Development of egg replacing gel type cake additive

By

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DECLARATION

The work describe in this thesis was carried out by me at the Department of Food Science and Technology, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka, under the supervision of Mr. M.C.N Jayasuriya and Mr.Hemantha Siyambalagoda. The report on this has not been submitted to another university for another degree.

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Affectionately Dedicated

to My Parents

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ABSTRACT

Large scale cake manufacturing process, adding of egg is a difficult and time consuming operation. It required more labored, additional equipments, will be a risk due to the law availability during the festival season. There fore study was conducted to develop a 50% egg replacing gel type cake additive.

A marketing survey was conducted using randomly selected thirty bakeries to identify future demand, by improving texture of cake egg replacing agent. Product development was carried out using food emulsifiers such as Glycerol Monostearate, combination of Glycerol Monostearate/ Sodium Stearoyl Lactylate and combination of Distilled Monoglyceride (E471) /Polyglycerol ester (E475). Sorbitol and Propylene Glycol ratio was changed to maintain the gel state. Experiment was design to identify the minimum amount of product that can replace 50% of eggs in a Madeira cake recipe using sugar batter method and to identify the water amount to give maximum volume.

50% egg replace cake was compared with a normal cake using physical measurement (height, weight) and observed crumb structure. Sensory test were conduct using thirty untrained panelist. Data was analyzed using Mann Whitney nonparametric MINITAB software statistical package. Total cost reduction was calculated using present market prices with Excel office package.

There is an 87% of future market demand for the cake egg replacing agent by considering the cost and shelf life of the product.38% local bakeries accept gel type texture and same percentage accept any type of texture.

Mixture (temperature 90^0C) of 14g distilled monoglyceride (more than 90% monoglyceride content). 11g of Polyglycerol ester and 34.7 ml of water are formed transparent gel structure at room temperature. Combination of Sorbitol and Propylene Glycol 30g and 10g respectively improve the above formed gel structure.5% of the developed gel type egg replacing cake additive can replace 50% egg of a Madeira cake (100g flour weight) and 8% of water maintain the maximum ($546cm^3$)volume. Texture, taste, color, moistness and odour of 50% egg replaced cake are not significantly different to a normal Madeira cake and egg replacing cake additive reduces 23.25% of total egg cost (per kg of baked cake).

CONTENT

ABBREVATIONS

C^0	Centigrade
Cm	Centimeter
Cm3	Cubic centimeter
CMC	Caboxy Methy Cellulose
DGMS	Distilled Monoglyceride
g	gram
GMS	Glycerol Monostearate
HLB	Hydrophilis Lipophilic Balance
IUPAC	International Union of Pure and Applied Chemistry
JECFA	Joint Expert Committee of Food Additives
Kg	kilogram
KJ	kilojoules
min	Minutes
ml	Millie Litter
PG	Propylene Glycol
PGE	Polyglycerol ester
Rs	Sri Lankan Rupees
SSL	Sodium Stearoyl Lactylate
SLSI	Sri Lanka Standard Institute

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CHAPTER 01
INTRODUCTION

1.1 Introduction

Cake is a sweet baked food made of flour, butter, eggs, and other ingredients, such as raising agents and flavorings (Stauffer, 1990). When the manufacturing of cakes, emulsions, foams and gel states are formed. The exact quantities of essential ingredients, optimum baking and mixing condition will enhance the qualities of cake such as color, shine, flavor, moist texture and evenly distributed minute cell in the product.

Chicken egg is the most important traditional raw ingredients use in manufacturing of cake. It is given natural whipping and emulsifier qualities to the cake mixture. The whipping emulsifier is important to produce a stable and light batter with a good stability (before and during baking) and given a pleasant and uniform crumb structure.

When consider the large scale cake manufacturing process, adding of egg (one by one) is a difficult and time consuming operation, required more labored, additional equipments and law availability during the festival season and it will being high cost effective.

Chemical composition of the egg york is more complex than that of the whites. The york contain fully 30% of fats (Bennion et al., 1966) which can be a impact for the health of the people. Specially egg yolk is not recommended for the people who are suffering from Cardio vascular desease and also vegitarian are refused the tasting of cakes due to adding of cakes.

There are some defects can be identified which give unsatisfactory charactors to the cake, including volume reducing, crumbliness, mold growth, drying out at long time storage and low shelf life.

To meet growing variations in demand and increasingly specific requirements created by the changing life styles of consumes, the food industry needs to display a huge capacity for innovations (Linden and Lorient, 1999) with continuous improvements.

Continuously updating knowledge in cake technology has engaged with new innovations and that makes the diversity and competition in the market.

1.2 Objective

Overall objective: -

Development of gel type cake additive to replace 50% egg in a cake recipe

Specific objective:-

1. Reduce the number of eggs apply to a cake recipe
2. Reduce the fat level of the cake recipe
3. Reduce time required for whipping
4. Improve the shelf life of the cake
5. Reduce the total cost for make cake

CHAPTER 02

REVIEW OF LITERATURE

2.1Cakes

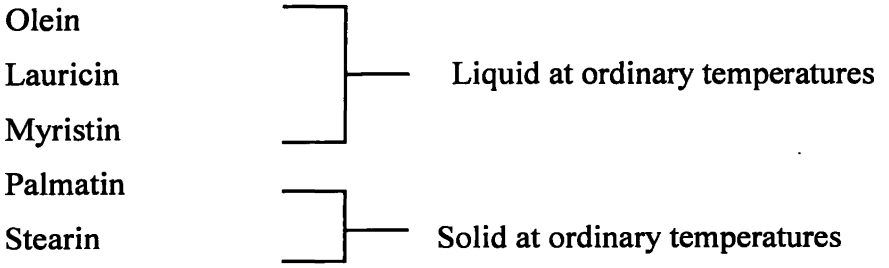
2.1.1 Introduction

Cake is a product obtained from a batter containing essentially wheat flour, sugar eggs and other ingredients of requisite mass put in to trays and baked in an oven with combination of suitable temperature and time. Each raw material play an important functional role form the cake structure and eating qualities.

2.1.2 Basic raw materials

2.1.2.1 Baking fat

Fat consist of carbon, hydrogen, and oxygen. Fat are complex mixture of glycerides some which are liquid and some solid at room temperature.



Firmness of a fat depends on the proportion of stearin presents as it is a waxy substance. Butter, Margarine, and neutral fats are mixture of these five glycerides in varying proportion.

Functions of fat

i. Nutritional value- Provide energy and essential fatty acids.
ii. To provide flavor to the cake.
iii. Influence the keeping qualities (fat by its emulsifying action hold the aqueous portion of a cake batter and so prevents the cake from drying out to a certain degree).
iv. Emulsifying properties (The emulsifying powers of fat determine how much liquid can be incorporated in s batter without curdling taking place).

v. Shortening power (Gluten in the flour is split up by films of fat. These films of fat weaken the structure sufficiently to make it tender and easily disintegrated by bringing a mechanical breakdown of the gluten structure) (Bennion et al, 1966).

vi. Cake volume- In mixing fat entraps a lot of air and the air is well dispersed through the batter, raising take place uniformly through out the mixture, giving fine, uniform grain structure).

2.1.2.2Cake flour

Generally made from

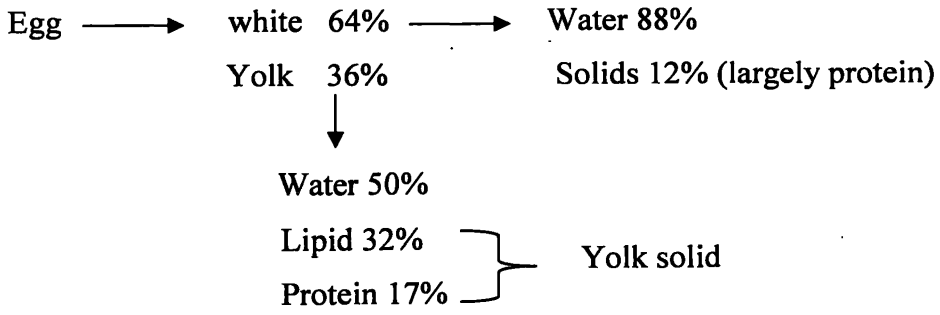
- Wheat with a lower protein level (about 9%)
- Starch
- Lipids (about 2%)
- Moisture content no more than 14%

Properties important for cake

- Water absorption properties of the starch.
- Degree of gelatinization in baking.
- Alpha amylase activity of the wheat must be in a low value (If not starch will degraded during baking and result a poor structure and a sticky structure).
- Low grist color (white flour).

Main function- To obtain satisfactory texture and appearance

2.1.2.3 Egg



Major protein classes of egg white

- Ovalbumin 54%
- Conalbumin 12%
- Ovomucoid 11%
- Lysozyme 3.5%
- Ovomucin 1.5% } stabilize the form
- Globulin fraction 8% }

Major protein classes of egg yolk solid

- Low density lipoprotein 66% → Protien 11%, Phospholipids 23% Triglyceride 63%, Cholesterol 3%
- High density lipoprotein 23%
- Livetin 11%

↓

Phosvitin 16%, Lipovitellin 70%, LDL 12%

Egg Yolk is considered to perform both emulsifying and aerating roles in the cake making (Friberg, 1976).

2.1.2.4 Baking powder

Baking powders are composed of,

- Sodium bicarbonate
- Acid
- Salt
- Starch – keep ingredient dry, prevent caking
- Small amount of egg white as drying agent

Main function

$NaHCO_3$ react with the hydrogen ions in the wet batter and release carbon dioxide (Meyer, 1987).

$$NaHCO_{3\,(S)} + H^+_{(aq)} \longrightarrow Na^+_{(aq)} + H_2O_{(l)} + CO_{2\,(g)}$$

2.1.2.5 Sugar

Sugar consist around 99% sucrose and there are two groups of carbohydrates used as sweetening agent in confectionary

i. The sucrose or Disaccharides ($C_{12}H_{22}O_{11}$).
ii. The simple sugars or Monosaccharides ($C_6H_{12}O_{22}$).

Functions related to cake making

- Sweetening effect.
- Control the degree of gelatinization of starch.
- Control heat setting temperature of egg proteins.
- Important for the shelf life of the baked cake – the high osmotic pressure of the sugar in solution in baked good leaves the equilibrium relative humidity and is a major factor in suppressing microbial spoilage (Friberg, 1976).

2.1.2.6 Vanilla Essence

Vanilla is the most widely used flavor for baking proposes. Its main component is vanillin. Minor components are resins, sugar, gum, organic acid, tannin, and cellulose. Its flavor is sharply acidic with slightly bitter back note.

2.1.3 Basic cake recipes

There are three basic types of cake recipes

i. Madeira cake - Consist of equal proportions of fat, sugar, egg and flour.
ii. High ratio yellow cake – sugar and egg are each in excess of flour weight.
iii. Sponge cake – low or no fat.

2.1.3.1 Madeira Cake

The traditional Madeira cake consists of equal proportions of fat, sugar, egg and flour. The sugar is beaten in to fat to form an aerated cream before blending in the first egg and then flour (Friberg, 1976).Modern commercial recipes are likely to cut back on the fat and egg ingredients. There are number of different ways of blending the ingredients, depending not only on the order of addition but whether batch or continuous, normal speed or high speed mixtures used (Friberg, 1976).

2.1.4 Basic cake mixing methods

i. Sugar batter method.
ii. Flour batter method.
iii. Blending method.
iv. Boiled method.
v. Sugar water method.
vi. All in process (Wheat associates USA, 1988).

2.1.4.1 Sugar batter method

In this method, all the fat and equal amount of sugar is creamed to gather. Sugar is added gradually continuing the creaming process. All the sugar should never be added to the fat at a time as it will adversely affect the aeration process and it may take extra time to achieve desired results. When adequate aeration is achieved, the mixture becomes very light and brighter in appearance (Wheat associates USA, 1988).

When adequate aeration is achieved in the fat sugar mixture, eggs are adding gradually. Eggs should be at room temperature at the time of adding to the cream.

When whipped eggs are added to the creamed mixture little at a time and mixed gently, the air cells of whipped eggs diffuse into the air cells already present in the cream and the liquid part of egg is evenly distributed in the mixture giving it a smooth velvety appearance. If too cold eggs are used, the fat will break down into small globules which will be coated with egg. This brake down of fat into small fragments separated by egg is known as curdling of batter (Wheat associates USA, 1988).

When all the egg is amalgamated, the mixture should have a smooth light and velvety appearance (Wheat associates USA, 1988).Next stage is to incorporate flour in the mixture. Flour should be sifted trice with baking powder in order to ensure a thorough blending. Incorporation of flour in the cream is an important stage in the cake making and even slight mishandling of the mixture will spoil the cake. This operation should be carried out in a fashion that the flour is evenly mixed with a minimum possible mixing operation (Wheat associates USA, 1988).

2.1.5- Mechanism of cake baking

Mechanism behind the cake baking can be divided in to mainly three stages.

- Stage 1- early part of baking
- Stage 2- Intermediate baking stage
- Stage 3- structure development

Stage 1

In the early stages of baking the batter, there is little apparent change. At 37-40C^0 fat in the batter melt and three things happen.

i. The irregular shaped fat particles roll up in to spherical droplets
ii. Any water in oil emulsion portions of the batter invert to oil in water emulsion
iii. Air bubbles are released from the fat phase to the aqueous phase.

Stage 2

- Final melting of the fat taking place
- Form is stabilized by egg protein molecules at the air water interface
- Flour particles are still suspended in continues aqueous phase.
- The air bubbles incorporated in the batter preparation step act as nuclei for the expansion of the total batter by the movement of water vapor and CO_2 in to the air cells

Stage 3

Total structure development take place at this stage.

- Partial gelatinization of the flour
- Coagulation of egg protein

2.1.6 Quality of a cake

Basic quality parameters of a cake are appearance, color, aroma, texture, moistness, tenderness and flavor and general eating quality. Appearance is sometimes divided in to general appearance including smoothness, grassiness, as well as general contours such as humped, sunk, flat etc. and into another evaluation for the volume of the product such as too large, good, too small. Occasionally odor and flavor may be

combined since they are so intertwined and often reflect the same quality (Meyer, 1987). Texture refers to the grain, the thickness or thinness of the cell walls, the size of the gas bubbles (Meyer, 1987). Tenderness can be includes as a measurement.

