UNIVERSITI PUTRA MALAYSIA

OPTIMIZATION OF BAKING PARAMETERS OF CAKE MADE FROM LEFT-OVER ICE CREAM USING RESPONSE SURFACE METHODOLGY

IDA SYARIZA KAMARUDDIN

Ip
FK 2021 12

OPTIMIZATION OF BAKING PARAMETERS OF CAKE MADE FROM LEFT-OVER ICE CREAM USING RESPONSE SURFACE METHODOLOGY

IDA SYARIZA BINTI KAMARUDDIN

192272

PROJECT REPORT SUBMITTED IN PARTIALLY FULFILLMENT OF THE REQUIREMENTS FOR THE

BACHELOR OF PROCESS AND FOOD ENGINEERING WITH HONOURS

DEPARTMENT OF PROCESS AND FOOD ENGINEERING

FACULTY OF ENGINEERING

UNIVERSITI PUTRA MALAYSIA

2020/2021

ACKNOWLEDGEMENT

All praises be to ALLAH, Lord of the universe. Only by His grace and mercy this thesis can be completed in the given time.

I would like to express my foremost appreciation to my supervisor for this project, Dr. Nur 'Aliaa Abdul Rahman for giving me this opportunity to do the final year project entitled "OPTIMIZATION OF BAKING PARAMETERS OF CAKE MADE FROM LEFT-OVER ICE CREAM USING RESPONSE SURFACE METHODOLOGY". It is my pleasure to have a chance to do this final year project. She has always patiently guided me throughout this project. Her guidance and advice have contributed to great part of the research. Without her guidance, this thesis would not have been completed very well.

Special thanks of appreciation to Ts. Dr. Mohd Salahuddin Mohd Basri for guiding me to complete this project. Also, my deepest gratitude goes to my examiners, Pn. Zanariah Mohd Dom and Prof. Ir. Dr. Chin Nyuk Ling on thoughtful comments and advice to improve my project work. I would like to convey my huge appreciation to Department of Process and Food Engineering staff and Laboratory staff that directly or indirectly helping me to finish the project. Not to forget, I would like to thank my Final Year Project partner, Syahmeza binti Muhammad Esa for helping me while conducting experiments for this project.

Finally, I would like to dedicate this thesis to my parents, Kamaruddin Mohamad and Hatifah Ali, all my siblings and my friends for always being supportive through my bachelor journey.

ABSTRACT

Baking is the last however, the most crucial step in cake making because it involves closely related to the changes in texture, browning, and volume. The processing conditions, as well as the ingredients, have an impact on the properties of product of final bakery. This study was carried out due to no research on the use of response surface methodology to improve the textural and colour change of cake made from melted left-over ice cream. The main objective of the research is to find the best combination of factors for achieving the lowest firmness and colour change while maintaining the highest springiness in cake made with melted left-over ice cream. In addition, the effect of baking time and temperature on the textural properties of the cake as well as the total colour change was investigated. Two stages of production were conducted which were the design of experiment using the central composite design (CCD) and the production of cakes. The central composite design (CCD) technique was used to generate 39 runs based on two factors with five levels each: baking time (30, 35, 40, 45, and 50 minutes) and baking temperature (150, 160, 170, 180, and 190 °C), as well as three replications. Results from ANOVA showed that all factors were statistically significant at $p < 0.05$. The estimated regression coefficient, R^2, for each response (firmness, springiness and colour change) were 88.10%, 85.83% and 91.11%, respectively. Baking temperature between 170°C and 190°C, and within 30 and 35 minutes for baking time resulted in cake with high firmness. High region springiness was observed for baking time between 30- and 40 minutes, and within 150°C and 165°C for baking temperature. Also, high total colour change was observed for baking time between 35 minutes and 50 minutes, and within 175°C and 190°C for baking temperature. The optimized values for baking time (V1) = 37 minutes

and baking temperature (V2) = 150 °C with minimum value of firmness, colour change and maximum value springiness. The predicted model (regression coefficient model) proved to be accurate in predicting the best factor value. The experimental validation showed the average relative deviation for firmness, springiness and total colour change was 9.37%, 0.80% and 2.37%, respectively.

ABSTRAK

Proses membakar adalah langkah yang terakhir dan paling penting dalam pembuatan kek kerana melibatkan perubahan yang berkaitan dengan tekstur, warna coklat, dan isipadu. Sifat produk kek akhir dipengaruhi bukan sahaja oleh ramuan, tetapi juga oleh keadaan pemprosesan. Kajian ini dilakukan kerana kurangnya penelitian sebelumnya mengenai penggunaan metodologi permukaan tindak balas untuk memperbaiki tekstur dan perubahan warna kek yang dibuat dari ais krim cair. Objektif utama penyelidikan adalah untuk mencari kombinasi faktor terbaik untuk mencapai kekerasan dan perubahan warna yang paling rendah sambil mengekalkan kekenyalan tertinggi dalam kek. Di samping itu, pengaruh masa dan suhu membakar pada sifat tekstur kek serta perubahan warna keseluruhan telah dikaji. Dua peringkat pengeluaran dilakukan iaitu reka bentuk eksperimen menggunakan reka bentuk komposit pusat (CCD) dan penghasilan kek. Teknik reka bentuk komposit pusat (CCD) digunakan untuk menghasilkan 39 varian berdasarkan dua faktor dengan masing-masing lima tahap: waktu membakar (30, 35, 40, 45, dan 50 minit) dan suhu mebakar (150, 160, 170, 180, dan 190 ° C), serta tiga ulangan. Hasil dari ANOVA menunjukkan bahawa semua faktor signifikan secara statistik pada $p < 0.05$. Pekali regresi yang dianggarkan, R^2, untuk setiap tindak balas (kekerasan, kekenyalan dan perubahan warna) masing-masing adalah 88.10%, 85.83% dan 91.11%. Suhu membakar antara 170 ° C hingga 190 ° C, dan dalam masa 30 dan 35 minit untuk waktu membakar menghasilkan kek dengan kekerasan yang tinggi. Purata kawasan kekenyalan kek yang tinggi diperhatikan untuk waktu membakar antara 30- dan 40 minit, dan dalam suhu 150 ° C hingga 165 ° C untuk suhu membakar. Juga, perubahan warna kerak kek yang tinggi diperhatikan untuk waktu membakar antara 35 minit dan 50 minit, dan dalam suhu 175 ° C dan 190 ° C untuk suhu membakar. Nilai yang dioptimumkan untuk waktu membakar (V1) = 37 minit dan suhu membakar (V2) = 150 ° C dengan nilai kekerasan minimum serta perubahan warna dan nilai maksimum kekenyalan. Model ramalan (model pekali regresi) didapati tepat dalam meramalkan nilai faktor optimum. Pengesahan eksperimen menunjukkan purata penyimpangan relatif untuk kekerasan, kekenyalan dan perubahan warna keseluruhan masing-masing 9.37%, 0.80% dan 2.37%.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

MSNF	Milk Solid Non-Fat
RSM	Response Surface Methodology
CCD	Central Composite Design

CHAPTER 1

INTRODUCTION

In this chapter, an overview of the project conducted which consist of the background, problem statement, objectives and scope of study was described.

1.1 Background of left-over ice cream and cake made from melted left-over ice cream

Ice cream is a popular dairy product treat that appeal among consumer of all ages. During hot day, ice cream is the best dessert to be consumed as it is refreshing and delicious. It is commonly served and sold in many forms which are individual single-serve such as in cones, sticks and small cups meanwhile typically found at grocery stores served in tubs, pints, and half gallon size. In 2010, 1318.4 million gallons of ice cream were produced from United States (Goff, n.d.)

Indeed, ice cream has a foam structure composed of a fat globule network, ice crystals, a serum phase, and air cells. With continuous agitation, ice cream is a dessert that made from mixture of milk, cream, sugar, and other ingredients. The main general ingredients to make ice cream are milkfat, milk solid non-fat (MSNF), sweetener, stabilizers, emulsifier, and water. The formulation consideration each of the ingredient is crucial to bring of the creamy, soft and a quality product of ice cream.

The range of components in ice cream may vary according to the formulation that has been considered in making ice cream. With these consideration in mind, ice cream can be categorised to super-premium, premium, standard and economy brands. This ice cream typically varies by fat content, total solids, overrun, flavours, packaging and cost (Tharp & Young, n.d.). The higher the fat content, the more expensive the ice cream. Likewise, a fresh trend in the industry was created by a new ice cream category known as 'Premium Light' that provides the eating quality of premium ice cream with lower fat content (Tharp & Young, n.d.).

