two independent variables, namely coconut milk and milk on overrun and melting of coconut milk frozen yoghurt was investigated using response surface methodology (RSM). The independent variables and their levels were selected on the basis of literature and preliminary researches. The response variable were overrun and melting rate of frozen yoghurt. The experimental design, data analysis and model building were performed using "Design Expert" software (Version 13.0, Stat-Ease Inc., USA).

Table 3.3 Different constraints of optimization for coconut milk frozen yoghurt

Name	Goal	Range
Coconut milk	To be in range	(0-50)%
Milk	To be in range	(50-100)%
Melting rate	To be minimized	To be determined
Overrun	To be maximized	To be determined

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), *β1*, *β2* (linear effects), *β11*, *β22* (quadratic effects), *β12* (interaction effect) and *ε* (random error).

Table 3.4 Different proportion of coconut milk and milk

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Sample	Coconut milk (%)	Milk (%)

Recheck list of tables in the contents (the page number)

A	87.5	25
B	100	0
C	75	25
D	100	0
E	50	50
F	100	0
G	50	50
H	67.5	37.5
I	75	25

3.3 Experimental procedure

3.3.1 Sensory evaluation

The frozen yoghurt samples, the best one in terms of sensory quality was determined. For sensory evaluation, hedonic rating method was used. CCT, Hattisar students and instructors made up the panel of experts. The data were statistically evaluated, and the panelists' scores were analyzed using the statistical software GENSTAT Release (version 12.1) produced by Lawes Agricultural Trust utilizing two-way analysis of variance (ANOVA) with no blocking at a 5% level of significance (1995). The estimated mean values of each sensory parameter were compared to the value in the LSD at a 5% threshold of significance to see if the samples were statistically different from one another and to see which one was preferable. Aroma, taste, color, body, and aftertaste were among the sensory criteria which was examined. The sensory card is presented in the Appendix A.

3.3.2 Physiochemical analysis

3.3.2.1 Chemical analysis of coconut milk

3.3.2.1.1 Acidity

Acidity was determined by titrimetric method as described in. Adhikari (2018).

3.3.2.1.2 Fat

Fat content in milk was determined by Gerber method as described by Adhikari (2018).

3.3.2.1.3 Protein

Protein was determined Kjeldahl method as described in Horwitz (1975).

3.3.2.1.4 Ash

Ash content was determined as described in Ranganna (1986).

3.3.2.1.5 pH

The pH value was determined by the direct reading with the digital pH meter as given in KC and Rai (2007).

3.3.2.1.6 Total Solid (TS)

Total solid was determined by subtracting the moisture from the 100 according to Ranganna (1986).

3.3.2.1.7 Moisture

Moisture content was determined as per the methods described by Ranganna (1986).

3.3.2.1.8 Total sugar

The total sugar was determined following the method of Ranganna (1986).

3.3.2.2 Chemical analysis of milk

3.3.2.2.1 Acidity

Acidity and was determined by titrimetric method as per Mohammed *et al.* (2020).

3.3.2.2.2 Fat

Fat content in milk was determined by Gerber method as described by Adhikari (2018).

3.3.2.2.3 Protein

Protein content was determined by formal titration method as described by Adhikari (2018).

3.3.2.2.4 Ash

The ash content was determined as described by Ranganna (1986).

3.3.2.2.5 pH

The pH value was determined by the direct reading with the digital pH meter as given in KC and Rai (2007)

3.3.2.2.6 Total Soluble Solid (TSS)

The total soluble solid of milk was determined by using Hand refractometer Adhikari (2018).

3.3.2.2.7 Lactose

Lactose content was determined by Lane and Eynon method as per Mohammed *et al.* (2020).

3.3.2.3 Analysis of frozen yoghurt

3.3.2.3.1 Overrun

Percentage overrun of frozen yoghurt was determined by the gravimetric method given in National Dairy Development Board (2001). Overrun was calculated as 100 (volume of frozen mix volume of unfrozen mixture)/(volume of unfrozen mix).(Innocente *et al.*, 2002).

3.3.2.3.2 Total solid

Total solids in frozen yoghurt were determined gravimetrically as per Pratap *et al.* (2016).

3.3.2.3.3 Fat

The fat content of frozen yoghurt was determined by Gerber method. 5ml melted frozen yoghurt sample was taken in a 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 (Hussein and Aumara, 2006)

3.3.2.3.4 Lactose

Lactose in frozen yoghurt was determined according to the method described in AOAC Pratap *et al.* (2016).

3.3.2.3.5 Protein

The protein content of frozen yoghurt was determined by Kjeldahl method described in AOAC Pratap *et al.* (2016).

3.3.2.3.6 Total ash

Ash content in frozen yoghurt was determined according to the method described in AOAC Pratap *et al.* (2016).

3.3.2.3.7 Acidity

Acidity and was determined by titrimetric method as per Pratap *et al.* (2016).

3.3.2.4 Data analysis

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.

Part IV

Result and discussion

This work was carried out for the preparation of standard quality of different varieties of frozen yoghurt with different proportions of coconut milk and milk. As frozen yoghurt is a product widely favored and consumed by the general population, coconut frozen yoghurt 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 butter and SMP were analyzed for fat and solid not fat (SNF). The results of analysis of milk, collected from DDC and coconut milk, collected from local market of Dharan and extracted in wet basis are tabulated in Table 4.1 and that of butter and SMP in Table 4.2.

Table 4.1 Proximate composition of milk and coconut milk

Parameters	Milk (%wb)	Coconut milk (%wb)
Moisture	87.23±1.81	84.96±0.32
Protein	3.13±1.87	3.3±0.2
Fat	2.53±0.25	8.2±0.2
Ash	0.6±0.1	1.33±0.15
Carbohydrate	4.9±0.2	1.8±0.1

Table 4.2 Analysis of butter and SMP

Parameters	Butter (%wb)	SMP (%wb)
Fat	80	0.5
SNF	3	96.5

4.2 Sensory analysis of coconut milk frozen yoghurt

Sensory analysis of coconut milk frozen yoghurt was performed with the aid of ten semi-trained panelists evaluating aroma, taste, color, body, aftertaste and overall acceptability of prepared coconut frozen yoghurt. Nine samples were subjected to sensory analysis.

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 of formulation on taste

The order of superiority for the samples in case of taste are as I, C>D, E>A, B, F, G, H.