2.1.6.1 Effect of the pH

The effect of the pH on the cake quality has been studied and the affect on the texture observed, but there's no direct study of the influence of pH on gas retention. The texture of a cake changes with change in pH, tending to be finer and more compact at lower pH while it becomes coarser on the alkaline side (Meyer, 1987).It happened due to the changes of the characteristics of proteins with change in the pH.

In general flavor and overall quality score for a cakes is better when pH is lower. The length of time for the development of staling is like wise prolonged with lower pH.

2.1.6.2 Moisture

The amount of the moisture in a cake and the manner of its distribution are doubtless factors important to the quality of a batter product. The feeling in the mouth of moistness or of the dryness added a great contribution to the enjoyment of eating (Mayer 1987). Moisture is held in a batter as the solvent for some compounds, particularly sugar, and as a hydrate of protein and starch. During baking, protein are denatured and the amount of water held in the molecule changes. The denatured protein still can hold the water through the hydrogen bonding. Starch swells and gelatinized. The granule swell, water passes in to the molecules, and is held there (Meyer, 1987).

2.2 Introduction to food emulsifiers

2.2.1 History

Development of science and Technology of food emulsifiers were introduced around the first half of the 20th century. After 15 to 20 years latter the production of food emulsifiers were established as an industry. However increasing industrialization of the manufacturing of food has being enhance the demand for food emulsifiers, use of new automatic and more rational manufacturing processes, and partly due to the development of new types of food products. Consequently the need for emulsifiers

can either be to facilitate greater production capacity or to modify the texture, rheological properties, or the shelf life of the finished product according to the consumer desires (Friberg, 1976)

2.2.2 Emulsifier and emulsification

Oil and water are immiscible since the interaction results in high energy at the common surface. Though the physical action of mixing one can break up the oil into fine droplets which may be dispersed/ distributed into the water phase. This result is an unstable system and when the physical mixing action is stopped the oil droplets will coalesce and the oil and water will again separate into two different layers. To prevent such coalescing of oil droplets and subsequent layer separation, certain chemical may be used which are known as emulsifiers.

Emulsifiers are made up of molecules that have a non-polar end, which carries no charge and has an affinity for oil and a polar end which carries a charge and has an affinity for water. Such a molecule can situate itself at the interface between oil and water. The polar end will immerse itself in the aqueous phase and the non-polar end will immerse itself in the lipid phase. An emulsifier has a surface energy that results in the prevention of he coalesce of the oil droplets. This helps the phases to stay intimately mixed and form an emulsion.

2.2.2.1 Origin The types of food emulsifiers dealt with esters of edible fatty acids from animal or vegetable origin and polyvalent alcohols such as glycerol, propylene glycol, sorbitol, sucrose etc. (Friberg, 1976).

2.1.2.2 Amphiphilic nature Emulsifiers belong to a class of materials which are characterized by having an amphiphilic nature, which means that they possess both hydrophilic and lipophilic properties (Friberg, 1976).

2.2.3 The HLB Concept for Emulsion Formation

2.2.3.1 Introduction

The HLB concept gives information about the solubility of the emulsifier in either the oil or the water phase and it may be used as a guide for predicting which types of emulsion will be formed (Friberg, 1976).

The HLB represent the "Hydrophilic Lipophilic Balance". The scale as it was originally proposed range from 0 to 20, the law end signifying an emulsifier that much more stable in oil than in water, and the high end meaning the reverse. (Stauffer, 1990) The lowest HLB values arbitrarily characterized the least hydrophilic emulsifying agents, and an increase of HLB value indicated increasing polarity of the emulsifier molecule (Wan 1990).

2.2.3.2 HLB value for a single emulsifier

The following equation may be used for calculating the HLB value.

$HLB = 20 \{1 - (S/A)\}$

Where S = Saponification value of the ester

A = Acid value of the fatty acid

Emulsifier with an HLB value in the range of 3 to 6 will promote W/O type emulsion. O/W type emulsions are formed with emulsifier having HLB values between 8 to 18. Emulsifiers with HLB value below 9 are lipophilic and those with values from 11 to 20 only be used for a homogeneous series of esters of polyvalent alcohols and fatty acid like Monoglyceridis, Polyglycerol esters, Sorbitan esers and other nono-ionic are hydrophilic and those with value between 8 to 11 are intermediate. The method can emulsifying agent (Ranganna and Prabhu, 1988).

In a practical system that includes other ingredients such as sugar, salt , protein, and other typical food components, the number for this optimum might shift and a series of tests would be necessary to determine the exact blend of emulsifiers that would be give with the best results.(Stauffer, 1990).

The calculation of the HLB value is based on the molecular formula of the emulsifier. This causes some problems regarding the use of HLB calculated in this way since

industrially produced emulsifying agents are never completely pure.(Friberg, 1976) Theoretically calculated HLB value are shown in table 2.1

Table 2.1 HLB values of some food emulsifiers (Freiberg, 1976)

Type of emulsifying agent	HLB value
Propylene Glycol Monolaurate	8.5
Propylene Glycol Monostearate	1.8
Glecerol Monostearate	3.7
Diglecerol Monostearate	5.5
Sodium Stearoly Lactylate	21.0
Sorbitan Monostearate	5.7

2.2.3.3 HLB value for blend of emulsifiers

HLB value of a blend of two emulsifiers is equal to their algebraic sum, that is the weight fraction of a times its HLB plus the weight fraction of B times its HLB value (Stauffer, 1990).It was pointed out that O/W emulsions prepared with blends of emulsifiers are more stable than emulsions prepared with a single emulsifier providing the HLB value maintained. Boyd et al. concluded that the use of theoretically calculated HLB values may leads to incorrect results, especially when blends of emulsifiers are used, due to the fact that such blends may undergo molecular association at the oil-water interface. In such cases, the momorphic behavior of the emulsifier-water mixture should be considered, and than is a subject of a further investigation (Friberg, 1976).

2.2.4 Function of food emulsifiers

Functions of food emulsifiers can be divided into three main steps

i. Reduction of surface tension at oil-water interfaces.
ii. Interaction with the starch and protein components in foods which modify texture and rheological properties.
iii. Modification of the crystallization of fats and oil.

2.2.5 Selection of the best emulsifier

The selection of the proper type of emulsifier for a given food product is normally based on experience and pilot plant tests by trial and error. A thorough understanding of the physical- chemical properties of emulsifiers will help to make the correct choice and cut down expensive tests (Friberg, 1976).

2.3 Cake Batter Emulsification

2.3.1 Aeration of a cake batter

A cake batter is a complex aerated emulsion of a shortening in an aqueous phase. Therefore cake batter is oil in water type emulsion. In high fat batters, the emulsion is aerated by the inclusion of air into the fat phase which in turn is dispersed the water phase. In low or no fat batters like sponge cakes the air is incorporated directly in to the aqueous phase at the mixing stage. The ideal aeration depends on both the number and size of the air bubbles in the form. Proper aeration has to be accompanied by a system to stabilize the air bubbles (American society of baking meeting, 2001).

2.3.2 Application of emulsifiers in cakes

2.3.2.1 Introduction

There are several researches behind the application of emulsifiers in cake. Monoglycerides or Distilled Monoglycerides represent by far most widely used group of emulsifiers in the cake and related products (Blanshard et al, 1985). It has an ability to improve the volume of a cake. Thus have a chance to replace a part of egg in cakes and save cost.

Blanshard et al describe a hydrated gel contains 20-30% blend of a Distilled Monoglyceride and PGMS to gather with 1-2% of an anionic co-emulsifier. This blend of emulsifiers must be stable in the alpha crystalline form to obtain maximum functionality. Friberg describe a commercially preferred stabilized gel which contain Monoglyceride in liquid crystalline form. Renso describe a past that consist with 30% GMS, 10% Propylene Glycol, 10% Glycerol, 4% co-emulsifier, and 46% water. According to the experiment 24% of that past gives a low density batter, good structure of the baked and high volume of cake per unit of the batter.

2.3.2.2 Monoglyceride and its derivatives

2.3.2.2.1 Development

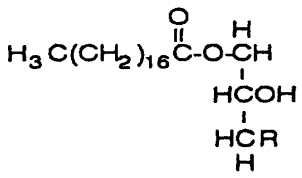
The use of Monoglycerides first began in the 1930s when supper glycerinated shortening became commercially available. It was widely use for making cakes, particularly once containing sugar at high levels (Stauffer, 1990).An effectiveness of Monoglyceride in retarding staling in bread became kwon at the same times. This need was met by suppliers of "Plastic Monoglyceride" .It was contained 50- 60% Monoglyceride with Diglyceride. When Industrial – scale molecular distillation process became available, it was logical to subject the Plastic Monoglyceride to Distilled Monoglyceride containing minimum 90% Monoglyceride and rest is a mixture of Diglyceride and small amount of fatty acids, Dilycerol and Triglyceride (Stauffer, 1990).The next stage was to make Hydrated Monoglycerides. It was done by adding some anionic surfactant (SSL) to stabilize the hydrated Monoglyceride. It was roughly contain 25% Monoglyceride, 3% SSL and 72% water (Stauffer, 1990).More recently manufactures have developed a powdered Distilled Monoglyceride. At this time bakers use all types of Monoglycerides to get good results. Plastic Monoglycerides are slightly less expensive and hydrated one is more functional. Powdered Monoglycerides are more convenient. The choice usually depends upon the personal prediction and experience of the individual bakers (Stauffer, 1990).

2.3.2.2.2 Manufacture

Common basic raw materials for Monoglycerides manufacture are lard and vegetable oil such as cotton seed oil. This result in a mixture of fatty acid moieties combined in random fashion with Glycerol (Sumuela, 1997).

2.3.2.2.3 Chemical background

Monoglycerides are emulsifiers consist of fatty acids chemically combined with either one (monoglyceride) or two (diglyceride) glycerol residues. Combined OH groups on the glycerol can act as a hydrophilic portion of the emulsifier (Sumuela, 1997).Figure 2.1 shows the structure of Monoglyceride molecule.



R	Emulsifier
-OH	Glycerol MonoStearate (GMS)
$-OOCH_2CH_2COO^-$	Succinyl Monoglyceride (SMG)
$-OOC\underset{OH}{\underset{\vert}{C}}HCH_3$	Lactylated Monoglyceride (LMS)
$-OOCCH_3$	Acetylated Monoglyceride (AMS)
$-OOC\underset{OOCCH_3}{\underset{\vert}{C}}HCHCOO^-$ $\underset{OOCCH_3}{\vert}$	Diacetyl-tartrate Ester of Monoglyceride (DATEM)
$-O(CH_2CH_2O)_nH$	Polyoxyethylene Monoglyceride (EMG)
H	Propylene Glycol Monostearate (PGMS)

Figure 2.1 derivative of Monoglyceride (Stauffer, 1990)

2.3.2.2.4 Derivatives of Monoglyceride

There are two types.

i. Dough strengtheners

These members added to bread dough to strengthen the gluten that is increase its resistance to shock during the production process and give larger loaf volume and finer internal crumb structure (Stauffer, 1990).

Eg: Succinylated Monoglyceride (SMS),Polyoxyethelene Monoglyceride (EMG),Diacetyl tartrate ester of Monoglyceride (DATEM).

ii. Alpha tending emulsifiers

These emulsifiers are mainly use in cake production. These types are dissolved in the shortening phase of the cake formulation, and they contribute to the emulsification of the shortening in the water phase, as well as incorporating on air into the fat phase (Stauffer, 1990). They form a solid film at the oil/water interface during cake batter mixing.

Eg:- Lactylated Monoglyceride (LMS), Acetylated Monoglyceride (AMS), Propylene Glycol Monostearate (PGMS)

Modified Monoglyceride can be made by reacting food acid with Monoglyceride. The most common types are Lactylated (lactic acid), Acetylated (acetic acid), and Succinylated (Succsinic anhydride) (Sumuela, 1997).Polyglycerol esters are formed by polymerizing 3-10 glycerin units and reacting compound with stearic acid, oleic acid or fat. Propylene Glycol Monostearate (PGMS) is produced by reacting Propyleneglycol with Stearic acid. Propylene Glycol Monoester (PGME) is manufactured by reacting Propylene Glycol with glycerin and fats.

2.3.2.2.5 Distilled Monoglyceride

Distilled Monoglyceride are Produced to enhance the functionality of Monoglyceride by highly purifying the Monoglyceride using Molecular Distillation process.

2.3.2.2.6 Safety of Consumption

According to the Evaluation performed by the JECFA (Report NMRS 53/TRS 539-JECFA 17/20, 1973) ADI value was not limited. There fore there is no any long term health effect due to intake of the chemical.

2.3.2.3 Polyglycerol ester of fatty acid

2.3.2.3.2 Properties

Polyglycerol esters are nonionic surfactants that are free from ethylene oxide and nitrosamines. They are bio compatible and biodegradable and are allowed for food used in many countries. Depending on the HLB value, Polyglycerol esters can act as water in oil or oil in water emulsifiers. The emulsification properties of Polyglycerol esters can be highlighted by the large reduction of interfacial tension between water and solutions of the ester in oils.

2.3.2.3.1 Production

Polyglycerol esters can be produced by direct esterification with a wide variety of fatty acids or by transesterification with methyl/ethyl esters. Their composition can be tailored by adjusting various parameters including nature of the Polyglycerol (length, eligemeric distribution), nature of the fatty acid (chain length, degree of unsaturation,

additional functionality), esterification method (with or without catalyst, direct esterification or transesterification), degree of esterification and position of the esterified hydroxyl group(s). Based on these selections, Polyglycerol esters with a wide range of properties can be produced, such as the desired hydrophile/lipophile balance (HLB).

2.2.2.3.3 Uses

In bakery industry the principal application has been in cakes, where it is claimed they contribute to improved mouth feel, crumb moistness, and volume (Stauffer, 1990). Polyglycerol esters are used to production of Polyglycerol polyricinoleates (PGPR) which use as an emulsifier in chocolate production.

2.2.2.3.4 Safety for consumption

ADI (mg/kg body weight) value is 0-25. (Joint FAO/WHO Expert Committee on food additives, WHO Report series, No 539, 1974)

2.3.3 Form Formation and stabilization

Lowering the interfacial (surface) tension favors the foam formation (Stauffer, 1990). Small surfactant molecules dissolved in the aqueous phase promote foaming. Stability of the foam is dependant on the stability of the film of water between air bubbles.