Aside from that, ice cream is one of the food materials that is extremely temperature sensitive. Ice cream is a delicate product that must be kept below always freezing and protected from ambient heat during storage and transportation. Two things occur when ice cream is placed in an ambient environment to melt (such as a scoop on a plate): the ice melts and the fat-stabilized foam structure collapses and these may result in changes in ice crystal size due to recrystallization phenomenon (Nazaruddin et al., 2008). The quality of ice cream is reduced and its shelf life is shortened when the mean ice crystal size is increased too much (Leducq et al., 2015).

The ice cream melting process can be divided into three phases: the lag phase, the fast-melting phase, and the stationary phase. Heat penetrates the ice cream during the lag phase, causing ice crystals to melt and dilute the serum phase, lowering its viscosity. Ice cream meltdown progresses to the second stage as the viscosity and flowability of the diluted serum phase decreases and fast-melting phase, in which ice cream drips through the wire mesh due to gravity's driving force to reach maximum meltdown rate (Goff & Hartel, 2013). Ice cream collapses at a rate and to a degree during the fast-melting phase, depending on the remaining structures, such as air cells and fat clusters or globules. If there are many fat clusters surrounding the air cells, they will collide and jam as the serum drains, forming a three-dimensional network. Meltdown is gradually slowed and comes to a halt with air cells phase of inactivity. Ice cream can drip through completely without leaving foam on the mesh if there are few fat clusters.

There are days in the ice cream business when retailers are unable to finish the ice cream in the machine. This could be several factors such as dwindling number of customers during winter season and occurrence of power shutdown at the shop (Jamaludin, 2020). In this instance, melted left-over ice cream appears to have a lot of potential for being converted into a bakery product, such as cake as it is consisting of ingredients that similar to ice cream i.e fat, protein, sugar, emulsifier, stabilizer and water.

A good quality cake should have large volume with a fine uniform moist crumb besides having a good colour and sheen, a good flavour, and the general appearance should be attractive, with a good eye appeal. During baking, volume expansion, enzymatic activities, protein coagulation and partial gelatinization of starch in batter are the most apparent interactions and affect the final product quality such as firmness, springiness and moisture content of crumb (Pyler & Gorton, 2014).

Baking temperature and time in the oven are two factors that influence the quality of a cake. As normal practices in baking processes, too high baking temperature will cause high crust colour, lack of volume with peaked tops, close or irregular crumb, and probably all the faults due to under-baking (Sani et al., 2014). In predicting the optimum baking parameters (time and temperature), statistical analysis and regression coefficient model (mathematical model) were therefore necessary.

1.2 Problem Statement

Leftover ice cream appears to have a lot of potential as a bakery product like a cake, muffin, or bread. However, numerous studies have focused the amounts of ingredient have been recommended in various homemade recipe books, no scientific study of the optimization of the baking parameters of cake made from melted left-over ice cream has been previously reported. At present, no studies on the optimization of the baking parameters such as time and temperature of the cake that made from melted left-over ice cream have been published.

A high-quality cake has moist and fine grains, even crumbs, tender texture, optimal volume, a delicate crust, and a light browning. The quality of a cake depends on several processing parameters, such as air flow, heat supply, humidity, oven load and baking time. Excessive baking temperature will result in high crust colour, lack of volume, peaked tops, closely packed or irregular crumbs, and the disadvantages of under-baking, according to previous studies on the effects of baking parameters. Otherwise, a low baking temperature can result in a pale crust colour, a lot of volume, and a poor crumb texture (Sani et al., 2014). The physical qualities such as specific volume, hardness and color were significantly influenced by the temperature and duration of baking (Im et al., 2003).

RSM (Response Surface Methodology) is a mathematical and statistical approach to problem solving practise that makes use of useful tools to develop, improve, and optimize processes. It is widely used to examine the interactions between factors and one or more response variables. Most researchers have used this method in optimizing the formulations and effects of processing conditions on the quality of bakery products (Gan et al., 2007). Since the widespread use of response surface methodology (RSM), specifically central composite design (CCD), in process optimization, it will, therefore, be used in this study to investigate the effect of factors including baking time and temperature on firmness, springiness and colour change of the cake made from melted left-over ice cream with large inclusion. Optimization and validation processes were performed to achieve the best possible combination of variables which produce the lowest firmness and colour change of crust and highest springiness in cake made from melted left-over ice cream.

1.3 Objectives

The main objective of this study was to optimize baking time and temperature on cake made from melted left-over ice cream in terms of physical quality (firmness, springiness and colour change).

1.4 Scope of the Study

The scope of the study was to design the experiment based on response surface method using MINITAB software and cakes were produces from melted left-over ice based on the designed experiment. Then, the analysis of the cake properties (firmness, springiness and colour change) were determined after production of the cake made from melted left-over ice cream. From the data analysis, the optimization of the baking parameters (time and temperature) on cake made from left-over ice cream was optimized to obtain the best combination of time and temperature with minimum value of firmness, colour change and maximum value springiness.

CHAPTER 2

LITERATURE REVIEW

This chapter will be discussed about the literature review on ice cream in all view based on journals paper, review paper and website that can be referred.

2.1 Overview of ice cream

Ice cream is a frozen dairy product that is made by freezing a pasteurised mixture with agitation to incorporate air and ensure consistency (*Ice Cream - Wendell S. Arbuckle - Google Books*, n.d.). The mix is made up of milk products, sugar, dextrose, corn syrup (dry or liquid), water, and may also contain eggs or egg products, flavourings, and a stabiliser or emulsifier. Frozen desserts, which include ice cream, frozen custard, ice milk, sherbet, water ice, and frozen confections, are generally classified as ice cream and related products.

2.2 Ice cream mix ingredients

The basic ingredients in ice cream mix are milkfat, milk solid non-fat (MSNF), sweetener solids, stabilizers and emulsifiers, flavorings, and water. The functional properties imparted by these different basic ingredients from which the mix is formulated and quite varied. According to Goff (n.d.), ice cream composition has greater than 10%

milkfat by legal definition, and usually between 10% and as high as 16% fat in some premium ice creams, 9 to 12% milk solids-not-fat (MSNF) as this component, also known as the serum solids, contains the proteins (caseins and whey proteins) and carbohydrates (lactose) found in milk, 12 to 16% sweeteners usually a combination of sucrose and glucose-based corn syrup sweeteners, 0.2 to 0.5% stabilizers and emulsifiers 55% to 64% water which comes from the milk or other ingredients. Table 2.1 lists the ingredients that are commonly used in ice cream recipes.

Table 2.1: Components in common ice cream mix recipes.

Component	Range (%)
Milkfat	10-16
Milk solids non-fat	9-12
Sucrose	9-12
Corn syrup solids	4-6
Stabilizers/Emulsifiers	0-0.5
Total solids	36-45
Water	55-64

2.2.1 Milkfat

Fat plays an important role in the stabilization of the ice cream structure, as partially coalesced fat is primarily responsible for air bubble and foam structure stabilisation (Koxholt et al., 2001). The fat component of the mix increases the richness of flavour of ice cream, produces a characteristic smooth texture by lubricating the palate, helps to give body, and aids in producing desirable melting properties (Marshall et al., 2003). The main or only fat source for dairy ice cream formulations is milkfat, which comes from cream, sweet (unsalted) butter, frozen cream, condensed milk blends, or whey cream. Fresh sweet cream from fresh sweet milk is the best source of butterfat in ice cream for high quality flavour and convenience. Non-dairy ice cream can also use vegetable fats as a fat source.

Fats are largely made up of triglycerides (98%), together with small amounts of phospholipids and diglycerides. Triglycerides are esters of glycerol (propan- 1,2,3-triol) and fatty acids (monocarboxylic acids). The fatty acids determine the physical properties of the triglyceride, such as the melting and crystallization behaviour and viscosity (Clarke, 2004).

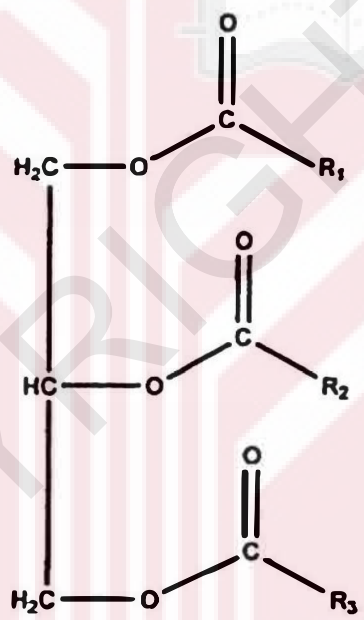


Figure 2.1: Structure of tryglycerides.