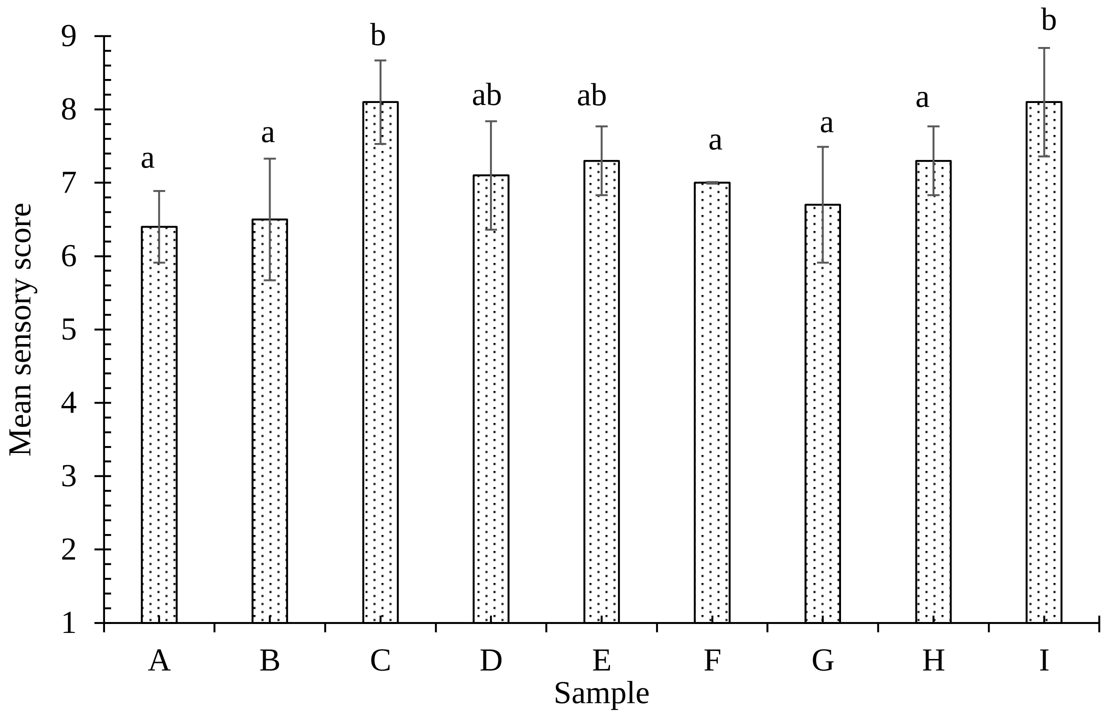


Fig. **4.1** Representation of the mean sensory scores for taste of coconut frozen yoghurt.

Fig.4.1 represents the mean sensory scores for taste of coconut frozen yoghurt 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.

4.2.2 Effect of formulation on body

The order of superiority for the samples in case of body are as I, C>G>A, B, D, E, F, G, H.

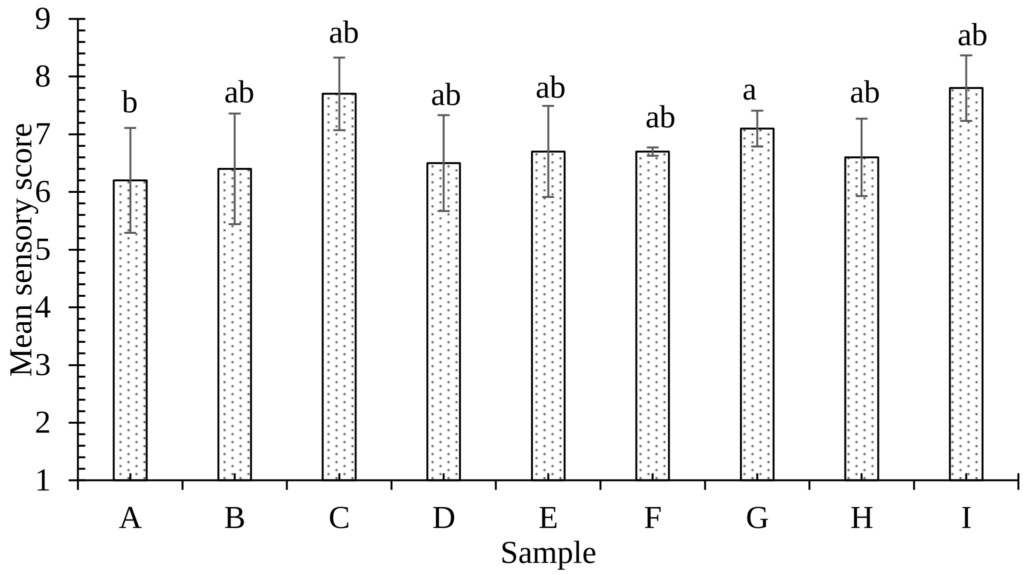


Fig. 4.2 Representation of the mean sensory scores for body and texture of coconut frozen yoghurt.

Fig. 4.2 represents the mean sensory scores for body and texture of coconut frozen yoghurt. 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 overall acceptance

The order of superiority for the samples in case of overall acceptability are as I> C> E, F, H>G> A.