In bakery practice the surfactant is often a protein. Proteins are amphiphilic molecules which contain hydrophilic side chains and hydrophobic side chains. Normally Protein such as egg albumin in solution (folded), hydrophobic side chains are berried in the non polar environment, while the hydrophilic side chains are on the surface of the molecule and interact with the polar aqueous environment. When air bubbles are introduced into the solution by the mixer, the air/water interface presents a new possibility for the lowest energy state of the protein. Unfold hydrophobic side chains entering the air phase and the hydrophilic chains remaining in the water phase.

In figure 2.2 the heavy lines in the magnified section represent unfolded proteins adsorbed at the air/water interface. The portion of the protein located in the aqueous phase hold water, preventing it from draining away from this region, and hence

preventing the air bubbles from coalescing and destabilizing the form (Stauffer, 1990).

The presence of lipid retards whipping, because the oil molecules migrate to the air/water interface before protein molecules, inhibiting the unfolding of the protein and thus the form formation (Stauffer, 1990).

Stabilization of form by a protein is necessary to make a cake with good volume and crumb structure. The addition of an emulsifier such as PGMS isolates in the cake from the air/water interface, thus promoting the action of the protein and enhancing the cake volume (Stauffer, 1990).Surfactant denaturizing enhances the ability to the protein to unfold at the air/water interface (Stauffer, 1990) thus increase the form formation.

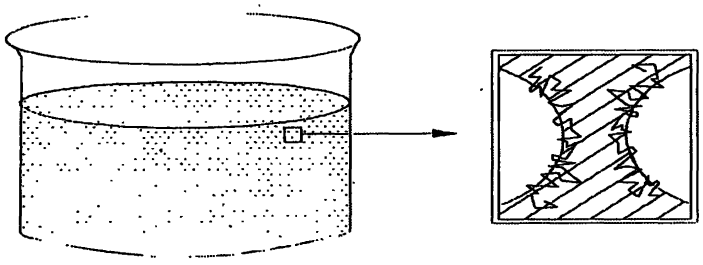


Figure 2.2 structure of a protein stabilized form. On the right side, crosshatching represents the aqueous phase, open area are air bubbles, and the heavy lines are unfolded protein molecules (Stauffer, 1990).

2.3.4 Formation of complexes with emulsifiers and starch/protein components

The formation of complexes with proteins or starch components is an important part of the function of the emulsifiers. It is strongly depend on the physical state of the emulsifier.

Very few emulsifiers are able to form molecular or to form a liquid crystalline phase in water, this becomes very important factor in reaction with starch component and protein (Friberg, 1976). Among possible liquid phases the lamellar type is the most active state, because it may swell in water to a great extent under the right condition. This gives the single molecules a high degree of molecular freedom.

The ability of monoglyceride to form insoluble complexes with amylase is an important function in many starch containing foods and is responsible for crumb softening and texture improving effect (Friberg, 1976).

Among commercial products, saturated Distilled Monoglycerides gave the highest complexing index, followed by Stearoyl Lactylates, Propylene Glycol esters, Sucrose esters, Sorbitain esters, Polysorbates, and Lecithin. (All have poor amylase complexing effect). It was calculated that the most important factor for the formation of helical complexes with amylase is that the chemical configuration of the emulsifier fits the dimensions of the amylose helix, which is around the complexing agent. Another factor of important is the ability of the emulsifier to form lamella mesophase in water. Since none of the emulsifiers of were soluble in water, the mesomorphic state gave the optimum condition for reaction with amylose (Friberg, 1976).

The rate of complexing formation between dissolved amylose and Monoglycerides in various physical form is decreasing in order of alpha crystalline gel form> Beta crystalline hydrate> non hydrated powder (Friberg, 1976).

It appears that the addition of Monoglyceride increase the pasting temperature of starch and increases the viscosity during gelatinization.

2.3.5 Practical improvement obtained by use of emulsifiers in cakes

Egg performs a number of roles in cake manufacture. In addition a variety of man made emulsifiers are used in cake manufacture. eg: Monoglycerides, Polyglycerol Esters, Propylene Glycol Monoesters etc (Friberg, 1976).

The use of emulsifiers in cake either as components in bakery fat or as individual additives may be aimed at giving one or more improvements in cake quality as listed below (Friberg, 1976).

- Grater cake specific volume.
- Improve eating quality due to increased and more rapid flavor release.
- Better crumb structure.

- Grater crumb softness.
- Retardation of staling.
- Improvement in performance of egg for use in cake mixes.
- Great cream specific volume for fat sugar cream.
- Cost saving by some reduction in expensive cake ingredients.(Friberg, 1976)

2.4 Physical States of Emulsifiers in water

2.4.1 Introduction

- Mixtures of surfactant and water form a number of different physical structures, depending on the surfactant/ water ratio and the temperature. These structures are called mesophases.(Stauffer, 1990)

- There are basically 3 mesophases/ mesomorphic structures (figure 2.3)
  i. Lamellar
  ii. Hexagonal 11
  iii. Cubic

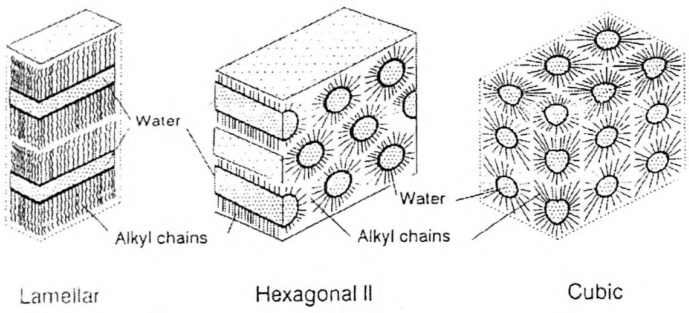
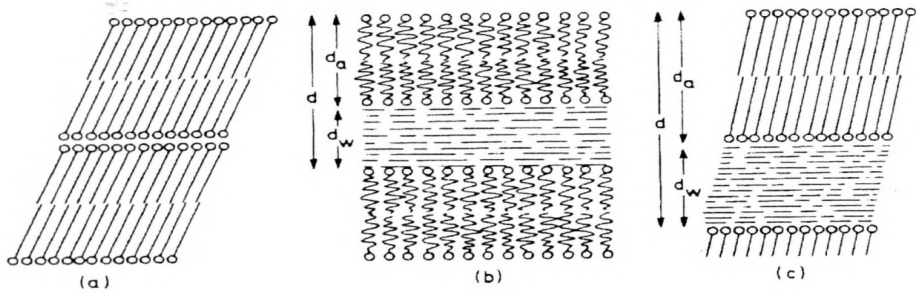


Figure 2.3 Structures of mesophases formed by surfactants in water (Stauffer, 1990).

2.4.2 Lamellar structure

In crystalline form, the emulsifier molecules are oriented with the polar groups against each other, and the lipophilic hydrocarbon chains are parallel and densely packed as shown schematically in figure 2.4 (a).

When the emulsifier crystals are in contact with water and temperature is raised to the point where the kraft temperature (Tc) is reached, the hydrocarbon chain will transform in to a disorder, liquid state due to the thermal energy (friberg, 1976).



Figuer 2.4 Schematic model showing the formation of a liquid crystalline, lamella mesophase and the alpha crystalline gel phase (Friberg 1976).

At the same time water will penetrate between the polar layers as shown in figure 2.4 (b). This is a liquid crystalline mesophase of the lamella type. Photomicrograph of Lamella type shown in figure 2.5

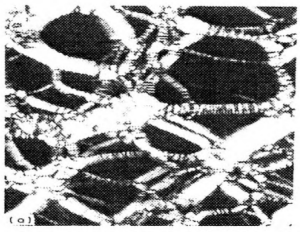


Figure 2.5 Photomicrograph of lamellar type Magnification x 300, polarized light (Friberg, 1976)

2.4.2.1 Gel formation

When the mixture is cooled down again below the Kraft point the hydrocarbon chains will crystallize and arrange them selves in a regular lattice. Water may still be present between the polar groups and this case a so-called gel (friberg, 1976) is formed shown schematically in figure 2.4 (c)

Such gels are normally metastable and will eventually change due to a decrease in the water layer thickness when the water is expelled; the gel phase is transformed into a microcrystalline suspension of the emulsion in water (coagel).

2.4.2.2 Monoglyceride (GMS) Gel formation

A Monoglyceride such as GMS Crystallizes in bilayers. (Thickness of the each bilayer defined by the length of two Monoglyceride molecule head to head).When

heated in water, the crystal melt, (fatty acid chains get thermal mobility and lose their ordered structure). Water begins to intrude between the bilayers along the plane defined by the glycerol head groups.

Under the proper conditions of temperature and water content, this intrusion results in the formation of the Lamella mesophase. When the mixture is cooled, the lipid layers solidify (in alpha crystalline state and the material becomes a gel with a lipid bilayer about 55A thick (Stauffer, 1990).

2.4.3 Lamellar Neat phase of Distilled monoglyceride/DGMS

It was found that a neutral pH and a low electrolyte concentration in the water were of great importance for the formation and stability of diluted dispersion of DGMS in water. When very dilute dispersions containing 5 to 10% DGMS were buffered to pH and, a clear homogeneous dispersion was obtained, and when cooled down, a stable gel could be formed. If pH was as law as 5 to 6 the dispersion was not clear, but milky and the gel transformed quickly into a coagel (beta crystalline + water) (Friberg, 1976).

A complete phase diagram of DGMS- water systems is shown in figure 2.6

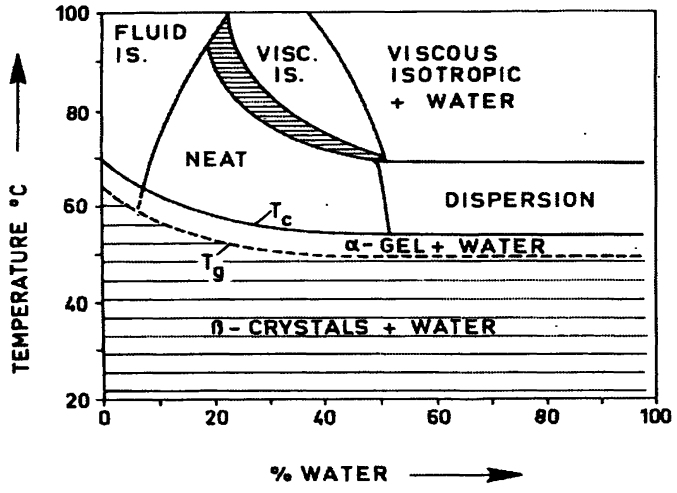


Figure 2.6 Complete phase diagram of the DGMS-Water systems

Theoretically the Lamella or Neat phase in the phase diagram should not exist at higher water contents than 30%, but the viscosity properties and optical texture do not change significantly until the water concentration is above 50% (Friberg, 1976).

2.4.4 Transformation of Lamellar Neat phase of DGMS to Gel state

When cooling down of the lamellar neat phase, space between two water layers of lamellar neat phase increases, although the proportion between the content of the water and the lipid phase kept constant.

This phenomenon is due to the crystallization of the hydrocarbon chains in the lipid bilayer, which results in the decrease in the specific surface area of the Monoglyceride molecules in contact with water. Thickness of the lipid bilayer increase in the lamellar phase to gel phase. Due to the crystallization process, where by the hydrocarbon chains are stretched out and aligned parallel to each other. At the same time specific surface area decrease from lamellar phase to gel phase (Friberg, 1976).

Water layer thickness increases during the formation of a gel although the total water content is constant. The main factor for this extension of the water layer is the decrease in specific surface of the Monoglyceride in contact with water, which is caused by a lateral contraction of the lipid molecules (Friberg, 1976).
Figure 2.7 shows photomicrographs of a Monoglyceride gel in its most active form (a), partial recrystallized (b), and completely recrystallized to a coagel(c).

Figure 2.7 photomicrographs of Distilled Monoglycerides in (a) gel form, (b) partially recrystallized, (c) completely recrystallized to a coagel (Friberg, 1976).

2.4.5 The swelling capacity of the lamellar phase and Stability of gel state of Distilled Monoglyceride / DGMS

The lamellar neat phase is considered as being a very important physical state for the food emulsifiers because the translational freedom between the molecular layer gives the highest possible rate of reaction with other ingredients, such as spreading at oil-water or air –water interfaces with starch or proteins(Friberg, 1976).

Recent work by Krog and Borop has shown that the swelling of the lamellar phase is strongly influenced by the presence of small quantities of ionic surface active agents. A simple way to obtain such conditions is to neutralize the free fatty acids, which are normally present in industrial distilled saturated Monoglyceride (Friberg, 1976). Neutralize DGMS (using NaOH) water systems show that the lamellar phase continuous to swell with an increasing in water content. DGMS- Distilled water mixture which was not neutralized only swelled to water content 30% (Friberg, 1976).

The swelling capacity of monoglyceride water system is also influenced by the presence of other surface active agents. Krog and Borop found that ionic surface active agents increases the swelling of the lamellar phase of DGMS-water system like those obtained by neutralizing the free fatty acids in DGMS.

The swelling capacity and stability of the gel of industrial Distilled Monoglyceride (DGMS) are strongly influenced by the presence of ionic active emulsifiers and the salt concentration in the water

Sodium salt of stearic acid added directly to DGMS increases the swelling capacity of the gel phase to the same extent found when neutralizing the free fatty acids with NaOH.

Stability of the gel phase is very sensitive to the ion concentration in the water. Addition of 0.04% NaCl to the lamellar phase of Monoglyceride in water inhibit the formation of total swollen gel at high water content (Friberg, 1976).

2.4.6 Alpha crystal gel state of PGE with water

Among the possible phases, the alpha gel phase (lamella) is the most efficient in the stabilization or emulsions, dispersions and foams. In water both Glycerol and Polyglycerol esters produce alpha crystal gel phases. However whereas the structure generated from Polyglycerol Monoesters remain stable at room temperature, those produced from the corresponding Glycerides transform over time to beta crystal structure called coagel. There is a particular importance in alpha crystal gel phases

lead to better emulsification properties while beta crystals have a lover ability to stabilize dispersed system.

In oil in water emulsions, the alpha gel phase will form a gel network in the continuous aqueous phase, increasing its viscosity and stabilizing the formula.

2.5 Thickening Agent

2.5.1 Sorbitol

2.5.1.1 Introduction

Sorbitol, also known as glucitol, is a sugar alcohol which body metabolizes slowly. It is obtained by reduction of glucose changing the aldehyde group to an additional hydroxyl group. Therefore it is a sugar alcohol.