2.2.2 Milk solids non-fat (MSNF)

The lactose, caseins, whey proteins, and minerals (ashcontent) of the product are all present in serum solids or milk solids-not-fat (MSNF). They are an important ingredient for improving ice cream texture, as protein functionality helps to give body and chew resistance to the finished product. They are also capable of allowing a higher overrun without the characteristic snowy or flaky textures associated with high overrun, as protein functionality helps to give body and chew resistance to the finished product (Goff, n.d.). Concentrated skimmed milk and spray process low heat skim milk powder are the best sources of serum solids for high-quality products.

Off flavours that may arise from some of the products, as well as an excess of lactose that can lead to the sandiness defect that occurs when lactose crystallises out of solution, are some of the limitations to their use. Lactose concentrations in the serum phase that are too high may lower the finished product's freezing point to an unacceptably low level.

2.2.3 Sweeteners

In ice cream and frozen confections, typical levels of sweeteners range from 8% to 14%. Sweeteners lower the freezing point of a frozen confection and control the size of the ice crystals that form as the mix freezes, giving these products their distinctive creaminess (Helstad, 2018). Sweeteners' primary purpose is to increase product acceptance by making it sweet and enhancing the pleasing creamy flavour and delicate fruit flavour. A flat taste is produced by a lack of sweetness; too much sweetness tends to overshadow desirable flavours.

Sweeteners also called 'nutritive' or 'caloric' sweeteners because they contribute metabolisable energy to the diet. Cane and beet sucrose ('sugar'), invert sugar, Corn Starch Hydrolysate Syrup (CSS), high maltose syrup, fructose or high fructose syrup, maltodextrin, dextrose, maple syrup or maple sugar, honey, brown sugar, and lactose are examples of sweeteners used in ice cream. A combination of sucrose (10-12 percent) and CSS is the most common nutritive sweetener (3-5 percent) (Goff & Hartel, 2013).

2.2.4 Stabilizers

Ice cream stabilisers are a class of ingredients (mostly polysaccharides) that are commonly used in ice cream recipes. Stabilizers in ice cream are primarily used to increase mix viscosity, stabilise the mix to prevent wheying off (e.g., carrageenan), and aid in the suspension of flavouring particles (Goff & Hartel, 2013). The increased viscosity of the unfrozen phase in ice cream is responsible for many of these functions. Stabilizers must also have a clean, neutral flavour, not bind to ice cream flavours, aid in ice cream meltdown, and provide a desirable texture when consumed. Excessive mix viscosity contributes to a heavy, soggy body, and production of undesirable melting characteristics are all drawbacks. Although stabilisers increase the viscosity of the mixture, they have little or no effect on the freezing point.

Most ice cream manufacturers use commercial stabiliser blends created by specialised firms using primary suppliers' ingredients. These blends are usually a mix of stabilisers and emulsifiers, but they are sometimes just called stabilisers. Guar and locust bean gums (LBGs), cellulose gum (primary hydrocolloids), carrageenan (secondary hydrocolloid), mono/diglycerides, and polysorbate 80 are the most commonly used ingredients in regular ice cream mixtures (the emulsifiers).

2.2.5 Emulsifier

Emulsifiers are utilized to promote fat destabilization, which affects sensory properties of ice cream. Emulsifiers are a class of compounds found in ice cream that help to develop the proper fat structure and air distribution required for smooth eating and good meltdown ice cream to be desired. Emulsifiers are not used more than 0.2% on weight basis. Polysorbate and sorbitan tristearate up to 0.1% are now allowed in dairy products as safe (Abbas Syed, 2018). Because each molecule of an emulsifier has a hydrophilic and ahydrophobic portion, they reside at the fat-water interface (Goff, n.d.). As a result, they reduce the interfacial tension, or the force between the two phases of the emulsion. This results in protein desorption from the fat droplet surface, which promotes fat emulsion destabilisation (due to a weaker membrane), resulting in a smooth, dry product with good meltdown properties, as shown in Figure 2.2.

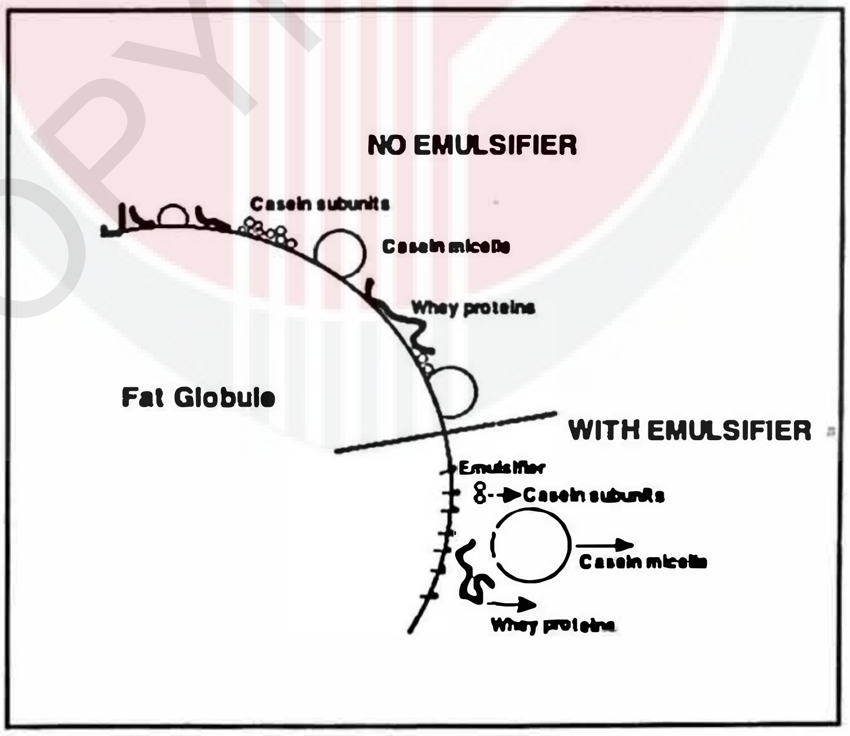


Figure 2.2: The mechanism of emulsifier in ice cream.

2.3 Left-over ice cream

Something that remains unused or unconsumed, most commonly food, is referred to as left-over. The amount of unused ice cream left over at the end of the ice cream production is known as left-over ice cream (Jamaludin, 2020). Food waste includes leftover ice cream. According to (Girotto et al., 2015), food waste consists of materials that were originally intended for human consumption but were later discarded, lost, degraded, or contaminated. Food waste is a growing issue that affects all aspects of waste management, from collection to disposal; finding sustainable solutions involves all participants in the food supply chain, including agricultural and industrial sectors, retailers, and final consumers.

There is not a lot of research on the use of unused ice cream in ice cream production. Typically, the issue of left-over ice cream arises in a small-scale ice cream company or ice cream shop that only sells or serves soft serve and hard ice cream from the freezer. Not only that, but issues with left-over ice cream have also arisen in an ice cream start-up company, as they are still experimenting and predicting customer patterns.

Usually, the cold weather is one of the factors that lead to ice cream leftover. When the ground is frozen and the air is chilled, cravings for cold ice cream treats tend to diminish. Many ice cream parlors see a decrease in traffic and a loss of profits during winter months (Anonymous (a), n.d.). During winter, people prefer to eat hot or warm foods rather than ice cream. Thus, the possibility of ice cream not being consumed by customers in the winter season is high and at the end of the night shift causes the ice cream left-over.

2.3.1 Leftover ice cream practises in small-scale ice cream production

It is known that in ice cream parlours, at the end of the day, there is a considerable amount of left-over ice cream. These left-over have limited conservation times and are often thrown away. The quality of ice cream is dropped, as it is easy to melt, low taste and not smooth as before. Furthermore, the ice cream loses quality each time it is removed from the freezer and the surface begins to thaw. When frozen ice cream thaws, the ice crystals dissolve, allowing coagulation to proceed. It results in a melt with a weak structure, as opposed to the fat network in the original mix (Sherman, 1966). Reusing leftover ice cream the next day may result in an unpleasant taste on the ice cream, negatively impacting the ice cream shop's reputation.