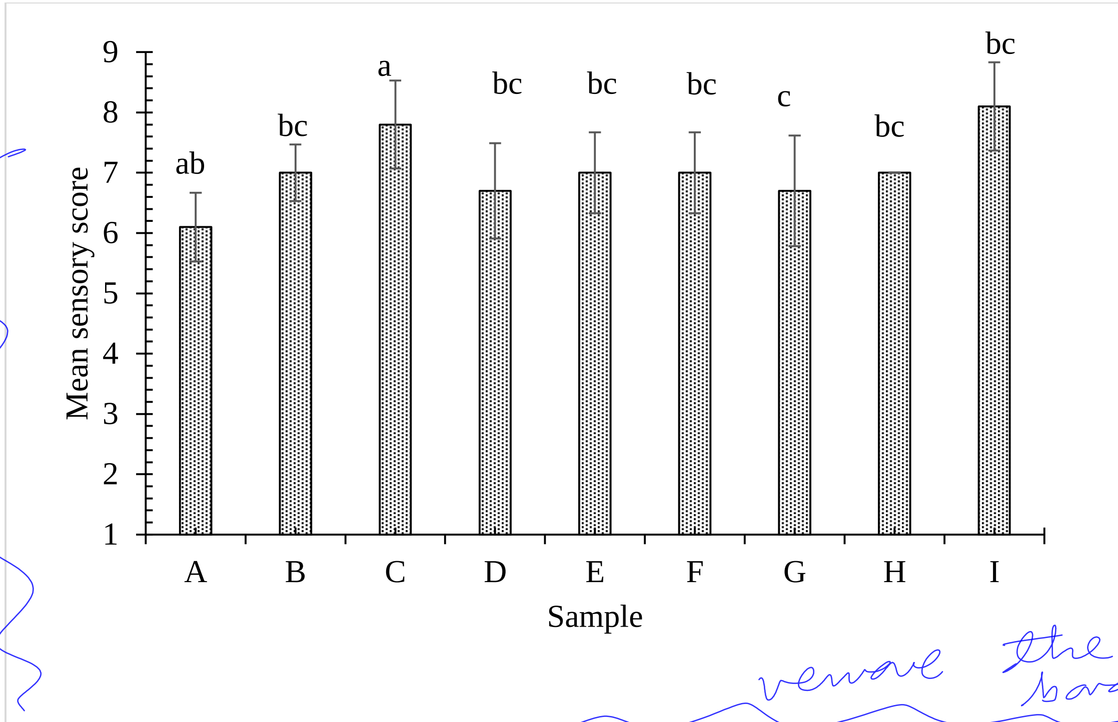


Fig.4.3 Representation of the mean sensory scores for overall acceptance of coconut frozen yoghurt.

Fig.4.2.4 represents the mean sensory scores for overall acceptance of coconut frozen yoghurt. 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 aftertaste

The order of superiority for the samples in case of body are as C> I> G> F, H > D, B > A.

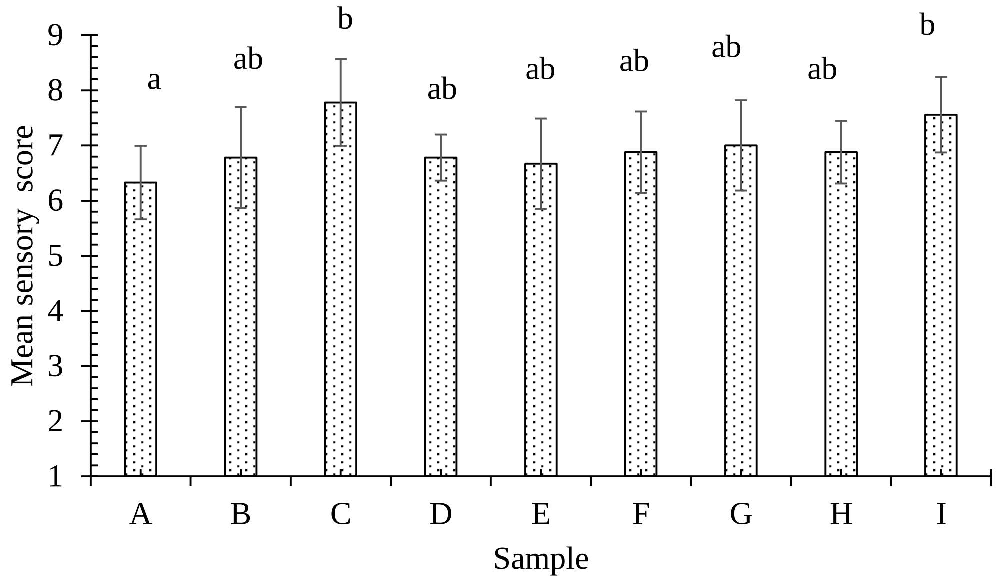


Fig .4.4 Representation of the mean sensory scores for aftertaste of coconut frozen yoghurt.

Fig .4.4 represents the mean sensory scores for aftertaste of coconut frozen yoghurt. 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.

4.3 Effect of different formulation on physical properties of coconut frozen yoghurt

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

4.3.1 Effect of different formulation on overrun and melting rate of frozen yoghurt

The overrun of coconut milk incorporated frozen yoghurt varied from 38.49% to 47.72%. Table 4.4 and 4.5 show the coefficients of model and other statistical attributes of overrun.

The calculated equations for overrun

Overrun = 38.92A+43.74B+14.54AB…… (4.1)

Melting rate = 0.5582A+0.5403B-0.3934AB…… (4.2)

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

In the quadratic equation (4.1), overrun had significant ($P<0.05$) positive effect of linear mixture at 95% confidence level. The interaction term of coconut milk and milk (AB) had also significant ($P<0.05$) positive effect on overrun.

Similarly, the quadratic equation (4.2) shows that of melting rate had not significant ($P<0.05$) positive effect of linear mixture at 95% confidence level. The interaction term of coconut milk and milk (AB) had a significant ($P<0.05$) negative effect on melting rate of frozen yoghurt.

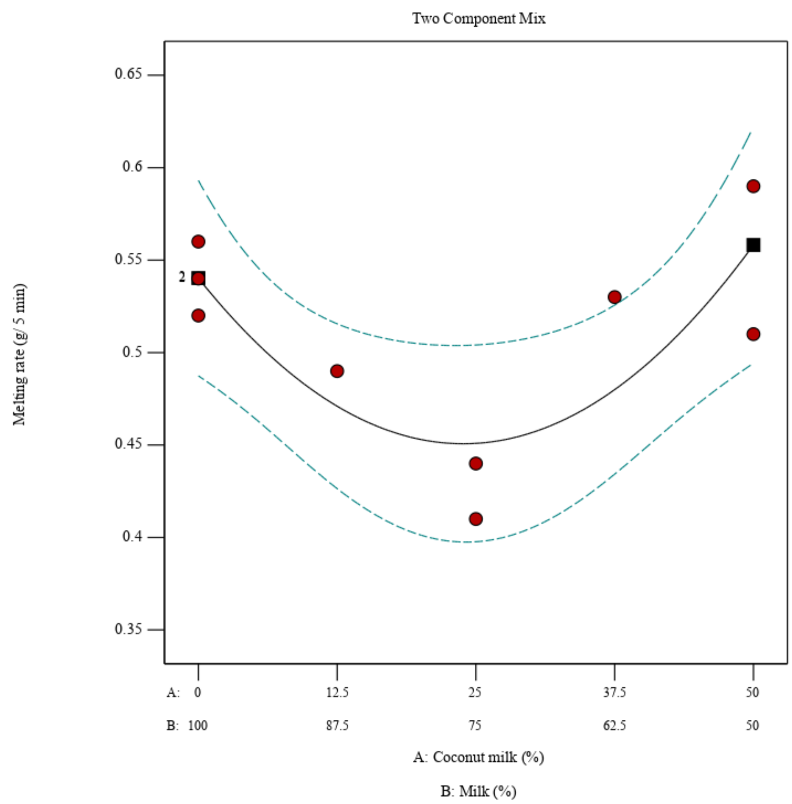


Fig. 4.5 Two component mix graph of melting rate as a function of coconut milk and milk