IUPAC name - hexane-1,2,3,4,5,6-hexoal

Molecular formula -$C_6H_{14}O_6$

Physical properties:

Molar mass -187.17g/mol

Melting point -95^{0}C

Boiling point -296^{0}C

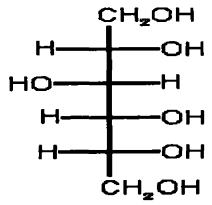


Figure 2.8 Sorbitol

2.5.1.2 Uses of Sorbitol

i. Sorbitol is often used as a humectants and thickener. Some transparent gels can only be made with Sorbitol as it has a refractive index sufficiently high for transparent formulations. It is also used as a humectant in some cigarettes.

ii. Can be used in various cough syrups, and is usually listed under the inactive ingredients. Too much Sorbitol (from 10 to 50g, or more for adults) can cause severe gastro-intestinal problems.

iii. Sugar substitute often used in diet foods (including diet drinks and ice cream) and sugar-free chewing gum. It also occurs naturally in many stone fruits and berries from trees of the genus Sorbus.

iv. referred to as a nutritive sweetener because it provides calories or energy to the diet: 2.6 calories (11 kilojoules) per gram versus the average 4 calories (17 kJ) of sugar and starch, while retaining 60% of the sweetness.

v. Can be used as a non-stimulant laxative, either in oral suspension or suppository form. The drug works by drawing water into the large intestine, thereby stimulating bowel movements. It has been determined safe to use in the elderly.

2.6 Humactant

2.6.1 Propylene glycol

2.6.1.1 Introduction

Propylene glycol is an organic compound (a diol alcohol), usually a tasteless, odorless, and colorless clear oily that is hygroscopic and miscible with water, acetone, and chloroform. It is manufactured by the hydration of propylene oxide.Acceptable daily intake for a man is 0-25 mg/kg body weight (Joint FAO/WHO Expert Committee on Food Additives, Geneva, 25 June - 4 July 1973, report NMRS 53/TRS 539-JECFA 17/21).

IUPAC Name	-	propane-1,2-diol
Chemical formula	-	$C_3H_8O_2$

Physical properties:

Molecular mass	-	76.09 g/mol
Density	-	1.036 g/cm^3
Melting point	-	-59 °C
Boiling point	-	188.2 °C

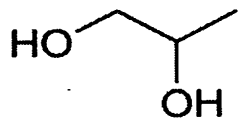


Figure 2.9 Propylene Glycol

2.6.1.2 Properties for use

- Thickening agents, foam stabilizer in Ice cream, cheese, candy, yogurt.
- Use in Artificial sweetener bases, liquid food color, essences, sweetened coconut, chewing gum, chocolates.
- Solvent for food colors and flavors.
- Its glycerin like taste has made it popular for children's medications and other elixirs.
- As a humactant in food products -substances that have a high affinity for water and have a stabilizing action on the water content of a material. Propylene Glycol is used to maintain moisture within a narrow range in certain food products, such as coconut and marshmallows, as well as in tobacco It is also used to absorb extra water and maintain moisture in certain medicines and cosmetics.
- Propylene Glycol is used in antifreeze and de-icing solutions. It is used as a solvent in the paint and plastics industries, and to make polyester compounds. It is used as a substitute for ethylene glycol mono-alkyl ethers in all purpose cleaners, coatings, inks, nail polish, lacquers, latex paints, and adhesives.
- As a dispersing agent in cosmetics.

2.7 Co-emulsifiers

2.7.1 Stearic acid

2.7.1.1 Introduction

Stearic acid is a saturated fatty acid (it has only single bonds between its carbon atoms) commonly found in animal fat, but also found in some plant foods like chocolate. Normally it is highly stable in storage and frying. Relatively large percentage of stearic acid consumed is converted in to oleic acid (a monounsaturated fat) also it used to form margarines, shortenings, spreads, and as a cream base for baked products. Unlike most saturated fats, stearic acid does not seem to increase cholesterol levels in the blood, because liver enzymes convert it to an unsaturated fat during digestion.

Chemical name - Octadecanoic acid

Chemical formula - $CH_3(CH_2)_{16}COOH$

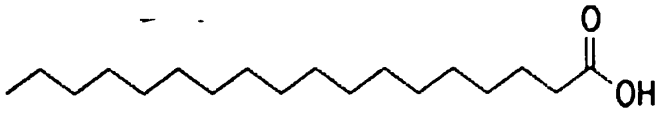


Figure 2.10 Stearic acid

Physical properties,

Molar mass	-	284.47 g/mol
Melting point	-	69.6 °C
Boiling point	-	383 °C
Acid value	-	200-210 mg KOH/g
Color	-	White or yellowish

2.8 Sensory Evaluation

2.8.1 Introduction

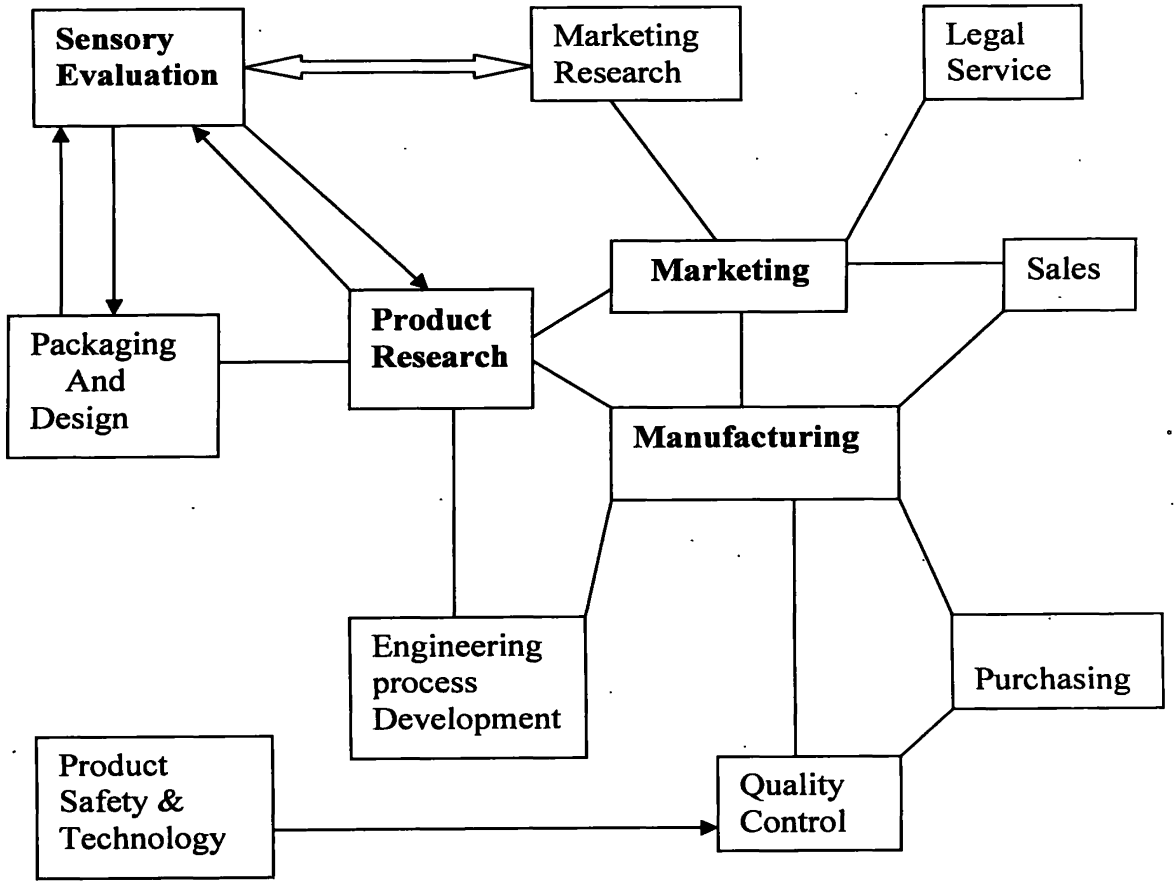


Figure 2.11 A sensory evaluation department may interact with many other departments in food or consumer products company (source: Lawlies and Heymann, 1998).

A sensory evaluation is made by the senses of taste, smell, touch, and hearing when food is eaten. It is also a science of measurement. Like other analytical test procedures. Sensory evaluation is concerned with precision, accuracy, sensitivity and avoiding false positive results. A good sensory test will minimize errors in measurement and errors in conclusion and decisions. In most applications, sensory tests function as risk reduction mechanism for both researches and marketing managers.

Sensory tests provide useful information about the human perception of product changes due to ingredients, processing, packaging or shelf life. (Lawlies and Heymann,1998)

2.8.2Type of tests

Sensory evaluation comprises a set of test methods with guidelines and established techniques for product presentation and well- defined response. Three primary kinds of sensory tests focus on the existence of overall differences among products. Discrimination test, specification of attributes-Descriptive analysis and measuring consumer likes and dislikes-Affective or hedonic testing. The discrimination and descriptive procedures require good experimental control and maximization of test precision. Affective tests, on the other hand, require use of representative consumers of the product and test conditions that enable generation to how products are experienced by consumers in the real world (lawlies and Heymann, 1998).

2.8.2.1 Hedonic test

Hedonic test is used in the food industry to determine acceptance of food. The major class of sensory tests is those that attempt to quantify the degree of the liking or disliking of a product, called hedonic scale or affective test methods.

This method provided a balanced 9-point scale for liking with a centered neutral category and attempted to produce scale point labels with adverbs that represented physiologically equal steps or changes in hedonic tone. In other words, it was a scale with ruler like properties whose equal intervals would be amenable to statistical analysis (Lawlies and Heymann, 1998).

2.8.3 Sensory parameters

Flavor:

A complex group of sensations comprising olfactory, taste and other chemical sensations such as irritation or chemical heat.

Aroma:

The fragrance or odor of a product as perceived by the nose from sniffing through the external naves. In some cultures, aroma may also refer to re- fro-nasal smell.

Odour:

The characteristic smell of a substance.

Texture:

Characteristic of a product perceived by the visual or tactile senses including geometric Quality, surface attributes, perceived changes under deformation.

Taste:

Specialized sense organs on the tongue and soft palate contain the receptors for our sense of taste.

The sense of taste has two important functional properties that it shares with smell. These are adaptation and mixture interaction.

i. Adaptation- A decreases in responsiveness under conditions of constant stimulation.
ii. Mixture interaction- A second feature of taste function is the tendency for mixtures of different tastes to show partially inhibitory or marking interaction.

2.8.4 Sensory panel and panelists

Panel: A group of people that comprises a test population chosen for specific characteristic such as product usage, sensory quality or willingness to participate in repeated sensory test.

Panelist: Generally, a participant in a sensory evaluation. Panelists cannot a participant as a member of a group that is often tested on more than one occasion (Larmond, 1987).

2.9 Market Research

2.9.1 Importance of a market research

Marketing research is studying and analyzing the market to find ways and means of satisfying customer needs profitably.

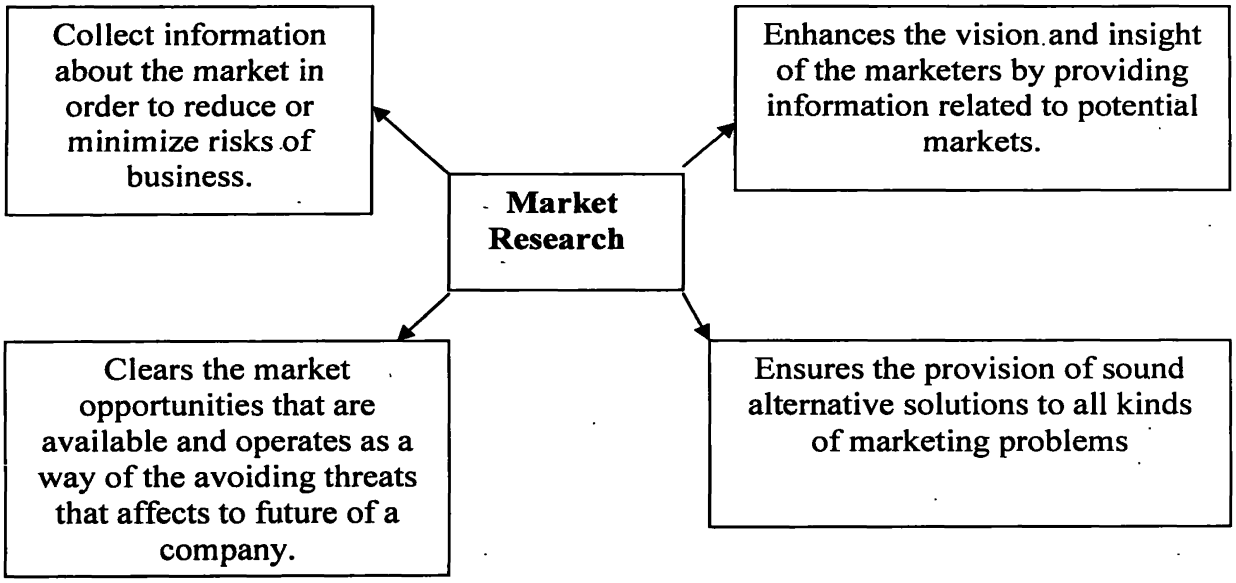


Figure 2.12 Importance of market research (Source: Gamage and Menike,1999).

2.9.2 Marketing research process

Marketing research is a logical process consisting of several steps to be accomplished. The steps of this process are in figure 2.14

Broad framework we can further illustrate this process with more steps as stated below,

1. Define the problems and establish the need for information needs.
2. Decide research objectives and information needs.
3. Determine research design and sources of data.
4. Develop the procedure for collecting data.
5. Design the sample
6. Collect the data.
7. Process the data
8. Analyses the data
9. Present research results (Gamage and Menike, 1999).