2.3.2 Application of left-over ice cream

Since the beginning of time, being creative has been a defining characteristic of humans. Many websites on the internet provide recipes for using up ice cream that has been left over. The aim of the present invention is therefore to use these leftovers as a liquid component in a flour and yeast mixture to create bakery products such as croissants, brioches and/or similar product. A bakery product made from left-over milk chocolate ice cream is used to produce chocolate croissant as shown in Table 2.2 (Racca, 2020).

Table 2.2 Chocolate croissant from left-over ice cream.

Ingredient	1500g wholemeal croissant flour, 800g milk chocolate ice-cream, 20g salt and 10g powdered brewer's yeast.
Instruction	1. Mix for 20' until fully blended. 2. Final temperature of the mixture 20° C – 22°C. 3. Leave to rest at ambient temperature for at least 2 hours, keep in the refrigerator at +4°C. 4. Sheet and portion as required with 500g of butter, performing two 4-folds. 5. Place in a retarder-proofer for at least 12 hours at 26°C. 6. Bake at 200° C in a static oven for 14/16'.

2.4 Butter cake

A butter cake is a cake in which one of the main ingredients is butter. Butter cake is baked with basic ingredients: butter, sugar, eggs, flour, and leavening agents such as baking powder or baking soda. It is considered one of the quintessential cakes in American baking (Anonymous (b), n.d.). Furthermore, the ice cream is found to contain ingredients that are similar to those found in butter cake, such as sugar, fat or butter, and vanilla extract (Jamaludin, 2020).

2.4.1 Standard composition of butter cake

The creaming method is used in traditional recipes to incorporate air into the batter, giving the cake its characteristic dense and moist texture. Creaming is the method to beat the sugar and butter together to form a homogeneous batter (Kwan, 2021). To reduce mixing times and achieve similar results, modern butter cakes use chemical leavening in the form of baking soda or baking powder, or a combination of both. While the traditional recipe called for equal amounts of flour, fat, sugar, and eggs, today's recipes have multiple variations.

Table 2.3: Standard composition of butter cake (Sani et al., 2014).

Ingredient	Weight Composition (%)
Superfine Flour	38.12
Castor sugar	35.25
Butter	26.63
Fresh milk	23.50
Eggs	25.59
Baking powder	0.78
Vanilla essence	2.35

2.4.2 Butter cake production

Butter cakes are traditionally made using the creaming method, which involves beating the butter and sugar until fluffy to incorporate air into the butter. The eggs are gradually added to create an emulsion, which is then followed by alternating portions of wet and dry ingredients. When stored at room temperature, butter cakes are typically rich and moist, but when refrigerated, they stiffen, dry out, and lose flavour, making them unsuitable for filling or frosting in advance with ingredients that must be refrigerated, such as cream cheese frosting or pastry cream.

First, measure all the ingredients using a weighing at controlled room temperature of 20°C to 25°C. Using an electric mixer, beat the butter and sugar on medium speed for 8 to 10 minutes, or until fluffy and light. The method of beating the sugar and butter together to form a homogeneous batter is known as mixing. During the process, air bubbles will accumulate in the mixture. The tiny air bubbles in the cake expand during baking to give it its light, airy, fluffy, and soft texture (Kwan, 2021). After that, gradually add the egg and continue mixing for another five minutes. In a mixer, combine all of the dry ingredients, such as superfine flour and baking powder. As the final ingredient, add the vanilla extract. To avoid gluten formation, continue to mix the ingredients at the slowest speed possible. Once the batter is homogeneous and lump-free, remove it from the heat immediately. Finally, pour the batter into a baking tray and bake for 35 minutes at 180°C. The temperatures and times for baking butter cake may differ slightly from one oven to the next. The size and position of the oven's elements, which affect the time and temperature required, cause this variation.

2.5 Response Surface Methodology (RSM)

Response Surface Methodology (RSM) is one of the more popular methods in simulation optimization. The term Response Surface Methodology originates from the graphical representation of the effect of the independent variables on the dependent variables that is created after the mathematical model is fitted (Yolmeh & Mahdi Jafari, 1947). As several factors are considered in the formulation of food products, researchers are looking for ways to optimise each response (factor), which could be done using RSM, which is useful for multi-response processes.

A second order model will likely be required for the case of two variables. The second order model is widely used in response surface methodoly as it is very flexible which can take a wide variety of functional form, so it will often work well as an approximation to the true response surface. Secondly, it is easy to estimate the parameters (the β's) in the second-order model and there is considerable practical experience indicating that scond-order models work well in solving real response surface problems (Myers et al., 2015). A second order model as shown in Equation (1):

$$n = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2 \quad (1)$$

2.5.1 Central Composite Design (CCD)

A second-order model can be constructed efficiently with CCD. Box and Wilson (1951) developed this approach for the first time. The CCD consists of three-point types: factorial points, a central point, and axial points which are at a distance α from the central point (Czyrski & Jarzebski, 2020). CCD is appropriate for sequential experimentation and provides a reasonable amount of information for testing lack-of-fit while not involving an unusually large number of experimental runs. Also, CCD is appropriate to study factors with three and/or five levels.

Table 2.4 shows a comparison between full factorial design and RSM based on 5-level factors. When compared to a traditional method like factorial design, which requires 25 runs to complete an experiment, RSM only requires 13 runs. When there are more than two variables to consider, RSM is particularly useful. This not only lowers overall costs (material and testing), but it also reduces the amount of time spent on the experiment (Basri et al., 2020).

Table 2.4: Total number of experiments between factorial design and response surface methodology (Basri et al., 2020).

Factors	**Level**	**Total Number of Experiments**	
		Factorial Design	RSM
2	5	25 (5^2)	13
3	5	125 (5^3)	20
4	5	625 (5^4)	31
5	5	3125 (5^5)	52

CHAPTER 3

METHODOLOGY

In this chapter, the method of the experiment was explained. The step consists of two stages which are design of experiment based on response surface method and production of cakes from melted left-over ice cream. The design of experiment based on response surface method was conducted using MINITAB software and then cakes were produces from melted left over ice based on the designed experiment. Analyis of cakes properties (firmness, springiness and colour) were determined after production of cakes in the second stages. Data obtained from analysis was recorded and discuss in next chapter to obtain the optimize of time and temperature with minimum value of firmness, colour change and maximum value springiness.

3.1 Design of Experiment based on Response Surface Method (RSM)

In the determination of the optimum baking temperature and time, RSM was performed using the MINITAB software version 16.2 (LEAD Technologies, Inc., USA). A 2-factor, 5-coded level central composite design (CCD) was selected to accommodate the 13 experimental conditions (Gan et al., 2007). The responses, i.e, firmness, springiness and colour change of the cake were assumed to be influnced by these factors.

Table 3.1. Factors and levels used for firmness, springiness and colour change.

Factor	Unit	Notation	Level				
			-2	-1	0	1	2
Time	min	V1	30	35	40	45	50
Temperature	°C	V2	150	160	170	180	190

3.1.1 Experimental design

A central composite design (CCD) involving five levels and two factors, with three replications was applied for all design points, comprising a total 39 of experimental runs. The complete CCD with coded and uncoded levels of the factors are shown in Table 3.2. The value for the total block is 1 with the experiments carried out in randomized order.

Table 3.2. Design matrix.

Sample	Coded factor		Uncoded factor	
	V1	V2	V1	V2
S1	-1	-1	35	160
S2	1	-1	45	160
S3	-1	1	35	180
S4	1	1	45	180
S5	-2	0	30	170
S6	2	0	50	170
S7	0	-2	40	150
S8	0	2	40	190

S9	0	0	40	170
S10	0	0	40	170
S11	0	0	40	170
S12	0	0	40	170
S13	0	0	40	170
S14	-1	-1	35	160
S15	1	-1	45	160
S16	-1	1	35	180
S17	1	1	45	180
S18	-2	0	30	170
S19	2	0	50	170
S20	0	-2	40	150
S21	0	2	40	190
S22	-1	0	40	170
S23	0	0	40	170
S24	0	0	40	170
S25	0	0	40	170
S26	0	0	40	170
S27	-1	-1	35	160
S28	1	-1	45	160
S29	-1	1	35	180

S30	1	1	45	180
S31	-2	0	30	170
S32	2	0	50	170
S33	0	-2	40	150
S34	0	2	40	190
S35	0	0	40	170
S36	0	0	40	170
S37	0	0	40	170
S38	0	0	40	170
S39	0	0	40	170

3.2 Melted ice cream

Ice cream is often softened before being used in recipes or when it is too hard to scoop for eating. Ice cream was taken out from the freezer to let it stand at room temperature for 10 to 15 minutes. The ice cream was expected to melt completely during this period for total loss of the ice cream structure.