In above fig. 4.5 melting rate decreased gradually reaching a melting rate of 0.41 g/5 min then increases sharply with increase in both milk and coconut milk In this case, negative effect is desirable since frozen yoghurt with high consistency coefficients have a greater resistance to flow and lower melting rates relate to sustainability of frozen yoghurt's shape.

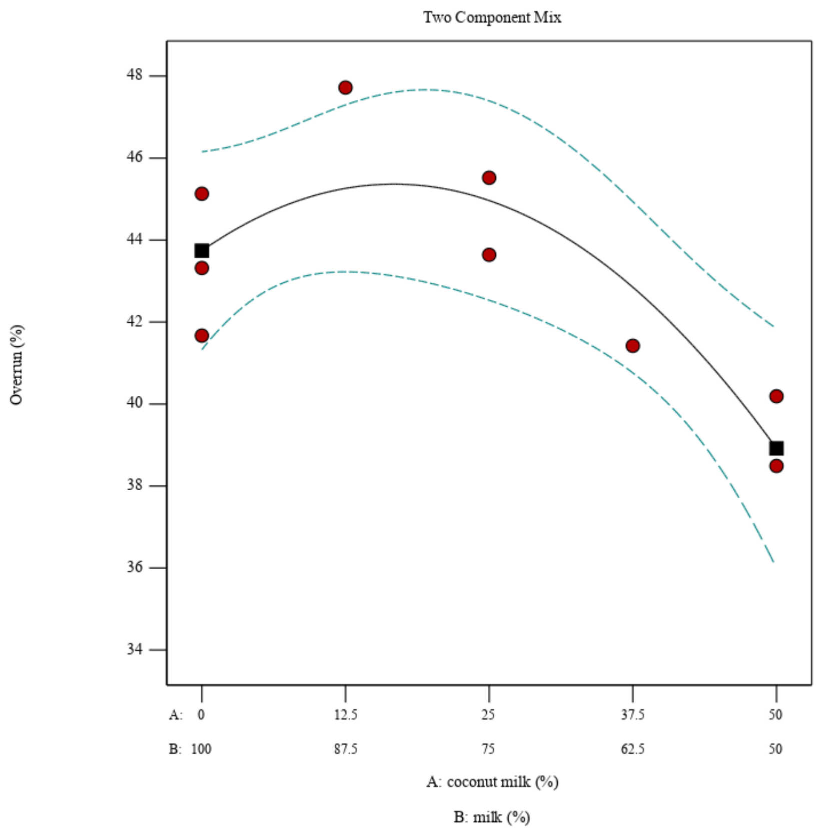


Fig. 4.6 Two component mix of overrun (%) of frozen yoghurt as a function of coconut milk and milk

The above fig. 4.6 shows that the overrun rises gradually at first but later starts to decline with the increase in coconut milk and milk.

4.4 Optimization study

A numerical multi-response optimization technique was applied to determine the optimum combination of coconut milk and milk in coconut milk frozen yoghurt. 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.

Table 4.3 Constraints

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A:coconut milk	is in range	0	50	1	1	3
B:milk	is in range	50	100	1	1	3
Melting rate	minimize	0.41	0.59	1	1	3
Overrun	maximize	38.49	47.72	1	1	3

Under these assumptions by Design expert, the uncoded optimum proportions of milk and solids for coconut milk ice cream preparation were 25% coconut milk and 75% milk. The response predicted by the software for these optimum proportions of constituents were overrun of 44.965% and melting rate of 0.451 g per 5 min.

The optimized sample given by Design expert was sample (20.795% coconut milk, 79.205% milk) and from sensory analysis, sample I (25% coconut milk 75% milk) 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. Proximate analysis of the best coconut milk frozen yoghurt sample (25% coconut milk and 75% milk) is shown in table 4.5

Table 4.4 Proximate analysis of the best coconut milk frozen yoghurt sample

Parameters	Results
Moisture content (%)	61±1.7
Toatal solid (%)	40.27±0.7
Fat (%)	10.45±0.3
Lactose (%)	3.1±0.52
Protein (%)	4.75±0.25

Acidity (%)	0.45±0.15
Ash content (%)	2.9±1.1
Overrun (%)	48.3
Melting rate (g/5 min)	0.49

4.5 Cost evaluation

The total cost associated with the best product was calculated and the cost of coconut milk frozen yoghurt per 100 g was NRs. 17.81 in 2022, 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 frozen yoghurt, 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 frozen yoghurt and to observe the effect of coconut milk and MSNF content on overrun and melting rate of frozen yoghurt. From the research following conclusions were made:

- From sensory analysis, coconut frozen yoghurt with 75% milk and 25% coconut milk was found best.
- From physical analysis, coconut frozen yoghurt with 20.795% coconut milk and 75.205% milk was found to be best respective of overrun and melting rate
- Coconut milk has no significant effect on color and aroma but it had significant effect on taste, aftertaste, overall acceptance and body of frozen yoghurt.
- Coconut milk and milk show significant effect on both overrun and melting rate of frozen yoghurt with 25% coconut milk content and highest milk representing the optimum formulation.
- Production cost of the prepared coconut milk frozen yoghurt 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 frozen yoghurt with not more than 25% 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 frozen yoghurt.
- Other fruit-based frozen yoghurt could be prepared and their quality studied.