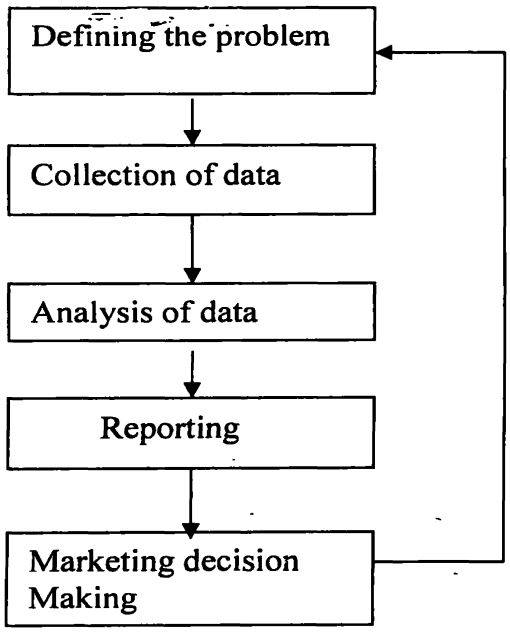


Figure 2.13 marketing research processes (source:Gamage and Menike, 1999)

CHAPTER 03

MATERIAL AND METHODOLOGY

3.1 Materials and Apparatus

3.1.1 Materials for preliminary Marketing Research

Standard Questionnaire

3.1.2 Study of X market sample

3.1.2.1 pH value

Apparatus

pH Meter (pH /mv Meter, YK 2001PH)

Measuring cylinder (50 ml $\pm$ 0.5 ml)

Electronic balance (max 20g, min 0.02g)

Laboratory Glass ware

Materials

Distilled water

Commercial X sample

3.1.2.2 Moisture Analysis

Apparatus

Moisture analyzer (MX 50 MF 50, A and D Company)

Electronic balance (max 20g, min 0.02g)

3.1.3 Development of gel Texture using Glycerol Monostearate (GMS)

3.1.3.1 Selection of the best mixing method

Apparatus

Thermometer (-10 ~ +110 ^{0}C)

Electronic balance (max 20g, min 0.02g)

Measuring cylinder (50 ml $\pm$ 0.5 ml)

Hot plate

Electrical mixer (universal motor, 220/230v 1 ph 50 cyl AC/DC)

Beaker

Glass rod

Materials

Glycerol Monostearate (GMS)

Propylene Glycol

Glycerin

Stearic acid

Potassium Hydroxide

Water

3.1.3.2 Selection of the best GMS %

Apparatus

Thermometer (-10 ~ +110^{0}C)

Electronic balance (max 20g, min 0.02g)

Measuring cylinder (50 ml $\pm$ 0.5 ml)

Hot plate

Beaker

Laboratory glass ware

Materials

Glycerol Monostearate (GMS)

Propylene Glycol

Glycerin

Stearic acid

Potassium Hydroxide

Water

3.1.3.3 using of food gum

Apparatus

Thermometer (-10 ~ +110^{0}C)

Electronic balance (max 20g, min 0.02g)

Measuring cylinder (50 ml $\pm$ 0.5 ml)

Hot plate

Beaker and other Laboratory glass ware

Materials

Glycerol Monostearate (GMS)

Propylene Glycol

Glycerin

Stearic acid

Potassium Hydroxide

Cellulose gum 40000PA (Carboxy Methyl Cellulose)

Water

3.1.3.4 using of oil

Apparatus

Thermometer (-10 ~ +110 ^{0}C)

Electronic balance (max 20g, min 0.02g)

Measuring cylinder (50 ml $\pm$ 0.5 ml)

Hot plate

Beaker

Laboratory glass ware

Materials

Glycerol Monostearate (GMS)

Propylene Glycol

Glycerin

Stearic acid

Potassium Hydroxide

Palm oil

Water

3.1.4 Development of gel texture using combination of GMS and SSL

Apparatus

Thermometer (-10 ~ +110^{0}C)

Electronic balance (Capacity 120g x 0.01g)

Measuring cylinder (50 ml $\pm$ 0.5 ml)

Hot plate

Beaker

Laboratory glass ware

Materials

Glycerol Monostearate (GMS)

Propylene Glycol

Stearic acid

Potassium Hydroxide

Sodium Stearoyl Lactylate (SSL)

Water

3.1.5 Development of gel texture using Distilled Monoglyceride/ DGMS

Apparatus

Thermometer (-10 ~ +110^{0}C)

Electronic balance (Capacity 120g x 0.01g)

Measuring cylinder (10 ml $\pm$ 0.5 ml)

Hot plate

Beaker

Laboratory glass ware

Materials

Distilled Monoglyceride

Propylene Glycol

Stearic acid

Potassium Hydroxide

Sorbitol

Water

Sample X

3.1.6 Development of gel texture using DGMS (Distilled Monoglyceride) and PGE (Polyglycerol ester)

3.1.6.1 Determination of required water amount to form a gel

Apparatus

Thermometer (-10 ~ +110^{0}C)

Electronic balance (Capacity 120g x 0.01g)

Measuring cylinder (10 ml ± 0.5 ml)

Hot plate

Beaker

Laboratory glass ware

Materials

Distilled Monoglyceride

Polyglycerol ester

Stearic acid

Water

3.1.6.2 Determination the shelf life of formed gel at room temperature condition

Apparatus

Thermometer (-10 ~ +110^{0}C)

Electronic balance (Capacity 120g x 0.01g)

Measuring cylinder (10 ml ± 0.5 ml)

Hot plate

Beaker

Laboratory glass ware

Materials

Distilled Monoglyceride

Polyglycerol ester

Stearic acid

Water

Polyethylene

Sealing machine

3.1.6.3 Determination of required Propylene Glycol and Sorbitol amount to improve the gel texture

Apparatus

Thermometer (-10 ~ +110^{0}C)

Electronic balance (Capacity 120g x 0.01g)

Measuring cylinder (50 ml ± 0.5 ml)

Hot plate

Beaker

Laboratory glass ware

Materials

Distilled Monoglyceride

Polyglycerol ester

Propylene Glycol

Sorbitol

Stearic acid

KOH

Water

3.1.7 Comparing of the pH value and moisture% of the F2, H3 with sample X

Apparatus

pH Meter (pH /mv Meter, YK 2001PH)

Measuring cylinder (50 ml $\pm$ 0.5 ml)

Electronic balance (max 20g, min 0.02g)

Laboratory Glass ware

Moisture analyzer (MX 50 MF 50, A and D Company)

Materials

Distilled water

Sample H3

Sample F2

3.1.8 Selection of the minimum quantity of product (Sample H3) to replace 50% of eggs in a Madeira cake recipe

Apparatus

Electronic balance (max 20g, min 0.02g)

Electronic balance (Capacity 120g x 0.01g)

Electrical oven

Cake mixer (3 speed, 230v)

Metal Tray (12x13x4 cm^3)

Cake mixing pan

Tea spoon

Ruler (cm)

Knife

Oil papers

Calculator

Materials

Flour

Sugar

Fat

Baking powder

Vanilla essence

Egg

Developed cake gel (sample H3)

Water

3.1.9 Selection of water amount

Apparatus

Electronic balance (max 20g, min 0.02g)

Electronic balance (Capacity 120g x0.01g)

Electrical Oven

Cake mixer (3 speed, 230v)

Metal Tray (12x13x4 cm^3)

Cake mixing pan

Tea spoon

Ruler (15cm, 0.1cm)

Knife

Oil papers

Calculator

Materials

Flour

Sugar

Fat

Baking powder

Vanilla essence

Egg

Developed cake gel (sample H3)

Water

3.1.10 Comparing of 50% egg replaced cake with a normal cake

3.1.10.1 Cake making

Apparatus

Electronic balance (max 20g, min 0.02g)

Electronic balance (Capacity 120g x0.01g)

Electrical Oven

Cake mixer (3 speed, 230v)

Metal Tray (12x13x4 cm^3)

Cake mixing pan

Tea spoon

Knife

Oil papers

Calculator

Materials

Flour

Sugar

Fat

Baking powder

Vanilla essence

Egg

Developed cake gel (sample H3)

Water

3.1.10.2 Height and weight measurement

Apparatus

Electronic balance (Capacity 1000g x 0.1g)

Ruler (15 cm, 0.1cm)

3.1.10.3 Determination of Moisture and pH

Apparatus

pH Meter (pH /mv Meter, YK 2001PH)

Measuring cylinder (50 ml $\pm$ 0.5 ml)

Electronic balance (max 20g, min 0.02g)

Laboratory Glass ware

Moisture analyzer (MX 50 MF 50, A and D Company)

Materials

Distilled water

Normal cake sample

Sample of 50% egg replaced cake

3.1.11 Sensory evaluation

Material

Sensory ballet papers

Glass of water

Sample 405

Sample 312

Minitab package

3.1.12 Cost calculation

Material

Microsoft Excel office package

3.2 Methodology

3.2.1 Preliminary Marketing Research

The market research was conduct to identify the considering factors, expecting texture and future demand for cake egg replaces by the local bakeries. The questionnaire was prepared with simple questions that related to the bakery expectations. Then the questionnaire was distributed among randomly selected thirty bakeries, which were represented different economic levels. Collected data were statistically analyzed by using Microsoft office Excel 2003 package.

3.1.2 Study of X market sample

3.1.2.1 pH value

5g of the sample and 45g of distilled water was measured accurately. Both were mixed well till homogeneous mixture was obtained. Reading was taken using the pH meter.

3.1.2.2 Moisture analysis

Accurately measured 1g of sample was used to analyze the moisture percentage at $180C^0$ temperature (9 min) using moisture analyzer. It was repeated three times and average was taken.

3.2.3 Development of gel texture using GMS

3.2.3.1 Selection of the best Mixing method

(a) Recipe development

GMS, Propylene Glycol (PG), Glycerin, Stearic acid, Potassium Hydroxide, were measured as mentioned in table 3.1 using the electrical balance and prepared three samples.

Table 3.1 samples to find best mixing method

Ingredients	Sample x (g)	Sample y (g)	Sample z (g)
GMS	15	20	25
Propylene glycol(PG)	20	15	10
Glycerin	05	05	05
Stearic acid	01	01	01
KOH	01	01	01
Water	53	53	53

3.2.3.1.2 Methods of mixing

Each sample (sample x, sample y, sample z) was mixed using four mixing methods.

Mixing method 1

All the ingredients were mixed together and heated using the hot plate. After all the ingredients were fully melted (temperature of the mixture 90^0C). Then mixture was kept to cool in room temperature. All the observations were note down.

Mixing method 2

Ingredients were separated to two parts. Oil phase (Stearic acid and GMS) was heated to 90^0C while water phase (Propylene glycol, Glycerin, KOH, water) was heated to 70^0C separately. Water phase was added to the Oil phase drop by drop and mixed well. Mixture was cool to room temperature. All the observations were noted down.

Mixing method 3

Oil phase (GMS, Stearic acid) was heated to 90^0C and water phase was heated to 70^0C separately. Oil phase was added to the water phase drop by drop and mixed well. Mixture was cool to room temperature. All the observations were noted down.

Mixing Method 4

All the ingredients were mixed together using the electrical mixture (150 rpm) while heating using the hot plate. After all the ingredients were fully melted (temperature of the mixture 90^0C) mixture was kept to cool to room temperature. All the observations were note down.

3.2.3.2 Selection of the best GMS%

Five samples were designed changing GMS (10%, 15%, 20%, 25%, 30%) and other ingredients were used as the below (table 3.2). Water amount was adjusted to get total 100%.

Table 3.2 changing of GMS content according to the sample

Ingredient	Sample A1 (g)	Sample A2 (g)	Sample A3 (g)	Sample A4 (g)	Sample A5 (g)
GMS	10	15	20	25	30
Propylene glycol	20	20	20	20	20
Glycerin	05	05	05	05	05
Stearic acid	01	01	01	01	01
KOH	01	01	01	01	01
water	63	58	53	48	43

Each sample was mixed as the mixing method 3 and texture was observed.

3.2.3.3 Use of food gum (CMC- Carboxy Methyl Cellulose)

Four samples were designed using the sample A2, changing CMC content as mentioned in the table 3.3. Water content was adjusted to get total 100%.

Table 3.3 Changing of the CMC content

Ingredient	Sample B1 (g)	Sample B2 (g)	Sample B3 (g)	Sample B4 (g)
GMS	15	15	15	15
Propylene glycol	20	20	20	20
Glycerin	05	05	05	05
Stearic acid	01	01	01	01
KOH	01	01	01	01
CMC	0.25	0.5	0.75	01
water	63	58	53	48

Each sample was mixed as the mixing method 3 and texture was observed

3.2.3.4 Use of oil

Three samples were designed using the sample A2, changing oil content (5g, 10g, and 15g) as mentioned in the table 3.4. Water content was adjusted to get total 100%.

Table 3.4 changing the palm oil content

Ingredient	Sample C1 (g)	Sample C2 (g)	Sample C3 (g)
GMS	15	15	15
Propylene glycol	20	20	20
Glycerin	05	05	05
Stearic acid	01	01	01
KOH	01	01	01
Palm oil	05	10	15
water	53	48	43

Each sample was mixed as the mixing method 3 and texture was observed.

3.2.4 Development of gel texture using GMS and SSL

3.2.4.1 Preparation of ester mixture

Ester mixture was prepared using 50% GMS, 3% SSL and 47% water. Total mixture was heated to 90^0C till it gets a pure solution. Mixture was kept to cool to room temperature with agitating.

3.2.4.2 Selection of best SSL %

Table 3.5 changing of SSL %

Ingredient	Sample D1 (g)	Sample D2 (g)	SampleD3 (g)	Sample D4 (g)
Ester mixture	20	20	20	20
SSL	1	2	3	4
PG	30	30	30	30
Stearic acid	0.5	0.5	0.5	0.5
KOH	0.4	0.4	0.4	0.4
water	45	45	45	45

Four samples were prepared by changing SSL % (1g, 2g, 3g, and 4g) as table 3.5. All the ingredients were mixed till it comes to the 90^0C. Then the mixture kept cooling. After it comes to room temperature, observations were noted down.

3.2.5 Development of gel texture using Distilled monoglyceride/ DGMS

3.2.5.1 Determination of required water amount to form a gel

10g of DGMS (Specification in appendix 4) was heated to 90^{0}C with 7g of Propylene Glycol and 0.2g of stearic acid. After came to the required temperature, water was added drop by drop and mixed well. While it was mixing with water removed from the hot plate and reduced the temperature to cool. Again temperature of the mixture was maintained to 90^{0}C and continued the process. Observations were recorded.

3.2.5.2 Texture improvement using Sorbitol

Changing the Sorbitol amount three samples was prepared as table 3.6. Ingredient were mixed to gather and heated to above 90^{0}C. Mixture was kept to cool till its came to room temperature and compared the final texture with Sample X.