(a) (b)

Figure 3.1: (a) Ice cream at freezing temperature. (b) Melted ice cream at room temperature.

3.3 Production of cakes from melted left over ice cream

The melted left-over ice cream was used as a main ingredient in the production of formulated cakes. The preparation and production of cakes from melted left-over ice cream were conducted as followed below.

3.3.1 Formulation of cake samples

Preparation of cake from melted ice cream samples were conducted in the Food Processing Quality Lab, Faculty of Engineering, University Putra Malaysia (UPM). Four main ingredients were used in the production of sample cakes which are self-raising flour (Federal Flour Mills Berhad, Malaysia), durian flavour melted left-over ice cream (Proville Tech Sdn Bhd, Malaysia), granulated sugar (Central Sugars Refinery Sdn Bhd, Malaysia) and grade A eggs (Ladang Ternakan Prudence Sdn Bhd, Malaysia). All samples were prepared using the same amount of ingredients as shown in Table 3.3.

Table 3.3 Ingredients used in cake from melted left-over ice cream.

Ingredients	Unit
Self-raising flour	150 g
Granulated sugar	125 g
Melted left over ice cream	100 ml
Eggs	3 eggs

3.3.2 Weighed ingredients

The calculated number of dry products, such as self-raising flour and granulated sugar were weighed using a weighing balance. For melted left-over ice cream was measured using measuring cup.

Figure 3.2: The ingredients were weighed using a weighing balance.

3.3.3 Mixed

Three eggs were beat with granulated sugar in a mixing bowl for 300 seconds at a speed of 6 until pale and fluffy using the mixer (Model 5K5SS, KitchenAid, St. Michigan, USA). Self-raising flour was added, and the mixing continued at speed of 6 for 150 seconds. Then melted ice cream were added, and mixing was continued at stir mode for 150 seconds until all the ingredients inside homogenized.

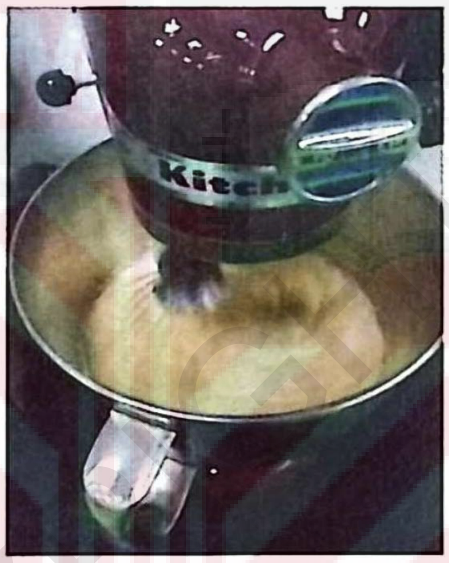


Figure 3.3: Mixing process.

3.3.4 Baking

After all the ingredients were mixed, the batter was poured into a cupcakes paper cup weighed 50g individually and baked based on experimental designed (Table 3.2) using an oven (Model OT52R, Khind, Malaysia). The baked cake then allowed to cool for 30 minutes in room temperature before stored in a closed container prior to testing.

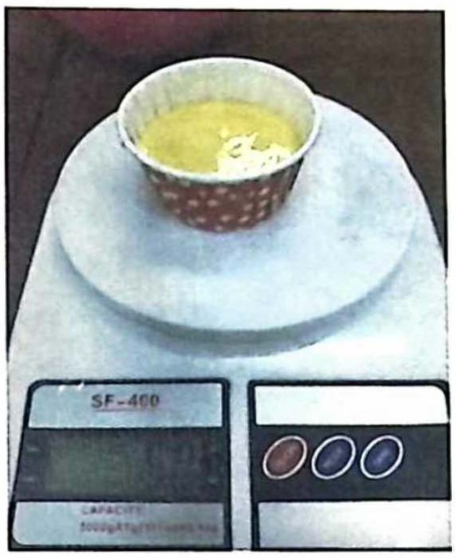


Figure 3.4: Batter was poured and weighed into a cupcakes paper before baking process.

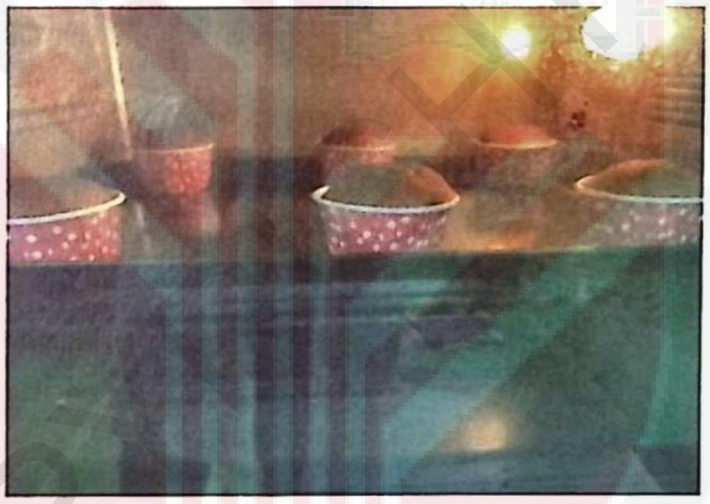


Figure 3.5: Cake was baked in the oven.

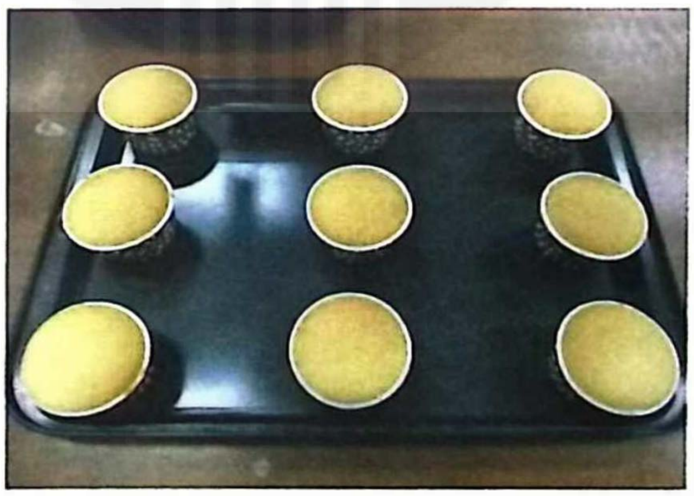


Figure 3.6: Cake was cooled at room temperature before prior testing.

3.4 Analysis of cake

The analysis of cake properties was performed on the sample of cake produced from melted left-over ice cream. The analysis that was conducted is textural properties and colour measurement. The textural analysis of cake consists of firmness and springiness. Then, data were analysed to obtain optimize baking temperature and time.

3.4.1 Textural properties analysis

Texture profile analysis were measured using Method CAK1/P36R (Stable Microsystems 2011). Cross sections of 2.5 cm thickness were cut from the center of each cake and subjected to a modified compression test using a TA-XT2I Texture Analyzer (TA.XT Plus, Stable Micro System, England) fitted with a 36-mm diameter cylindrical probe. A standard double-cycle program was used to compress the cake at a probe speed of 1.0 mm/s and with 50% strain of its original cube height (Sani et al., 2014). Data were collected and expressed as force versus time. Firmness and springiness were calculated from the TPA graph.

Figure 3.7: TA-XT2 texture analyzer (Stable Microsystems, Surrey, UK).

3.4.2 Colour measurement

The top surface colour of the baked cake was measured with HunterLab Ultrascan PRO color spectrophotometer (Hunter Associates Laboratory, Inc., Reston, VA, USA) and expressed as the International Commission on Illumination (CIE) L*, a*, and b* color scale (Mior Zakuan Azmi et al., 2019). The device was calibrated using a standard white tile provided by the manufacturer. Measurements were taken directly on the top of muffins to ensure accurate measurement of the crust color. Total color change (ΔE) was calculated from Equation (2).

$$\Delta E = \sqrt{(L^* - L_0)^2 + (a^* - a_0)^2 + (b^* - b_0)^2} \quad (2)$$

where L_0, a_0, and b_0 were selected as initial points and L^*, a^*, and b^* of the baked cake crust surface.

Figure 3.8: HunterLab Ultrascan PRO color spectrophotometer (Hunter Associates Laboratory, Inc., Reston, VA, USA).