Part VI

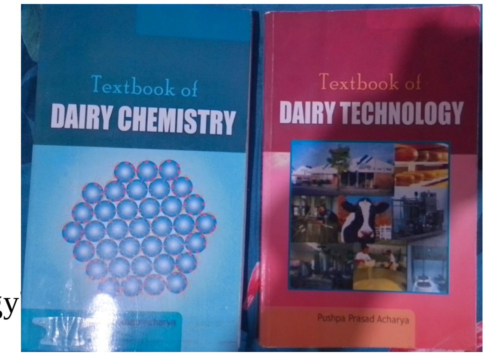
Summary

Coconut milk frozen yoghurt is a frozen product prepared by mixing, pasteurizing, homogenizing, ageing, mixing with yoghurt, freezing and hardening the mix using coconut milk. Frozen yoghurt is a popular dessert, and coconut milk, which is lactose-free and high in nutrients, is an excellent lactose-free and vegan option. As a result, the current study focuses on the customer acceptance of coconut milk frozen yoghurt, as well as its physical and chemical quality.

For raw materials, SMP was acquired from Dairy Development Corporation (DDC), Biratnagar. Coconut, milk, cream, and sugar were purchased at Dharan's local market. Coconut milk was made by crushing the coconut in a 1:1 ratio with water. For experimental combinations, an optimum design was created for two variables (coconut milk and milk). The mixture was made using coconut milk and milk, pasteurized, homogenized, flavored, aged, mixed with yoghurt and frozen in an ice cream freezer according to the recipe.

The prepared coconut frozen yoghurt was analyzed physically, chemically and by sensory analysis. From sensory analysis, the sample with 25% coconut milk and 75% milk was found to be the best. It was found that coconut milk and milk has no effect on aroma and color but had significant effect on taste, body overrun and melting rate of ice cream. The product with 20.795% coconut milk and 79.205% was optimized to have maximum overrun and minimum melting rate. The chemical composition of the best frozen yoghurt was analyzed. Moisture content, total solid, fat, acidity, lactose, protein, ash content, overrun and melting rate of sample I were found to be 61%, 40.27%, 10.45%, 0.45%, 3.1%, 4.75%, 2.9%, 45.52% and 0.41 g/ 5 min, respectively, in wet basis.

According to the findings, coconut frozen yoghurt has the same nutritional value as dairy or plain frozen yoghurt. It was discovered to be slightly yellowish in hue and flavorful like coconut. The texture of coconut frozen yoghurt was found to be slightly firmer, with a larger overrun and a much slower melting rate.



References

Acharya, P. (2006). "A Textbook of Dairy Chemistry and Technology
Science and Technology. Nepal.

Adhikari, B. (2018). Preparation and quality evaluation of coconut milk incorporated yoghurt. B.Tech Thesis. Tribhuwan Uni., Nepal.

Adziezak, J. D. (1988). Emulsifiers: The interfacial key to emulsion stability. *Food Technol.*. **42** (10), 172-186.

Afzal, A., Kilpatrick, S. and Turner, L. R. (2022). Sustainability in the Global Dairy Sector: Challenges and Opportunities. *Sustainability*. **14** (21), 14585. [doi:10.3390/su142114585].

Ahmed, S. K., Haroun, R. and Eisa, M. O. (2010). Banana frozen yoghurt from camel milk. *Pakistan J. Nutr.* **9** (10), 955-956.

Ahuja, J., Montville, J. B., Omolewa-Tomobi, G., Heendeniya, K. Y., Martin, C. L., Steinfeldt, L. C., Anand, J., Adler, M. E., LaComb, R. P. and Moshfegh, A. J. (2012). Food and nutrient database for dietary studies. *Procedia Food Sci.* **2** (ISSN: 2211-601), 99-112. [doi;10.1016/j.profoo.2013.04.016].

Airani, S. (2007). Nutritional quality and value addition to jack fruit seed flour. M. tech Thesis. Univ. Agric. Sci., India.

Alfaro, L., Hayes, D., Boeneke, C., Xu, Z., Bankston, D., Bechtel, P. J. and Sathivel, S. (2015). Physical properties of a frozen yogurt fortified with a nano-emulsion containing purple rice bran oil. *Food Sci. Technol.* **62** (2), 1184-1191. [doi:10.1016/j.lwt.2015.01.055].

Alyaqoubi, S., Abdullah, A., Samudi, M., Abdullah, N., Addai, Z. R. and Musa, K. H. (2015). Study of antioxidant activity and physicochemical properties of coconut milk (Pati santan) in Malaysia. *J. Chemical Pharm. Res.* **7** (4), 967-973.

Arbuckle, W. S. (2013). "Ice cream" (Fourth ed.). Vol. 1. The AVI Publishing Co. Inc. Baltimore, Maryland. [ISBN 978-1-4757-5449-0].

Baer, R. J., Krishnaswamy, N. and Kasperson, K. M. (1999). Effect of emulsifiers and food gum on nonfat ice cream. *J. Dairy Sci.*. **82** (7), 1416-1424. [doi:10.3168/jds.S0022-0302(99)75368-3].

Baer, R. J., Wolkow, M. D. and Kasperson, K. M. (1997). Effect of emulsifiers on the body and texture of low fat ice cream. *J. Dairy Sci.* **80** (12), 3123-3132. [doi:10.3168/jds.S0022-0302(97)76283-0].

Bahramparvar, M. and Mazaheri Tehrani, M. (2011). Application and functions of stabilizers in ice cream. *Food Rev. Int.* **27** (4), 389-407. [doi:10.1080/87559129.2011.563399].

Banzon, J. A. (1990). Coconut Palm and its Fruit. *J. Coconut Stud.* **5** (1), 31-36.

Banzon, J. A., Gonzalez, O. N., De Leon, S. Y. and Sanchez, P. C. (1990). "Coconut as Food". Philippine Coconut Research and Development Found. Philippine. [ISBN 971 9 117 907].

Belewu, M. A. and Belewu, K. Y. (2007). Comparative physico-chemical evaluation of tiger-nut, soybean and coconut milk sources. *Int. J. Agric. Biol.* **5** (785), 787. [doi:1560–8530/2007/09–5–785–787].

Bharti, B. K., Badshah, J. and Beniwal, B. (2021). A review on comparison between bovine milk and plant based coconut milk. *J. Pharm. Innovation*. **10** (3), 374-378. [doi:10.22271].

Boltong, A., Keast, R. and Aranda, S. (2012). Experiences and consequences of altered taste, flavour and food hedonics during chemotherapy treatment. *Supportive Care Cancer*. **20** (11), 2765-2774. [doi: 10.1007/s00520-012-1398-7].

Cancel, L. E. (1979). Coconut food products and bases. *Food Sci. Techno. Res.*, 202-239. [doi:10.3136/fstr.19.729].