Table 3.6 Changing of Sorbitol amount

Sample	Sample F1 (g)	Sample F2 (g)	Sample F3 (g)
Sorbitol	5	7	9
DGMS	25.8	25.8	25.8
PG	23	23	23
KOH	0.2	0.2	0.2
Stearic acid	0.65	0.65	0.65
Water	42.6	42.6	42.6

3.2.6 Development of gel texture using Distilled Monoglyceride/ DGMS and PGE/ Polyglycerol ester

3.2.6.1 Determination of required water amount to form a gel

Three samples were prepared by changing the DGMS and PGE (table 3.7) ratio and total of the DGMS and PGE was adjusted to 25g. Each Sample was heated to 90^{0}C till it gets a clear solution. After it showed transparent solution, water was added drop by drop and mixed well and identified the jell stage. Reading of the required water amount was recorded to each sample. Final texture was observed for each sample.

Table 3.7 DGMS and PGE ratio of each sample

Ingredient	Sample G1 (g)	Sample G2 (g)	Sample G3 (g)
DGMS	20	15	14
PGE	05	10	11
Stearic acid	01	01	01

3.2.6.2 Determination the shelf life of formed gel at room temperature condition

Sample was prepared by heating 28g of DGMS, 22g of PGE, 2g of stearic acid and 69.4g of water to 90^0C till it get a clear solution. It was cooled to room temperature and kept to form a gel. Gel was kept in room temperature in a properly sealed polyethylene bag and observed daily. All the observations were recorded.

3.2.6.3 Determination of required Propylene Glycol and Sorbitol amount to maintain the gel structure

Three samples were prepared changing the propylene Glycol and Sorbitol as in table 3.8. All the ingredients were put to gather and heated to 90^0C till product get the transparent. Product was kept the same temperature about 5 minutes. Then it was kept cooled to room temperature Final texture was observed for each sample and compared with the X sample.

Table 3.8 Ingredient amount according to the sample

Ingredient	Sample H1 (g)	Sample H2 (g)	Sample H3 (g)
Sorbitol	10	15	30
PG	30	25	10
DGMS	14	14	14
PGE	11	11	11
Water	34.7	34.7	34.7
Stearic acid	0.9	0.9	0.9
80% KOH	0.4	0.4	0.4

3.2.7 Comparing of the pH value and moisture% of the sample F2, H3 with the Sample X

pH value 5g of the sample and 45g of distilled water was measured accurately. Both were mixed well till homogeneous mixture was obtained. Reading was taken using the pH meter. Reading was compared with the sample X value

Moisture analysis Accurately measured 1g of sample was used to analyze the moisture percentage at $180C^0$ temperature (9min) using moisture analyzer. It was repeated three times and average was taken. Reading was compared with the sample X value.

3.2.8 Selection of the minimum quantity of product (Sample H3) to replace 50% of eggs in a cake recipe

Ingredients in the sample H3 was calculated to % and prepared a total 200g bulk. Changing the amount of sample applying to the recipe (15g, 10g, 8g 5g, 3g) Madeira cakes were prepared using Sugar batter method. Recipe is in table 3.9.

Table 3.9 Recipe of the Madeira cake

Ingredient	Amount
Flour	100g
Sugar	100g
Egg	1 egg
Baking powder	1 ½ tea spoon
Fat	100g
Vanilla	few drops
Sample	Wg
water	15ml

Procedure of sugar batter method

Sugar, fat, Wg of Sample, water beat at low speed about 3 minutes and high speed about 5 minutes

↓

Add egg

↓

Beat the mixture 3 minutes at low speed and 8 minutes at high speed

↓

Add flour and baking powder mixture

↓

Beet the mixture 3 minutes at low speed

↓

Add vanilla essence

↓

Beet 1 minute to mixed well

↓

Pore mixture into a tray (12 x 13 x 41/2 cm^3)

↓

Keep oven (35minutes at 160^0C).

After baking and cooling, the height of the cake was measured and volume was calculated. Its crumb structure (pore size, pore distribution and evenness of pores) was assessed visually to an arbitrary scale as Bad, good and extremely good. All the observations were noted down.

3.2.9 Selection of water amount

Changing the amount of water (15ml, 8ml, and 5ml) applying, three Madeira cake were made using table 3.8 recipe(Sample weight was 5g) and the sugar batter method in 3.2.8. After baking and cooling, the height of the cake was measured and volume was calculated. Its crumb moistness was assessed visually to an arbitrary scale as bad good and extremely good.

3.2.10 comparing of 50% egg replaced cake with a normal cake

Cake was made according to the recipe in table 3.9 and procedure was same as the method 3.1.8

Table 3.10 Cake recipe for 50% egg replacement

Ingredient	Amount
Flour	100g
Sugar	100g
Egg	1 egg
Baking powder	1 ½ tea spoon
Fat	100g
Vanilla	few drops
Developed cake gel	5g
water	08ml

Normal cake was baked using the table 3.10 recipe with 2 eggs and without cake gel and water. Procedure was same as method 3.1.8.

Height of the batter was measured after pore the mixture in to tray. After the cake was cooled, height and weight was measured. Each result was compared. Crumb structure of the 50% egg replaced cake was compared with the normal one (cake with 2 eggs).

Moisture % of cake was measured using Moisture analyzer (160^{0}C at 7min).PH also measured according to the method described in 3.2.7.

3.2.11 Sensory evaluation

Thirty untrained panelists were participated for the sensory evaluation. Ballot paper was prepared by using 9 point hedonic scale and two samples were coded as three digits numbers. (Appendix 06) Coded samples (405= cake pieces from 50% egg replaced cake, 312=non egg replaced cake pieces), ballot papers and water glass were given for each and every panelists and suitable environment was provided for them to do their work freely.

Finally, collected data was analyzed by using Mann Whitney nonparametric MINITAB software statistical package.

3.2.12 Cost calculation

According to the present market prices total cost was calculated using the Microsoft Excel office package.

CHAPTER 04

RESULT AND DISCUSSION

4.1 Preliminary marketing research

Marketing surveys are conducted to systematically gather and analyze the data about the problems that are relating to the marketing of goods and services. In this study, marketing research was conducted to collect information about the market in order to identify the characteristics of the product that demand by the consumer and the potential market in the future.

According to the statistically analyzed data, following results were observed.

Cake production per week

According to the thirty random data collected from cake producing bakeries, 23% of them producing less than 10 cakes per week. 33% bakeries are release between ten to fifteen cakes for the market during a week and 44% of the cake bakeries weekly produce more than 50 cakes. Therefore 77% of cake bakeries produce more than 10 cakes per week.

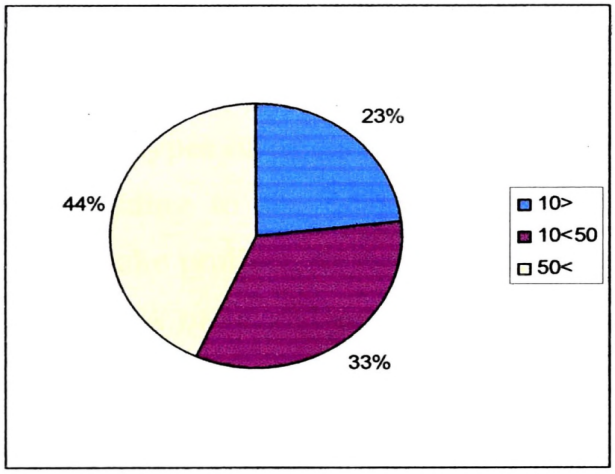


Figure 4.1 Cake productions per week

Present market for egg replacements

There are several egg replacement are available in the market today. Most of these products are exported food additives. The analyzed results prove that among the cake producing bakeries, 10% of them are using egg replacement for their products. However 90% of bakeries are still not aware about those additives.

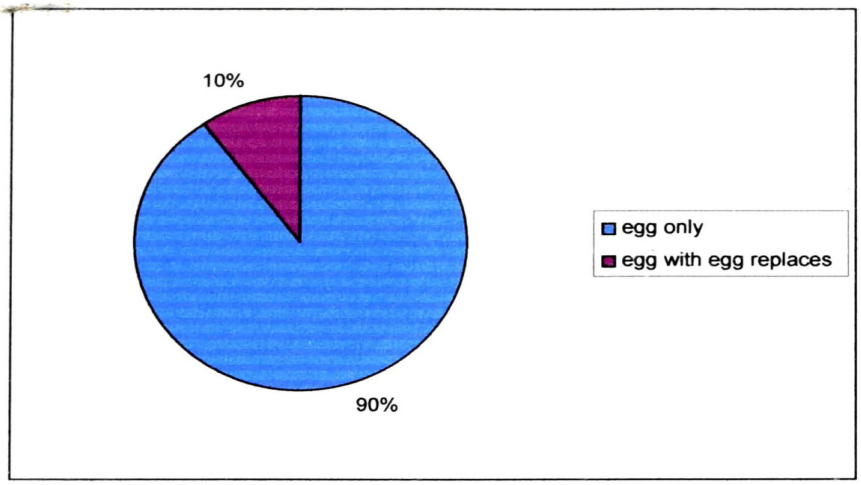


Figure 4.2 Present market for egg replacement

Market for the cake type

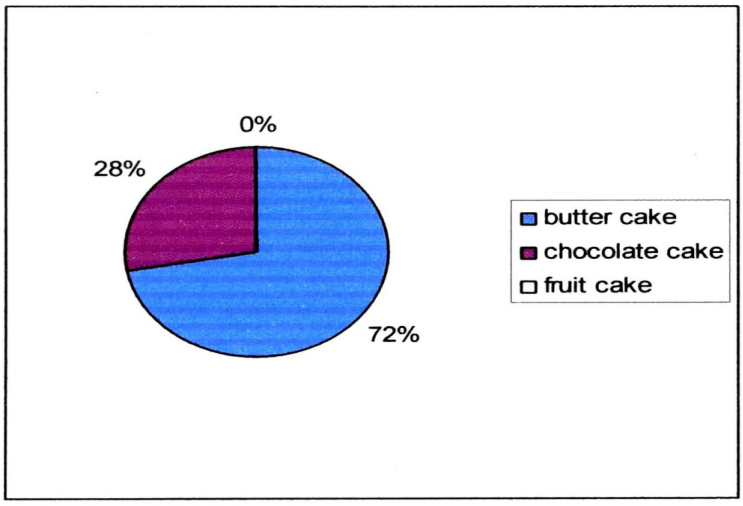


Figure 4.3 Market for the cake type

There are mainly three types of cakes in the local market. They are butter, Chocolate and fruit cake. According to the demand of the consumer and bakery facilities, frequency of type of cake production from a bakery may vary. However according to the analyzed result, 72% of local bakeries produce butter cake most. Only 28% of them produce chocolate cake. None of bakeries produce fruit cake as there major production.

Future market for cake egg replacing agent

87% of the cake bakeries are willing to buy egg replaces for there production and 13% of them are not expect any egg replaces.

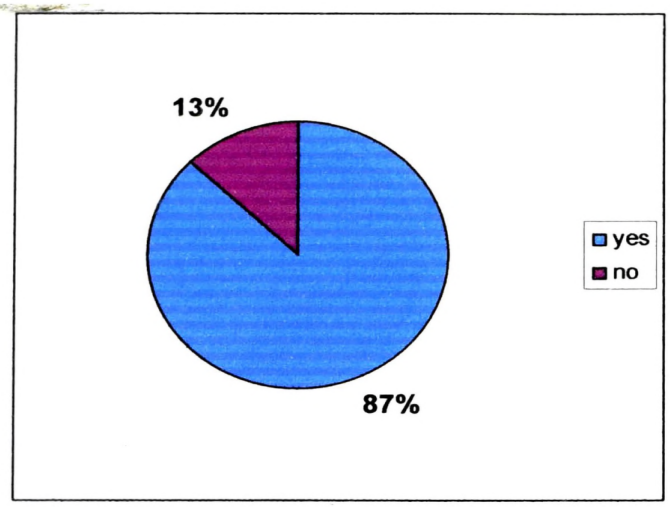


Figure 4.4 Future market for cake egg replacing agent

Most considering factors for buying an egg replacing agent

According to the analyzed result, 35% of bakeries consider about the price of an egg replacing agent.30% of bakeries consider about the shelf life. Comparative to the price and shelf life color of the product do not influenced the demand for a cake egg replacing agent. Therefore it is very necessary to give an attention to reduce the cost and improve the shelf life before introducing a new cake egg replace to the market.

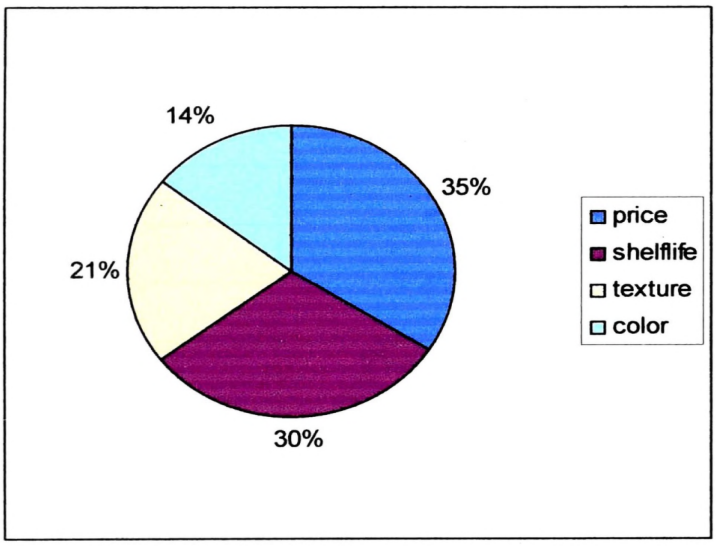


Figure 4.5 Most considering factors for buying an egg replacing agent

Expecting texture type of the product

According to the analyzed result, 38% bakeries accept the gel texture. Same % accepts "any type" texture for an egg replacing agent. Only 17% accept "liquid type" texture."cream type" texture expecting only 7% of bakeries.