3.4.3 Statistical analysis

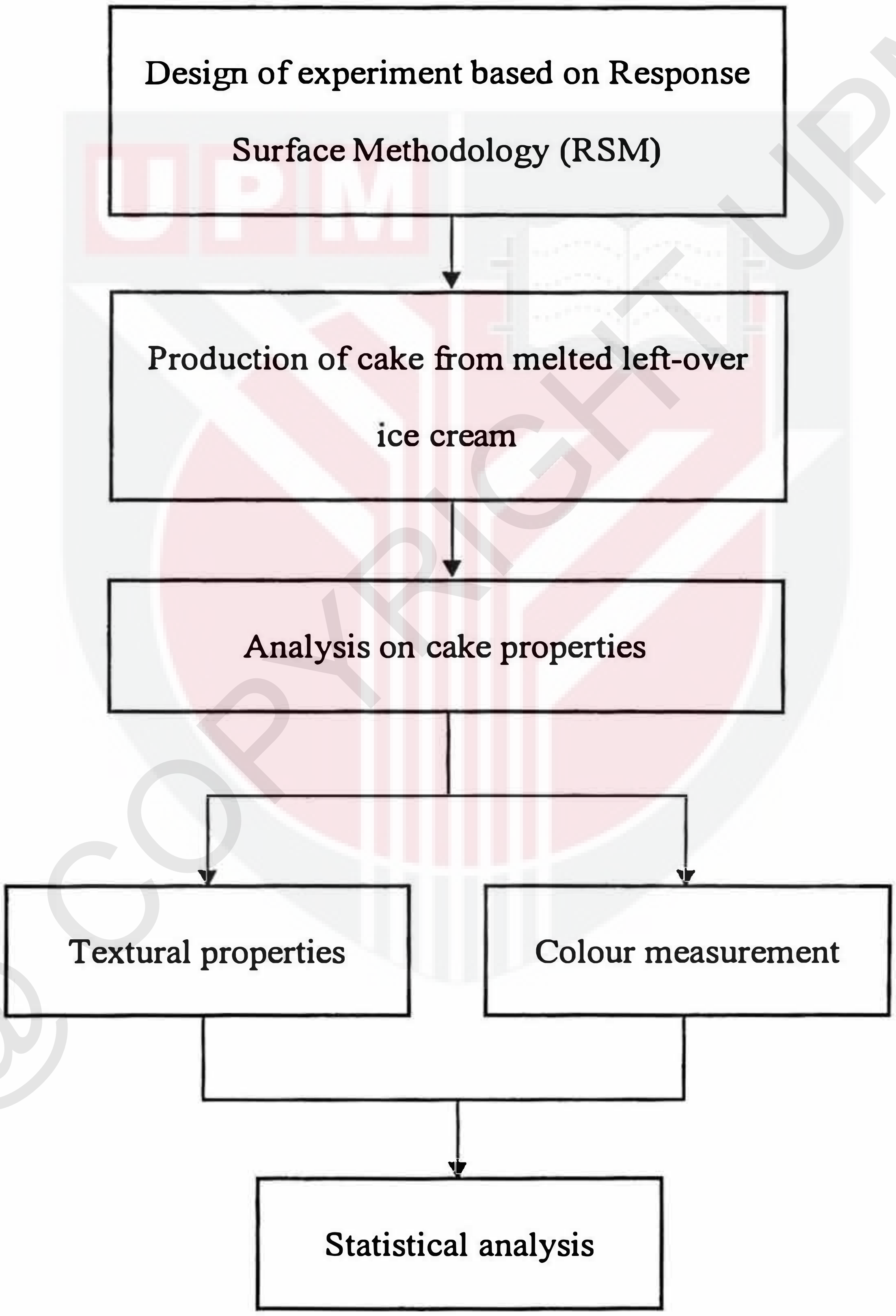
Data were analysed using an analysis of variance (ANOVA) to determine the significance of the main factors and their interactions. The significance level was set at 95% with a p-value of 0.05. The regression coefficient model (mathematical model) generated from the ANOVA table will be used for optimization purpose depending on the value of correlation coefficient, R^2. Experimental data were fitted to the second-order polynomial model to derive the regression coefficient model. The model for the response surface analysis is shown in Equation (3),

$$\gamma = \beta_0 + \sum_{t=1}^{3} \beta_i X_i + \sum_{i}^{3} \beta_{ii} X_i^2 + \sum_{i-j}^{2} \sum_{j=1+i}^{3} \beta_{ij} X_i X_j, \qquad (3)$$

where Y is the response, β_0, β_i, β_{ii}, and β_{ij} are regression coefficients for the intercept, linear, quadratic, and interaction terms, respectively. X_i and X_j are coded values for the independent variables (Tabaraki & Nateghi, 2011). Multiple regression equations were used to plot contour surfaces, and optimum conditions were determined by using the response optimizer in Minitab Release 16.2 software ((LEAD Technologies, Inc., USA) to perform multiple optimizations. The significant difference between independent variables ($p \leq 0.05$) was determined by analysis of variance (ANOVA).

3.5 Summary of methodology

Chapter 3 discussed on the methodology used in this study the preparation and the production of cake sample throughout the process. After that, the tests required for analyses such as firmness, springiness, and colour were explained.



CHAPTER 4

RESULTS AND DISCUSSION

This chapter consist of the results obtained from the experiments which is textural analysis (firmness and springiness) of the cakes produced from melted left-over ice cream. Besides, there is also the analysis result of colour change the crust of the cake. The statistical analyis was performed using the obtained results and optimization of baking parameters which are time and temperature were optimized. The experimental validation was conducted to validate the optimized baking parameters.

4.1 Response surface methodology

Data obtained from the experiments were analyzed using MINITAB software (Minitab Inc., State College PA, USA) and results on the responses (firmness, springiness and colour change) are given in Appendix A1. Time and temperature are represented by V1 and V2, respectively.

4.1.1 Statistical analysis of textural properties

The ANOVA table is shown in Table 4.1. The texture parameter tested were firmness and springiness of the cake.

Table 4.1: Textural properties value for different time and temperature.

Term	Notation	Firmness			Springiness		
		Coeff.	Std. error of coeff.	P	Coeff.	Std. error of coeff.	P
Const.		2.47859	0.05467	0.000	54.7773	0.2846	0.000
Time	V1	0.15596	0.03801	0.000	-0.9394	0.1979	0.000
Temp.	V2	-0.11018	0.03801	0.007	-2.3703	0.1979	0.000
Time* Time	V1*V1	0.27765	0.02750	0.000	0.1776	0.1432	0.224
Temp.* Temp.	V2*V2	-0.05819	0.02750	0.042	0.0575	0.1432	0.691
Time* Temp.	V1*V2	-0.62521	0.06583	0.000	1.9477	0.3427	0.000
		$R^2 = 0.8810$			$R^2 = 0.8583$		

Based on the results shown in Table 4.1 the main factors, which are time and temperature are significant at p-value of 0.000 and 0.007, respectively for firmness. Meanwhile, the interaction term (interaction between different factors, V1*V2) showed a p-value of 0.000 which indicates that there was a very strong significant relationship between the factors. The coefficient of determination (R^2) is 0.8810 which indicates that 88.10 percent of the sample variation in the firmness was attributed to the factors V1 and V2. The proportion of variation in the response attributed to the model rather than random error is known as the coefficient of determination (R^2) (Turabi et al., 2008). The estimated regression coefficient, R^2, should be at least 80% for good-fitting model (Gan et al., 2007). All terms were significant at p-value < 0.050 with the squared term of V2*V2 being the least significant term. The interaction term of V1*V2 was found to have the strongest effect on the response due to the highest absolute coefficient value of 0.62521. The squared term which is significant (p-value < 0.005) indicates that the relationship between the factor and the response follows a curved line. The regression coefficient model for the factors on the firmness of cake is given in Equation (4).

$$Y_f = 2.47859 + 0.15596(V1) - 0.11018(V2) + 0.27765(V1)(V1) - 0.05819(V2)(V2) - 0.62521(V1)(V2) \quad (4)$$

Y_f represents the firmness (response) while V1 and V2 are time and temperature, respectively. This regression coefficient model (mathematical model) can be used to calculate and analyze the effect of factors on the firmness of the cakes.

The height that the food recovers between the end of the first compression and the start of the second compression is measured by springiness (Chiş et al., 2020). The results showed that the main factors, which are time and temperature, are highly significant at 0.000 for springiness of the cake. The interaction terms (interaction between different factors, V1*V2) are highly significant at p-value of 0.000 which indicates that there was a very strong significant relationship between the factors.