Chan, E. and Elevitch, C. R. (2006). Cocos nucifera (coconut). *Species Profiles Pacific Island Agroforestry*. **2** (1), 1-27.

Chandan, R. (1997). "Dairy-based ingredients". Eagan Press St. Paul, Minn., USA. [ISBN 0913250945].

Chandan, R. C. and Shahani, K. M. (1995). "Other Fermented Dairy Products". Vol. 9. Verlagsgesellschaft Germany. [ISBN 35-2-728-3102].

Chhetri, S. (2016). Preparation and quality evaluation of fiber-enriched ice cream. B.Tech Dissertation. Tribhuwan Univ., Nepal.

Clarke, C. (2004). The science of ice cream. *Chemistry Industry*. **24** (19), 38-57. [doi:10.1039/B500979K].

Conforti, F. D. (1994). Effect of fat content and corn sweeteners on selected sensory attributes and shelf stability of vanilla ice cream. *Int J. Dairy Techol.* **47** (2), 69-75. [doi:10.1111/j.1471-0307.1994.tb01275.x].

Desai, S. R., Toro, V. A. and Joshi, S. V. (1994). Utilization of different fruits in the manufacture of yoghurt. *Indian J. Dairy Sci.* **47**, 870-870.

Dissanayaka, T., Gimhani, K. and Champa, W. (2019). Evaluation of Nutritional, Physico-chemical and Sensory Properties of Jackfruit (Artocarpus heterophyllus) Incorporated Frozen Yoghurt. **9** (6), 627-632.

Donkor, O. N., Henriksson, A., Singh, T. K., Vasiljevic, T. and Shah, N. P. (2007). Inhibitory activity of probiotic yoghurt. *Int. Dairy J.* **17** (11), 1321-1331. [doi:10.1016/j.idairyj.2007.02.009].

Dudhrejiya, P. T. (2017). Standarization of technology of frozen yoghurt fortified with moringa. *Int. J. Phytomedicines Related Industries*. **10** (3), 176-184. [doi:10.5958/0975-6892.2018.00029.1].

El-Sayed, H. S., Salama, H. H. and Saad, S. A. (2017). Impact of artichoke puree in frozen yoghurt with encapsulated and free lactic acid bacteria. *J. Food Sci.* **15** (1), 81-94.

Fredrickson, A. G. (1977). Behavior of mixed cultures of microorganisms. *Annu. Rev. Microbiol.* **31** (1), 63-88. [doi:113.199.151.48].

Gandhi, D. N. (2006). "Food and Industrial Microbiology". National Dairy Research Institute Haryana, India. [ISBN 978-1-4615-7476-7].

Goff, H. D. and Hartel, R. W. (2013). "Ice cream". Vol. 2. Springer US. Boston. [ISBN 1461460964].

Guinard, J. X., Little, C., Marty, C. and Palchak, T. R. (1994). Effect of sugar and acid on the acceptability of frozen yogurt to a student population. *J. Dairy Sci.* **77** (5), 1232-1238. [doi:10.3168/jds.S0022-0302(94)77062-4].

Hallfrisch, J. (1990). Metabolic effects of dietary fructose. *J. Federation American Soc. Exp. Biol.* **4** (9), 2652-2660. [doi:10.1096/fasebj.4.9.2189777].

Hartel, R. W., Muse, M. and Sofjan, R. (2004). "Effects of Structural Attributes on Hardness and Melting Rate of Ice cream". International Dairy Federation. Brussels, Belgium. [ISBN 9290980389].

Horwitz, W. (1975). "Official Methods of Analysis" (18 ed.). Vol. 222. Association of Official Analytical Chemists Washington. USA.

Hussein, G. A. and Aumara, I. (2006). Preparation and properties of probiotic frozen yoghurt made with sweet potato and pumpkin. **14** (2), 679-695.

Hyde, K. A. and Rothwell, J. (1973). "Ice cream". Hawksbury Agricltupe. Australia. [ISBN 0443010501].

Innocente, N., Comparin, D. and Corradini, C. (2002). Proteose-peptone whey fraction as emulsifier in ice-cream preparation. *Int. Dairy J.* **12** (1), 69-74. [doi:10.1016/S0958-6946(01)00166-2].

Jana, A., Pinto, S. and Moorthy, P. R. S. (2016). "Ice cream and Frozen Desserts". Agrimoon. Tirupati.

Jayasundera, M. and Fernando, K. (2014). Development and quality evaluation of coconut milk based soft ice cream [Abstract]. Ann. Food Sci. Tech. **15**, 227-230. Retrieved from https://web.p.ebscohost.com/abstracts/. [Accessed 13 May].

Kavaz Yuksel, A. (2015). The Effects of Blackthorn (P runus Spinosa L.) Addition on Certain Quality Characteristics of Ice Cream. *J. of Food Qual.* **38** (6), 413-421. [doi:10.1111/jfq.12170].

KC, J. B. and Rai, B. K. (2007). "Basic Food Analysis Handbook" (1st ed.). Prompt Printers Pvt Ltd. Kathmandu, Nepal.

Kirby, R. H. (1963). "Vegetable Fibres, Botany, Cultivation and Utilization". World Crops Books. New York.

Koeferli, C. R. S., Piccinali, P. and Sigrist, S. (1996). The influence of fat, sugar and non-fat milk solids on selected taste, flavor and texture parameters of a vanilla ice-cream. *Food Qual. Preference*. **7** (2), 69-79. doi:10.1016/0950-3293(95)00038-0].

Kofi Tulashie, S., Amenakpor, J., Atisey, S., Odai, R. and Amoah Akpari, E. E. (2022). Production of coconut milk: A sustainable alternative plant-based milk,. *Case Studies Chemical Environmen. Eng.* **6**. [doi:10.1016/j.cscee.2022.100206].

Krishna, A. G. G., Gaurav, R., Singh, B. A., Kumar, P. K. P. and Preeti, C. (2010). Coconut oil: chemistry, production and its applications [Abstract]. Coconut Development Board. **53**, 15-27. Retrieved from http://www.coconutboard.nic.in. [Accessed 18 August, 2023].

Lee, F. Y. and White, C. H. (1991). Effect of ultrafiltration retentates and whey protein concentrates on ice cream quality during storage. *J. Dairy Sci.* **74** (4), 1170-1180. [doi:10.3168/jds.S0022-0302(91)78270-2].