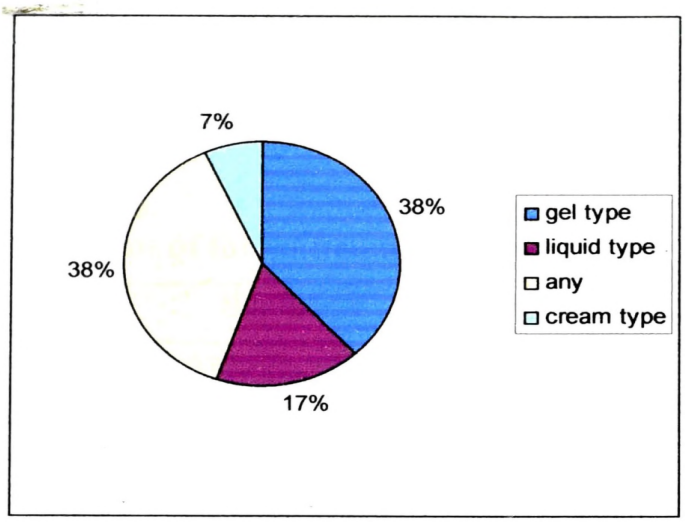


Figure 4.6 Expecting texture type of the product

Result of the marketing research revealed that there will be an 87% market for a cake egg replaces. There most expecting texture type is "gel". Most considering factors of buying an egg replaces are Cost and shelf life. There fore new product must aim to fulfill above factors to have a better demand.

4.2 Study of the X market sample

It was an exported ready to use cake improver especially designed to the conditions of Sri Lanka. Observations and readings were at table 4.1

Table 4.1 Observations and readings of X market sample

Parameter	Observations and readings
Texture	Transparent Gel texture
Color	yellow
Water solubility	Soluble in water after properly mixed
pH value	8.53
moisture	49.51%

4.3 Development of gel texture using GMS

4.3.1 Selection of the best mixing method

Commercially available Glycerol Monostearate (specification in appendix 2) is a less cost effective emulsifier which is widely used to improve the volume of the cake with shortenings or fat. It was not soluble in water. Therefore it is necessary to identify

best mixing method without any layer separation to make oil in water emulsion. Considering those factors four types of mixing methods were developed. According to those mixing methods observations were noted down (Table 4.2).

Table 4.2 Observations of four different mixing methods

Mixing method	Sample x	Sample y	Sample z
1	Layer separation	Layer separation	Layer separation
2	Layer separation	Layer separation	Layer separation
3	No layer separation	No layer separation	No layer separation
4	No layer separation Too creamy	No layer separation Too creamy	No layer separation Too creamy

At all the mixing methods, GMS was heated 90^0C to get a homogeneous mixture which is completely clear. Method 1and 2 resulted complete layer separation. High speed mixing method was resulted a too creamy texture which not accepted. Accepted result was obtained by method 3. GMS is an emulsifier which has both lipophilic and hydrophilic properties. When adding properly melted GMS drop by drop to the water phase hydrophilic portion of GMS have time to make bond with water molecule. According to the HLB concept GMS have more lipophilic properties than hydrophilic properties (HLB value less than 8). Therefore mixing facilitates bonding and whole method prevents layer separation.

4.3.2 Selection of the best GMS%

GMS percentage was changed to identify the point that will form a gel structure. Observations are in table 4.3

Table 4.3 observation for different GMS%

Sample	Sample A1	Sample A2	Sample A3	Sample A4	Sample A5
observation	Cream texture	Close to Gel texture But Not transparent ,less thickness	Cream texture	Cream texture	Hard texture

GMS Crystallizes in bilayers. (Thickness of the each bilayer defined by the length of two monoglyceride molecule head to head).When heated in water, the crystal melt and (fatty acid chains get thermal mobility and lose their ordered structure) Water begins to intrude between the bilayers along the plane defined by the glycerol head groups (Stauffer, 1990).Under the proper conditions (proper GMS and water proportion) results in the formation of the lamella mesophase. When the mixture is cooled, the lipid layers solidify in alpha crystalline state and the material becomes a gel. Therefore 15% GMS result was close to gel structure. Stearic acid and KOH was used as co-emulsifiers. Propylene glycol was used to enhance the solubility of two phases. Glycerin used as a thickening agent.

4.3.3 using of food gum (CMC-Carboxy Methyl Cellulose)

Basic aim of using of food gum is to get the proper thickness as the commercial X sample. Observations are in table 4.4

Table 4.4 observations of use of food gum

Sample	Sample B1	Sample B2	Sample B3	Sample B4
CMC	0.25%	0.5%	0.75%	01%
observation	Thick, cream texture	Thick, cream texture	Thick, cream texture	Gum type

Using of food gum didn't result an acceptable thickness. When increasing the gum % result was close to gummy texture than expected.

4.3.4 using of oil

Applying of oil aims to improve the texture of gel and to get a transparent texture. Observations in table 4.5

Table 4.5 observation of use of oil

Sample	Sample C1	Sample C2	Sample C3
Palm oil	05%	10%	15%
observation	Oily cream texture	Oily texture	Oily hard texture

Result of applying oil didn't close to the acceptable texture.

4.4 Development of gel texture using GMS and SSL

GMS (appendix 4) is not water soluble. When hydrating the GMS, water going to separate as a layer. This can be avoiding using a Hydrated Monoglyceride stabilizer.

Sodium Stearoyl Lactylate is an anionic emulsifier which can be use as a stabilizer for hydrated monoglyceride (Stauffer, 1990). It can ionization in the water layer which is necessary for stabilize the Hydrated Monoglyceride (Stauffer, 1990).These both emulsifying and stabilizing properties were considered. Observations are in the table 4.6.

Table 4.6 Observations of changing SSL%

Sample	Sample D1	Sample D2	Sample D3	Sample D4
SSL%	1g	2g	3g	4g
Observation	Small layer separation at the bottom	No layer separation, Close to the gel texture, Not transparent, fully whitish color	No layer separation, Close to gel texture, Not transparent, fully creamy whitish color	No layer separation, Hard texture which cannot accept, Not transparent, fully creamy whitish color

According to the observation, there was no layer separation with 2g SSL and above .SSL is readily water soluble. It ionized the water layer and prevent layer separation with GMS at the position of 2g and above, with 20g of ester mixture. It didn't show transparent gel texture for any trail. While increasing the SSL% improved the color of white which cannot be accepted for the product.

4.5 Development of gel texture using Distilled Monoglyceride

4.5.1 Determination of required water amount to form a gel

It is necessary to select water soluble emulsifier to prevent layer separation. DGMS (appendix 4) is readily water soluble. It consists more than 90% of Monoglyceride which have a higher ability to improve the volume of the cake than GMS consist with

40% Moglyceride (appendix 2).That properties were considered for selection of the emulsifier.

When adding water drop by drop to the 90^{0}C heated mixture of DGMS, PG and Stearic acid results were as below.

Table 4.7 result according to the water amount

Water amount	Observation
05ml	Transparent Liquid
10ml	paste
13ml	Transparent Gel texture
14ml	Transparent gel with Water layer

DGMS is commercially produced by the Molecular distillation process. Therefore it consist more than 90% Monoglyceride and maximum 1% of free fatty acid which effected for the performances of Monoglyceride.

In crystalline form of DGMS, molecules are oriented in bilayer (emulsifier molecules are oriented with the polar groups against each other, and the lipophilic hydrocarbon chains are parallel and densely packed). When heated in water, the crystal melt, (fatty acid chains get thermal mobility and lose their ordered structure) and water begins to intrude between the bilayers along the plane defined by the glycerol head groups (Friberg, 1976). Therefore it observed as transparent liquid. It represents the lamellar mesophase of the DGMS.

When adding water continuously these DGMS molecules going to swelled and increase the length of the water layer. Therefore there was no layer separation of water. DGMS have less than 1% free fatty acid which helps to prevent the inhibition of swelling capacity of DGMS. Sodium salt of stearic acid added directly to DGMS also increases the swelling capacity. At the point of 13ml of water, it showed the maximum swelling and transformed paste to the gel state.

This phenomenon is due to the crystallization of the hydrocarbon chains in the lipid bilayer, which results in the decrease in the specific surface area of the Monoglyceride

molecules in contact with water. Thickness of the lipid bilayer increase in the lamellar phase to gel phase. Due to the crystallization process, where by the hydrocarbon chains are stretched out and aligned parallel to each other. At the same time specific surface area decrease from lamellar phase to gel phase (Friberg, 1976).

4.5.2 Texture improvement using Sorbitol

According to the JECFA report TRS 683-tecfa 26/27 1982, sorbitol considered as functional group of sweetening agent, humectants, texturizer, stabilizer and bulking agent. These all properties were considered to select the chemical and texture changes were considered mainly to maintain the gel state.

Observations of samples (changing of sorbitol content) were at table 4.8

Sample	Sample F1	Sample F2	Sample F3
Sorbitol	5g	7g	9g
Observation	Not a gel	Close to gel	Not a gel

Comparing with the Commercial sample or the controller (Sample X), acceptable amount was 7g. There fore Sample F2 was considered as the best sample.

4.6 Development of gel texture using Distilled Monoglyceride and Polyglycerol ester

4.6.1 Determination of required water amount to form gel using DGMS and PGE

Rather than using of one emulsifier combination gives the maximum results (Friberg, 1976).PGE is an alpha stable emulsifier which can be used as humactant, contribute to improved mouth feel, crumb moistness, and volume of cake(Stauffer, 1990).

According to the different ratio of DGMS and PGE in table 3.6, best texture was observed at the sample G3 and G2. Both textures are closed to the texture of commercial X sample. G1 sample formed a soft gel comparative to the commercial X sample. G3 was absorbed maximum 34.7 ml of water to form a gel. Sample G1 was absorbed 26.6ml to form a gel. Sample G2 was absorbed 32ml of water to formed gel. Considering to the water requirement and texture formed G3 selected as the best sample. Theory behind the gel formation is same as the 4.5.1 description.

4.6.2 Determination of shelf life of formed gel at room temperature condition

Maintaining the alpha gel texture in room temperature is important to the performances of a cake as well as retains the market for acceptable period. Retailers cannot provide definite storage condition. There fore product should be aim to durable in normal room temperature condition.

According to the observation, there was a slight color change started at the gel after 2 weeks. With time transparency of the gel converted to whitish. This is happen due to the transformation of gel phase in to coagel. With time water amount in the gel will decreased and converted to beta crystalline stage which give fever performances to a cake. There fore maintaining the water content in the gel is very important.

4.6.3 Determination of required propylene Glycol and Sorbitol amount to maintain the gel structure

Sorbitol and Propylene Glycol normally used as solvents in order to keep the Monoglyceride in the alpha crystalline gel form during storage (Friberg, 1976). Normally with the time, water layer of the gel state will decrease and water was expelled from the gel. With time this gel phase is transformed into a microcrystalline suspension of the emulsion in water called as coagel. This coagel is equal to the beta crystalline phase which gives fewer performances for cake compared to alpha stable phase. Therefore it is mandatory to maintain the gel phase to improve the shelf life of the new product.

KOH was applied to neutralize the free fatty acid at the DGMS. It improves the swelling capacity and enhanced the water retention inside the gel. Sodium salt of stearic acid also added directly to DGMS to increases the swelling capacity of the gel phase.

Sample H1 and sample H3 were formed more oily gel relative to the commercial X sample. Considering the cost effectiveness and texture maintained, best ratio of PG and Sorbitol was obtained at sample H3.This sample texture was equal to the Sample X (commercial sample) which has acceptable transparent gel texture.

4.7 Comparing pH value and moisture % of the sample F2, H3 with Sample X

It was found that a neutral pH and a low electrolyte concentration in the water were of great importance for the formation and stability of diluted dispersion of DGMS in water. If pH was as law as 5 to 6 the dispersion was not clear, but milky and the gel transformed quickly into a coagel (beta crystalline + water) (Friberg, 1976). Therefore pH value of the product will influenced the maintaining of gel stage at storage.

According to the readings, results were in table 4.9

Table 4.9 moisture% and pH value of samples

Sample	Sample X	Sample F2 (DGMS only)	Sample H3 (DGMS+PGE)
Moisture %	49.51%	69.05%	50.91%
pH value	8.53	8.85	8.55

Among the two prepared samples, sample H3 values are more closed to the Sample X (commercial sample).Therefore further studies were carried out to Sample H3.

4.8 Selection of the minimum quantity of product (Sample H3) to replace 50% of eggs in a cake recipe

Egg is a basic ingredient of a cake recipe. It is the main source of the protein and protein of a cake recipe contribution to five types of functionality. There are air incorporation, Air stabilization, Fluidity of batter during batter expansion stage, Structural setting-coagulation, and Transformation of form to cake structure (Blanshard et al, 1985).

Rater than applying of a protein source, it is difficult to replace 100% of eggs in a cake recipe, due to its structural setting function which cannot done by application of emulsifier combination. Therefore changing the amount of product applying to cake recipe, find the minimum quantity replace 50% of egg which gives good volume and crumb structure. Observations are in table 4.10

Table 4.10 Volume and crumb structure for different quantity of product (cake gel)

Quantity of the product (g)	Volume (cm^3)	Crumb structure
15	288	bad
10	358.8	good
08	468	good
05	468	good
03	468	bad

According to the observations maximum volume was 468cm^3. It was gained using the quantity of product between 08-03 grams. Crumb structure was cannot accepted at the 3g. Concerning the cost effectiveness, and safety for consumption 5g can be considered as the most suitable quantity to replace 50% of egg in a cake recipe for 100g of flour at Madeira cake.

4.9 Selection of water amount

Water amount in a cake recipe affect the structure development of a cake. It controls gelatinization of the starch at baking thus contributing to form the final texture of the baked goods. More over amount of water vapor generated is control the expansion of total batter. According to the blanshard et al there is 73.4% water amount in the edible portion of a hen egg. There fore it is necessary to apply extra water amount to the recipe, when replacing egg using a combination of emulsifiers. Observation of different water amount in table 4.11

4.11 volume and crumb structure for different quantity of water

Quantity of water (ml)	Volume(cm^3)	Crumb moistness
15	468	bad
08	546	Extremely good
05	546	good

15ml of water have less volume and bad crumb structure due to its high water content. It contributed to sticky crumb with moister. 5ml water cake gave the maximum volume and dry crumb. Cake with 8 ml water resulted highest volume and extremely good crumb structure. Therefore using of 5g of cake gel with 8ml of water gives the

maximum volume and extremely good crumb structure for 100g of flour weight for 50% egg replaced cake recipe.