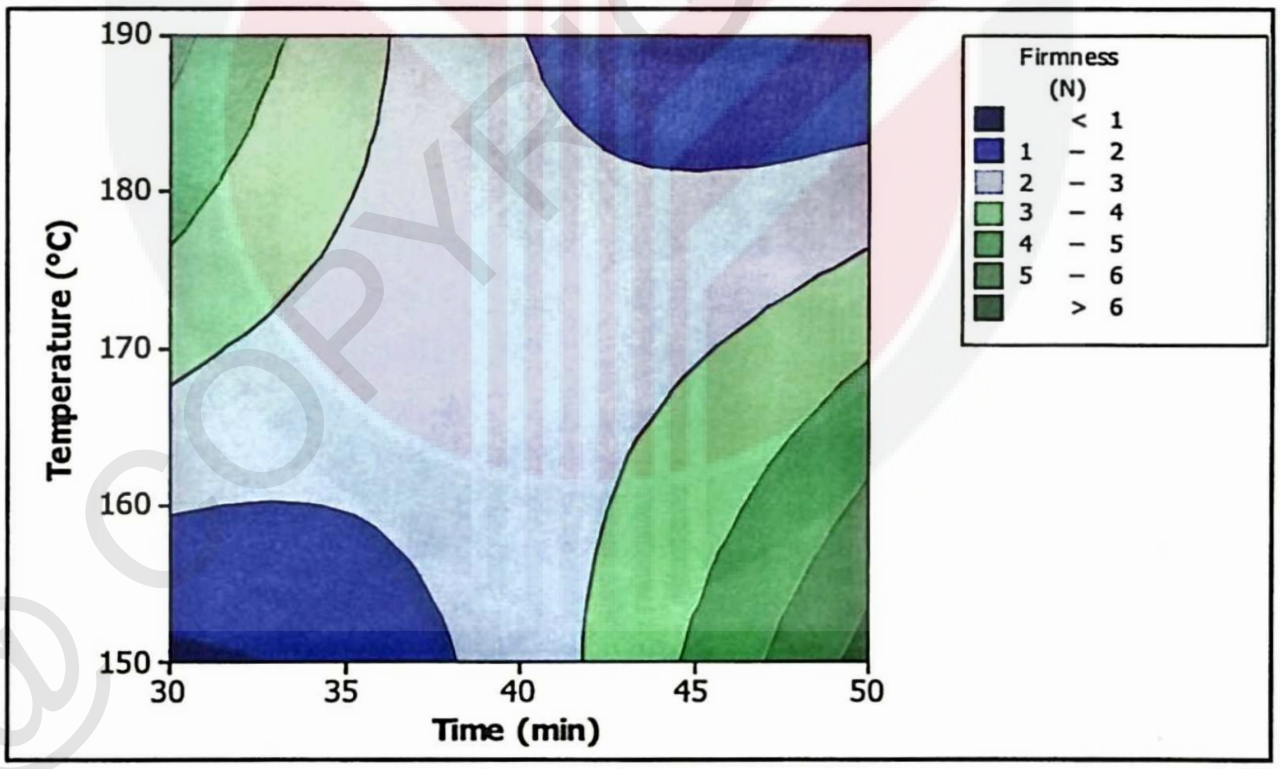
The coefficient of determination (R^2) was 0.8583 which indicates that 85.83 percent of the sample variation in the springiness was attributed to the factors V1 and V2. All main factors (V1 and V2) and their interaction term of V1*V2 were highly significant at 0.000. The main factor of V2, which is temperature was found to has the strongest effect on the response due to the highest absolute coefficient value of 2.3703. The squared term which has no significant (p-value < 0.005) indicates that the relationship between the factor and the response does not follows the curved line. The regression coefficient model for the factors on the springiness of cake is given in Equation (5).

$$Y_s = 54.7773 - 0.9394(V1) - 2.3703(V2) + 0.1776(V1)(V1) + 0.0575(V2)(V2) + 1.9477(V1)(V2) \quad (5)$$

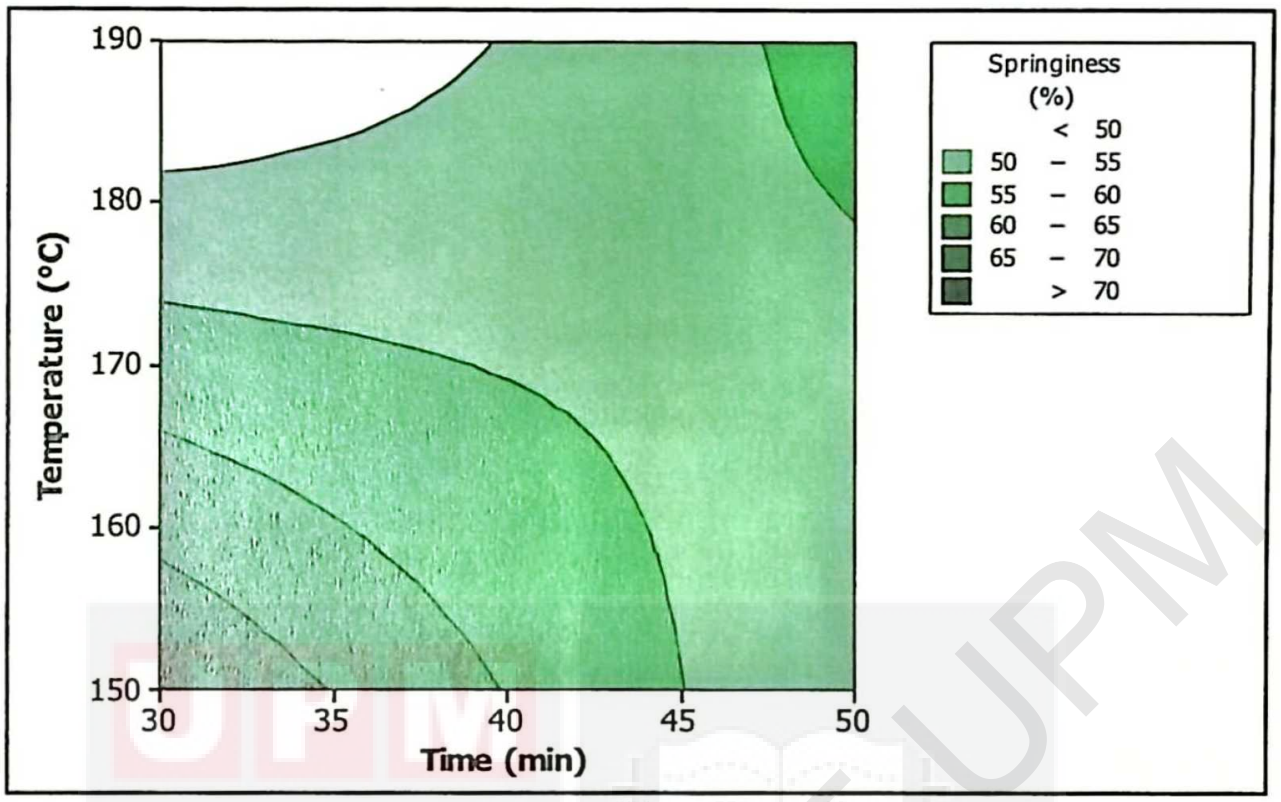
Y_s represents the springiness (response) while V1 and V2 are the time and temperature, respectively. This regression coefficient model (mathematical model) can be used to calculate and analyze the effect of factors on the springiness of the cakes.

4.1.2 Effect of factors on textural properties

From the analysis, ANOVA and regression coefficient model were used in analyzing the effect of factors on firmness. Contour plots, which showed the effect of time and temperature on the firmness and springiness of the cakes, were used for better illustration and are shown in Figure 4.1.



(a)



(b)

Figure 4.1: (a) Contour plot of time vs. temperature for firmness.; (b) Contour plot of time vs. temperature for springiness.

It was observed in Figure 4.1(a) that when the baking temperature increase with baking time, the firmness of cake increased. High firmness was observed for baking temperature between 170°C and 190°C, and within 30 and 35 minutes for baking time. Similarly, high firmness was recorded between 42 minutes and 50 minutes at between 150°C and 170°C. The results agreed with those reported by Sani et al. (2014) the firmness of the cake increased as the temperature was raised. Other studies by Turabi et al. (2008) also reported as moisture loss is a function of baking time, as the baking time increased, the moisture loss and therefore firmness of cakes increased.

Indeed, at the baking temperature 150°C, the firmness increased as the baking time increased. This is because, as the baking time increased, the weight loss increased due to higher moisture loss, and the firmness increased as a result (Şakıyan, 2015).