Lin, F. M. and Wilkens, W. F. (1970). Volatile flavor components of coconut meat. *J. Food Sci.* **35** (5), 538-539. [doi:10.1111/j.1365-2621.1970.tb04802.x].

Ludvigsen, H. K. (2011). Manufacturing High Quality Ice Cream With High Overrun. Palsgaard Technical Paper. *Food Market Techno.* **1**, 4-7.

Marshall, R. T., Goff, H. D. and Hartel, R. W. (2003). "Ice cream" (6 ed.). Plenum Publiser. New York. [0306477009].

Milani, E. and Koocheki, A. (2011). The effects of date syrup and guar gum on physical, rheological and sensory properties of low fat frozen yoghurt dessert. *Int. J. Dairy Technol.* **64** (1), 121-129. [doi:10.1111/j.1471-0307.2010.00631.x].

Moeenfard, M. and Tehrani, M. M. (2008). Effect of some stabilizers on the physicochemical and sensory properties of ice cream type frozen yogurt. *J. Agric. Environ. Sci*. **4** (5), 584-589.

Mohammed, M. E. A., Alsakti, A., Showeal, A., Alasidi, A., Ibrahim, A., Alshehri, A. M., Ghrmah, H. A. and Brima, E. I. (2020). Investigation of altitude effect on some physiochemical properties of milk samples obtained from camels and small ruminants. *J. Prac. Res.* **27** (1), 49-54. [doi:10.5958/2277-8934.2020.00007.7].

Muse, M. R. and Hartel, R. W. (2004). Ice cream structural elements that affect melting rate and hardness. *J. Dairy Sci.* **87** (1), 1-10. [doi:10.3168/jds.S0022-0302(04)73135-5].

Nagpal, R., Behare, P., Kumar, M., Mohania, D., Yadav, M., Jain, S., Menon, S., Parkash, O., Marotta, F. and Minelli, E. (2012). Milk, milk products, and disease free health: an updated overview. *Food Sci. Technol. J.* **52** (4), 321-333. [doi:10.1080/10408398.2010.500231].

Nawal Galal, K. B., Osman, M. and Abbas, F. (2019). Functional Low-Fat Frozen Yoghurt with Carrot (Dascus carota L.) Puree. **6** (1), 19-34.

Nieuwentus, R. and Nieuwelink, J. (2002). Promotion of coconut in the production of yoghurt. *J. Food Sci.* **3** (5), 147-149.

North, C. E. and Park, W. H. (1927). Standards for Milk Pasteurization. *American Journal of Hygiene*. **7**, 147-173.

Ohmes, R. L., Marshall, R. T. and Heymann, H. (1998). Sensory and physical properties of ice creams containing milk fat or fat replacers. *J. Dairy Sci.* **81** (5), 1222-1228. [doi:10.3168/jds.S0022-0302(98)75682-6].

Ozdemir, C., Dagdemir, E., Celik, S. and Ozdemir, S. (2003). An alternative ice cream production for diabetic patients. *Milchwissenschaft-Milk Sci. Int.* **58**, 164-166.

Pangan, J. T., Rosida, S. U. and Widiyanto, S. (2015). Physical quality of cconut milk powder using lecithin emulsifier and dextrin filler). *J. Food Technol.* **7** (2).

Patil, U. and Benjakul, S. (2017). Characteristics of albumin and globulin from coconut meat and their role in emulsion stability without and with proteolysis. *J. Food sci.* **69**, 220-228. [doi:10.1111/1750-3841.14223].

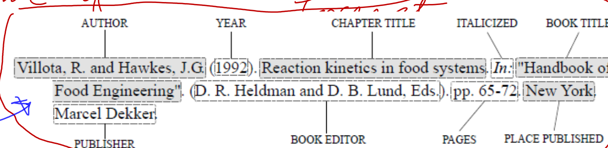
Patil, U. B. S. (2018). Coconut milk and coconut oil: their manufacture associated with protein functionality. *J. Food Sci.* **83** (8), 2019-2027. [doi:10.1111/1750-3841.14223].

Pearson, D., Kirl, R. and Sawyer, R. (1981). Pearson's Chemical Analysis of Foods Churchill Livingstone.

Perera, K. D. S. S. and Perera, O. D. A. N. (2021). Development of Coconut Milk-Based Spicy Ice Cream as a Nondairy Alternative with Desired Physicochemical and Sensory Attributes. *Int. of J. Food Sci.* **2021**. [doi:10.1155/2021/6661193].

Perera, L., Perera, S. A. C. N., Bandaranayake, C. K. and Harries, H. C. (2009). Coconut. *In:* "Oil crops".). pp. 369-396. Springer.

Pon, S. Y., Lee, W. J. and Chong, G. H. (2015). Textural cream. *Int. Food Res. J.* **22** (4).



Pratap, Y. S. M., Chandra, R., Shukla, S. and Ali, M. N. (2016a). Optimization of the chemical properties of frozen yoghurt supplemented with different fruit pulp. **4** (2, Part B).

Pratap, Y. S. M., Chandra, R., Shukla, S. and Ali, M. N. (2016b). Optimization of the chemical properties of frozen yoghurt supplemented with different fruit pulp. *Pharma J.* **4** (2, Part B).

Prindiville, E. A., Marshall, R. T. and Heymann, H. (1999). Effect of milk fat on the sensory properties of chocolate ice cream. *J. Dairy Sci.* **82** (7), 1425-1432. [doi:10.3168/jds.S0022-0302(99)75369-5].

Qamar Abbas Syed, S. A. R. S. T. Z. (2018). Effects of different ingredients on texture of ice cream. *J. Nutr. Health Food Eng.* **8** (6), 422-435. [doi:10.15406/jnhfe.2018.08.00305].

Ranganna, S. (1986). "Handbook of analysis and quality control for fruit and vegetable products". Tata McGraw-Hill Education. [ISBN 0074518518].

Rezaei, R., Khomeiri, M., Kashaninejad, M. and Aalami, M. (2011). Effects of guar gum and arabic gum on the physicochemical, sensory and flow behaviour characteristics of frozen yoghurt. *Int. J. Dairy Technol.* **64** (4), 563-568. [doi:10.1111/j.1471-0307.2011.00705.x].

Rybka, S. and Kailasapathy, K. (1995). The survival of culture bacteria in fresh and freeze-dried yoghurts. *J. Dairy Technol.* **50** (2), 51.