4.10 comparison of 50% egg replaced cake with a normal cake

Egg is the ingredient responsible for the aerated state of the batter (Blanshard et al, 1985). Aeration of the batter occurs due to protein of an egg. Proteins are amphiphilic molecules which contain hydrophilic side chains and hydrophobic side chains. Normally Protein such as egg albumin in solution (folded), hydrophobic side chains are berried in the non polar environment, while the hydrophilic side chains are on the surface of the molecule and interact with the polar aqueous environment. When air bubbles are introduced into the solution by the mixer, the air/water interface presents a new possibility for the lowest energy state of the protein. Unfold hydrophobic side chains entering the air phase and the hydrophilic chains remaining in the water phase. The portion of the protein located in the aqueous phase hold water, preventing it from draining away from this region, and hence preventing the air bubbles from coalescing and destabilizing the form (Stauffer, 1990). Like wise eggs are help to incorporate and stabilized the air in a batter.

Same thing was happened in the cake batter which includes emulsifier combination (cake gel). Using of emulsifiers increased the amount of unfolded protein at the air water interface by replacing the folded protein due its amphiphilic nature thus promote incorporation of air into the batter and increased the volume. According to the table 4.12, both cake batters represent the same height. Therefore it revealed that 5g of cake gel mixture can replaced one egg of a cake batter. When compared the baked cake height, values were equal to 3.5 cm. Crumb structure of the cake with egg replaces also didn't show significant different with the normal cake. Moisture % of the both cakes are between the values of 15-27% which not exceeding the SLSI standards (appendix 05).

Table 4.12 Reading according to different parameters of cakes

parameters	Cake with egg replaces	Normal cake
Height of the batter	2cm	2cm
Height of baked cake	3.5cm	3.5cm
Weight of the cake	340g	350g
Moisture%	20.12%	25.70%
PH value	7.53	7.44

Therefore it proves that, 5% the cake gel product can successfully replaced the 50% of eggs in a cake recipe.

4.11 Sensory evaluation

4.11.1 Sensory evaluation of the taste of cakes

Table 4.13 statistically analyzed result of the sensory evaluation of taste

Sample	median
1(405)	3.0000
2(312)	2.0000

W= 950.0

P= 0.6100 or p= 0.6005 adjusted for ties

According to the statistically analyzed result of the test statistic w =950.0 has a p value of 0.6100 or 0.6005 when adjusted for ties. Therefore p value is not less than the chosen level of 0.05. It concludes that there is insufficient evidence to reject Ho. Therefore the data does not support the hypothesis that there is a difference between the population median. Taste of the two cake samples have no significant different at 5% significant level.

4.11.2 Sensory evaluation of the texture of the cakes

Table 4.14 statistically analyzed result of the sensory evaluation of texture

Sample	Median
1(405)	2.0000
2(312)	2.0000

W= 964.5

P = 0.4688 or P=0.4548 adjusted for ties

According to the statistically analyzed result of the test statistic w =964.5 has a p value of 0.4688 or 0.4548 when adjusted for ties. Therefore p value is not less than the chosen level of 0.05. It concludes that there is insufficient evidence to reject Ho. Therefore the data does not support the hypothesis that there is a difference between the population median. Texture of the two cake samples have no significant different at 5% significant level.

4.11.3 Sensory evaluation of the color of the cakes

Table 4.15 statistically analyzed result of the sensory evaluation of color

Sample	Median
1(405)	2.0000
2(312)	2.0000

W= 1002.5

P= 1.1984 or P= 0.1792 adjusted for ties

According to the statistically analyzed result at the test statistic w =1002.5 has a p value of 1.1984 or 0.1792 when adjusted for ties. Therefore p value is not less than the chosen level of 0.05. It concludes that there is insufficient evidence to reject Ho. Therefore the data does not support the hypothesis that there is a difference between the population median. Color of the two cake samples have no significant different at 5% significant level.

4.11.4 Sensory evaluation of the moistness of the cakes

Table 4.16 statistically analyzed result of the sensory evaluation of moistness

Sample	Median
1(405)	3.0000
2(312)	2.0000

W= 1007.5

P= 0.1738 or P= 0.1603 adjusted for ties

According to the statistically analyzed result at the test statistic w =1007.5 has a p value of 0.1738 or 0.1603 when adjusted for ties. Therefore p value is not less than the chosen level of 0.05. It concludes that there is insufficient evidence to reject Ho. Therefore the data does not support the hypothesis that there is a difference between the population median. Moisture of the two cake samples have no significant different at 5% significant level.

4.11.5 Sensory evaluation of the odour of the cakes

Table 4.17 statistically analyzed result of the sensory evaluation of odour

Sample	Median
1(405)	2.0000
2(312)	2.0000

W= 993.0

P= 0.7958 or P= 0.7854 adjusted for ties

According to the statistically analyzed result at the test statistic w =993.0 has a p value of 0.7958 or 0.7854 when adjusted for ties. Therefore p value is not less than the chosen level of 0.05. It concludes that there is insufficient evidence to reject Ho. Therefore the data does not support the hypothesis that there is a difference between the population median. Odour of the two cake samples have no significant different at 5% significant level.

4.11.6 Sensory evaluation of the overall acceptability of the cakes

Table 4.18 statistically analyzed result of the sensory evaluation of overall acceptability

Sample	Median
1(405)	2.0000
2(312)	2.0000

W= 953.0

P= 0.5793 or P= 0.5509 adjusted for ties

According to the statistically analyzed result at the test statistic w =953.0 has a p value of 0.5793 or 0.5509 when adjusted for ties. Therefore p value is not less than the chosen level of 0.05. It concludes that there is insufficient evidence to reject Ho. Therefore the data does not support the hypothesis that there is a difference between the population median. Overall acceptability of the two cake samples have no significant different at 5% significant level.

4.12 Cost calculation

Total cost of material (with vat) used in developed cake egg replacing additive (see appendix 07)	=Rs 214.13 /kg
Quantity of the product required for 1kg cake	=5g x 10 50g
Total cost for the cake gel additive for a 1kg of cake	= (214.13/1000) x 50 =Rs.10.70
Cost of one egg at market	=Rs.8.00
Cost for the egg at egg replaced cake (1kg)	=8.00 x 2 1/2 =Rs. 20.00
Total cost at a egg replacing cake (1kg)	=20.00+10.70 Rs.30.70
Total cost for the egg at non egg replaced cake (1kg)	=Rs8.00 x 5 =Rs.40.00
Total cost reduction per 1kg of cake due to the use 50% egg replaced cake gel additive	= 40.00- 30.70 Rs.9.30
Total egg cost reduction as % (per kg of baked cake)	= (9.30/40) x 100 23.25%

CHAPTER 05

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

After considering all the observations and results from beginning to end, fallowing conclusion can be expressed.

- There is a 87% of future market demand for cake egg replacing agent.
- Cost and shelf life are the most considering factors for demand of a cake egg replacing agent.
- 38% of bakeries expect gel texture and same percentage prefers any texture for cake egg replacing agent.
- Mixture (temperature 90^0C) of 14g Distilled Monoglyceride (more than 90% Monoglyceride content), 11g of Polyglycerol ester and 34.7 ml of water form an alpha stable gel structure at room temperature.
- Sorbitol with propylene glycol respectively 30g and 10g can maintain the above formed stable gel structure.
- 5g of the developed gel type egg replacing cake additive can be replaced 50% of a Madeira cake (100g flour weight).
- 8ml of water with 5g of cake gel (for 100g of flour weight) maintain the maximum volume of a 50% egg replaced cake.
- Texture, taste, color, moistness and odour of 50% egg replaced cake are not significantly different to a normal Madeira cake.

- Overall acceptability of 50% egg replace cake is not significantly different to a normal cake.

5.2 Recommendation

- Distilled Monoglyceride should have less than 1% free fatty acids
- Shelf life evaluation for 50% egg replaced cake should be carrying out.
- Suitability of the product can be test to the "All in process method" to reduce the whipping time

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APPENDIX -01

Questionnaire for the market research

1. Do you make cakes at your bakery?

   Yes ☐ No ☐

2. How many cakes were released to the market per week?

   10> ☐ 10- 50 ☐ 50< ☐

3. What are the basic ingredients that you use when make cakes?

   Flour ☐ Butter ☐ only egg ☐

   Sugar ☐ egg with egg replacing agent ☐

4. What type of cake your bakery produced most?

   Butter cake ☐ chocolate cake ☐ fruit cake ☐

5. If there is a product, replacing egg % of a cake, do you suppose to buy it?

   Yes ☐ no ☐

6. If you buy that type of a product what are the basic points that you considered? (number according to your priority starting from1)

   Price ☐ shelf life ☐ texture ☐ color ☐

7. What type of texture you accept most?

   Gel ☐ cream ☐ liquid ☐ any ☐

Thank you!

APPENDIX -02

Specification of Glycerol Monostearate

Analytical parameters	Standard	Results
Appearance	White powder	White powder
Acid value	3.0 max	1.063
Iodine value	2.0 max	0.610
Saponification value	160-175	170.173
Monoester content	40%min	40.29
Free glycerin	3.5% max	2.976
Melting point	58C0 $\pm$ 3	58C0
Moisture content	Less than 2	0.545
Lovibond 5 ¼' cell	Max 1.5R 10.0Y	1.1R 4.7Y

APPENDIX – 03

Specification of polyglycerol esters

Product type Polyglycerol esters

Declaration Polyglycerol esters of fatty acids E475

Product data

Appearance	off-white powder
Lipid source	Palm oil
Iodine value g iodine / 100g, max	2
Saponification value mg KOH/g	140-155
Free fatty acids (as % oleic acid) max	6
Melting point, approx 0C	58

APPENDIX- 04

Specification of Distilled Monoglyceride

Product type Distilled Monoglyceride

Declaration Mono and Diglyceride of fatty acids E471

Product data

Appearance	off-white powder
Lipid source	Vegetable fat
Monoglyceride	90
Monoglyceride ,typical value %	95
Free glycerol max %	1.0
Free fatty acid max %	1.5
Iodine value, g iodine/100g, max	2
Melting point, approx ^{0}C	68

APPENDIX -05

SLS Standards required for cakes

Characteristics	Requirements for cakes
Moisture % by mass	15- 27
Acid insoluble ash, on dry basis, % by mass, max	0.1

(Source: Sri Lanka Standards institution, SLS 1074:1995)

APPENDIX -06

Sensory evaluation ballot paper

Name:.....

Date:.....

Sample codes:- 405 312

Like extremely.....1

Like very much.....2

Like moderately.....3

Like slightly.....4

Neutral.....5

Dislike slightly.....6

Dislike moderately.....7

Dislike very much.....8

Dislike extremely.....9

Functional properties	405	312
Taste		
Texture		
Color		
Moistness		
Odour		
Overall acceptability		

Thank you!

APPENDIX 07

Statistically analyzed data of sensory evaluation

Sensory evaluation of taste of cakes

Mann-Whitney Test and CI: sample 405, sample 312

```
sample 4   N =  30     Median =       3.000
sample 3   N =  30     Median =       2.000
Point estimate for ETA1-ETA2 is       0.000
95.2 Percent CI for ETA1-ETA2 is (-1.000,1.000)
W = 950.0
Test of ETA1 = ETA2  vs  ETA1 not = ETA2 is significant at 0.6100
The test is significant at 0.6005 (adjusted for ties)

Cannot reject at alpha = 0.05
```

Sensory evaluation of texture of cakes

Mann-Whitney Test and CI: sample 405, sample 312

```
sample 4   N =  30     Median =       2.000
sample 3   N =  30     Median =       2.000
Point estimate for ETA1-ETA2 is      -0.000
95.2 Percent CI for ETA1-ETA2 is (-0.000,1.000)
W = 964.5
Test of ETA1 = ETA2  vs  ETA1 not = ETA2 is significant at 0.4688
The test is significant at 0.4548 (adjusted for ties)

Cannot reject at alpha = 0.05
```

Sensory evaluation of color of cakes

Mann-Whitney Test and CI: sample 405, sample 312

```
sample 4   N =  30     Median =       2.000
sample 3   N =  30     Median =       2.000
Point estimate for ETA1-ETA2 is      -0.000
95.2 Percent CI for ETA1-ETA2 is (-0.000,1.000)
W = 1002.5
Test of ETA1 = ETA2  vs  ETA1 not = ETA2 is significant at 0.1984
The test is significant at 0.1792 (adjusted for ties)

Cannot reject at alpha = 0.05
```

Sensory evaluation of moistness of cakes

Mann-Whitney Test and CI: sample 405, sample 312

```
sample 4   N =  30     Median =       3.000
sample 3   N =  30     Median =       2.000
Point estimate for ETA1-ETA2 is       0.000
95.2 Percent CI for ETA1-ETA2 is (-0.000,1.000)
W = 1007.5
```

```
Test of ETA1 - ETA2  vs  ETA1 not = ETA2 is significant at 0.1738
The test is significant at 0.1603 (adjusted for ties)

Cannot reject at alpha = 0.05
```

Sensory evaluation of odour of cakes

Mann-Whitney Test and CI: Sample 405, sample 312

```
Sample 4    N =  30     Median =       2.000
sample 3    N =  30     Median =       2.000
Point estimate for ETA1-ETA2 is      -0.000
95.2 Percent CI for ETA1-ETA2 is (-1.000,1.000)
W = 933.0
Test of ETA1 = ETA2  vs  ETA1 not = ETA2 is significant at 0.7958
The test is significant at 0.7843 (adjusted for ties)

Cannot reject at alpha = 0.05
```

Sensory evaluation of overall acceptability of cakes

Mann-Whitney Test and CI: sampel 405, sample 312

```
sampel 4    N =  30     Median =       2.000
sample 3    N =  30     Median =       2.000
Point estimate for ETA1-ETA2 is       0.000
95.2 Percent CI for ETA1-ETA2 is (0.000,1.000)
W = 953.0
Test of ETA1 = ETA2  vs  ETA1 not = ETA2 is significant at 0.5793
The test is significant at 0.5509 (adjusted for ties)

Cannot reject at alpha = 0.05
```

APPENDIX 08

Cost of material of cake egg replacing agent

Ingredient	Quantity/kg	Unit price	Cost (Rs)
Sorbitol	0.3000	90.00	27.00
E 421	0.1400	600.00	84.00
E 475	0.1100	700.00	77.00
E 1520	0.1000	250.00	25.00
Stearic acid	0.0040	120.00	0.48
KOH	0.0033	200.00	0.65
water	0.3428	-	-
Cost of material	1.0000		214.13

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