Sakurai, K. (1996). Effect of production conditions on ice cream melting resistance and hardness. **51**, 451-454.

Sanful, R. E. (2009). Promotion of coconut in the production of yoghurt. *Afri. J. Food Sci.* **3** (5), 147-149.

Seow, C. C. and Gwee, C. N. (1997). Coconut milk: chemistry and technology. *Int. J. Food Sci. Technol.* **32** (3), 189-201. [doi:10.1046/j.1365-2621.1997.00400.x].

Shukla, F. C., Jain, S. C. and Sandhu, K. S. (1987). Technological and physico-chemical aspects of yoghurt and fruit yoghurt. *Indian J. Dairy Sci.* (12), 90.

Siriphanich, J., Saradhuldhat, P., Romphophak, T., Krisanapook, K., Pathaveerat, S. and Tongchitpakdee, S. (2011). Coconut (Cocos nucifera L). *In:* "Postharvest biology and technology of tropical and subtropical Fruits"(.). pp. 8-35e. Elsevier.

Sofjan, R. P. and Hartel, R. W. (2004). Effects of overrun on structural and physical characteristics of ice cream. *Int. Dairy J.* **14** (3), 255-262. [doi:10.1016/j.idairyj.2003.08.005].

Sommer, H. H. (1946). "The Theory and Practice of Ice Cream Making". The author.

Soukoulis, C. and Tzia, C. (2008). Impact of the acidification process, hydrocolloids and protein fortifiers on the physical and sensory properties of frozen yogurt. *Int. J. Dairy Technol.* **61** (2), 170-177. [doi:10.1111/j.1471-0307.2008.00385.x].

Tamime, A. Y. and Robinson, R. K. (1999). "Yoghurt: science and technology". Woodhead Publishing. [1855733994].

Tamime, A. Y. and Robinson, R. K. (2007). "Tamime and Robinson's yoghurt: science and technology" (Third ed.). Woodhead Publishing Limited. England. [ISBN 1845692616].

Tansakul, A. and Chaisawang, P. (2006). Thermophysical properties of coconut milk. *J. Food Eng.* **73** (3), 276-280. [doi:10.1016/j.jfoodeng.2005.01.035].

Thampan, P. K. (1981). "Handbook on coconut palm". Oxford and IBH Publishing Co. New Dehli.

Tribby, D. (2008). Yogurt. *In:* "The sensory evaluation of dairy products"(.). pp. 191-223. Springer.

Tur, J. and Bibiloni, M. (2016). Encyclopedia of food and health: Elsevier Amsterdam, The Netherlands:.

Van Dam, J. E. G., van den Oever, M. J. A., Teunissen, W., Keijsers, E. R. P. and Peralta, A. G. (2004). Process for production of high density/high performance binderless boards from whole coconut husk *Ind. crops and prod.* **19** (3), 207-216.

Walstra, P., Wouters, J. T. M. and Geurts, T. J. (2005). "Dairy Sci. Technol." (2nd ed.). CRC press. New York. [ISBN 978-1-4665-4891-6].

Appendices

Appendix A

Sensory evaluation score sheet for frozen yoghurt Date:

Hedonic rating test

Name of the panelist: ………………………………….

Name of the product: Frozen yoghurt

Please test the following samples of frozen yoghurt 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	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Attributes									
Aroma									
Taste									
Aftertaste									
Body									
Color									
Overall									

Comments……………………………………………………………………………………….

Signature…………………….

Appendix B

Cost calculation of the product

Ingredients	Quantity	Rate NRs	Quantity Used	Rate NRs
Milk	1000ml	80	62.018	4.96
Coconut	1	60	20.15	4.83
SMP	1000gm	650	2.4	1.56
Butter	1000gm	800	1.39	1.11
Sugar	1000gm	100	1.46	0.146
Emulsifier and Stabilizer	100gm	50	0.33	0.165
Overhead Cost	40%			5.1
Total Costing				17.871per 100gm

Appendix C

Run	Factor 1 A:Coconut Milk %	Factor 2 B:Milk %	Response 1 Melting Rate g/5 min	Response 2 Overrun %
1	12.5	87.5	0.49	41.72
2	0	100	0.56	41.67
3	25	75	0.44	43.64
4	0	100	0.54	43.32
5	50	50	0.51	40.19
6	0	100	0.52	45.13
7	50	50	0.59	38.49
8	37.5	62.5	0.53	41.42
9	25	75	0.41	45.52

Appendix D

ANOVA for physical analysis of samples

Analysis of variance

Table D.1 One-way ANOVA (No blocking) For Taste

Analysis of variance

Variate: Taste

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	8	26.1728	3.2716	6.42	<.001
Residual	72	36.6667	0.5093		
Total	80	62.8395			

Table D.2 One-way ANOVA (No blocking) For Body &Texture

Analysis of variance

Variate: Body andTexture

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	8	23.9506	2.9938	4.85	<.001
Residual	72	44.4444	0.6173		
Total	80	68.3951			

Table D.3 One-way ANOVA (No blocking) For Overall acceptability

Analysis of variance

Variate:Overall acceptibility

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	8	25.7778	3.2222	6.48	<.001
Residual	72	35.7778	0.4969		
Total	80	61.5556			

Table D.4 One -way ANOVA (No blocking) for aftertaste

Analysis of variance

Variate: Aftertaste

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	8	14.2222	1.7778	3.60	0.006
Residual	72	42.6667	0.5926		
Total	80	56.8889			

Appendix E

Summary of ANOVA of sensory of coconut milk frozen yoghurt

Sample	Body	Taste	Aftertaste	Overall
A	6.2±0.91	6.4±0.49	6.3±0.67	6.1±0.57
B	6.4±0.96	6.5±0.83	6.7±0.91	7±0.47
C	7.7±0.63	8.1±0.57	7.7±0.79	7.8±0.73
D	6.5±0.83	7.1±0.74	6.7±0.41	6.7±0.79
E	6.7±0.79	7.3±0.47	6.6±0.82	7±0.67
F	6.7±0.07	7±0.01	6.8±0.74	7±0.67
G	7.1±0.31	6.7±0.79	7±0.82	6.7±0.92
H	6.6±0.67	7.3±0.47	6.8±0.57	7±0
I	7.8±0.57	8.1±0.74	7.5±0.68	8.1±0.73
LSD (5%)				