Figure 4.1(b) shows that as baking time and temperature increase, the springiness of the cake decreases. The high region springiness was observed for baking time between 30- and 40 minutes, and within 150°C and 165°C for baking temperature. Springiness increased with decreasing convective baking time (Al-Muhtaseb et al., 2013). Similarly reported by Cauvain and Young (2008), the firmness of the cake increased as the temperature and baking time were increased, while the springiness of the cake decreased.

Further, at the baking time of 30 minutes, the springiness was decreased with increases of baking temperature. Due to the extreme increased pressures exerted by leavening vapour and gases as the temperature of the cake rose, the bubbles within the cake structure became less homogeneous and more distorted. As a result, the cake hardens and loses its springiness (Al-Muhtaseb et al., 2013).

4.1.3 Statistical analysis of colour change

The ANOVA table is shown in Table 4.2. The results showed that both main factors are highly significant at p-value of 0.000. The interaction term (interaction between different factors, V1*V2) showed a p-value of 0.000 which indicates that there was a very strong relationship between the factors.

Table 4.2: Colour change value for different time and temperature.

Term	Notation	Coefficient	Std. error of coefficient	P
Constant		62.7057	0.3154	0.000
Time	V1	0.9389	0.2193	0.000
Temperature	V2	3.0248	0.2193	0.000
Time*Time	V1*V1	0.2206	0.1587	0.174
Temperature*Temperature	V2*V2	1.5947	0.1587	0.000
Time*Temperature	V1*V2	1.9360	0.3798	0.000
			$R^2 = 0.9111$	

The coefficient of determination (R2) is 0.9111 which indicates that 91.11 percent of the sample variation in the colour change was attributed to the factors V1 and V2. Except for the squared term of V1*V1, all main factors (V1 and V2), the squared term of V2*V2 and the interaction term of V1*V2 are highly significant at 0.000. The main factor of V2 which is temperature was found to has the strongest effect on the response due to the highest absolute coefficient value of 3.0248. The squared term of V1*V1 shows that no significant (p-value > 0.05) indicates that the relationship between the factor and the response do not follow the curved line. The regression coefficient model for the factors on the colour change of cake made from melted left-over ice cream is given in Equation (6).

$$Y_c = 62.7057 + 0.9389(\mathrm{V1}) + 3.0248(\mathrm{V2}) + 0.2206(\mathrm{V1})(\mathrm{V1}) + 1.5947(\mathrm{V2})(\mathrm{V2}) + 1.9360(\mathrm{V1})(\mathrm{V2}) \qquad (6)$$

Y_c represents the colour change (response) while V1 and V2 are the time and temperature, respectively. This regression coefficient model (mathematical model) can be used to calculate and analyze the effect of factors on the colour change of the cake made from melted left-over ice cream.

4.1.4 Effect of factors on colour change

From the analysis, ANOVA and regression coefficient model were used in analyzing the effect of factors on colour change. Contour plots, which showed the effect of time and temperature on the colour change of cake, were used for better illustration and are shown in Figure 4.2.

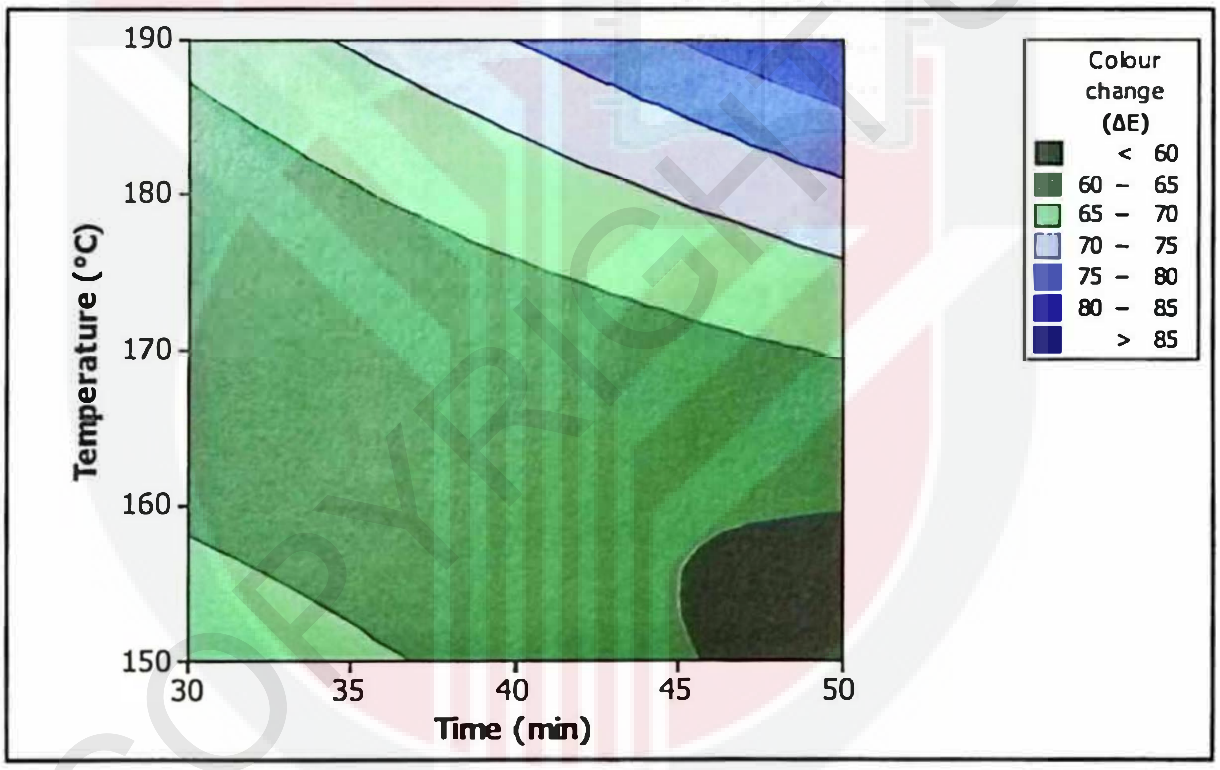


Figure 4.2: Contour plot of time vs. temperature for colour change.

The evolution of color is an important appearance quality of cake product and important physical property to represent the influence of different baking modes on the baking cake. Crust colour is one of the critical quality characteristics, according to Mundt and Wedzicha (2007) because its value has a direct impact on initial consumer acceptance. In Figure 4.2 shows that increases in baking temperature and time, increased the total colour change of cakes. High total colour change was observed for baking time between

35 minutes and 50 minutes, and within 175°C and 190°C for baking temperature. As discussed by Mior Zakuan Azmi et al. (2019) when temperature and time are increased, the low moisture content of the cake produces and enhances the high colour change, resulting in an increase in cake firmness.

Furthermore, at the baking time of 50 minutes, the total colour change was increased with increase of baking temperature. Sample S26 recorded the highest total colour change (73.9153) (Appendix A1) at baking temperature of 170°C. Higher temperatures caused a rapid drop in thermal conductivity within the product, enhancing Maillard reactions and causing browning to appear earlier and faster. At that point, the cakes were too dark at all temperatures (Mohamad et al., 2015). Similarly, Ho et al. (2013) reported that the crust colour is mainly cause by Maillard reaction during baking.

At 180 and 190 °C of baking temperature, samples with high firmness value (those with 35- and 45-minutes baking time) exhibited comparably high colour change value. Based on this pattern, it can be concluded that the higher the fimness of the cake, the greater the likelihood of crust colour change. The results obtained similar from the present study similar to those from Purlis (2010) founded that as the temperature and baking time increase, the water activity at the product surface decreases, allowing for more colour compound formation.

(a) (b) (c)

Figure 4.3: The crust colour of cake at 40 minutes of baking time with different baking temperature at (a) 150°C; (b) 170°C; (c) 190°C.

(a) (b) (c)

Figure 4.4: The crust colour of cake at 170°C baking temperature at (a) 30 minutes; (b) 40 minutes; (c) 50 minutes.

4.2 Optimization of the responses

Optimization plot is shown in Figure 4.5. The purpose of conducting optimization is to obtain the best combination of time and temperature in producing cake made from left-over ice cream with minimum value of firmness, total colour change and maximum value springiness. The composite desirability value, D was calculated to be close to 1, therefore the factors were within the working range. Based on the ranges selected, it is suggested that the optimized value of factors were time (V1) = 37 minutes and temperature (V2) = 150°C.

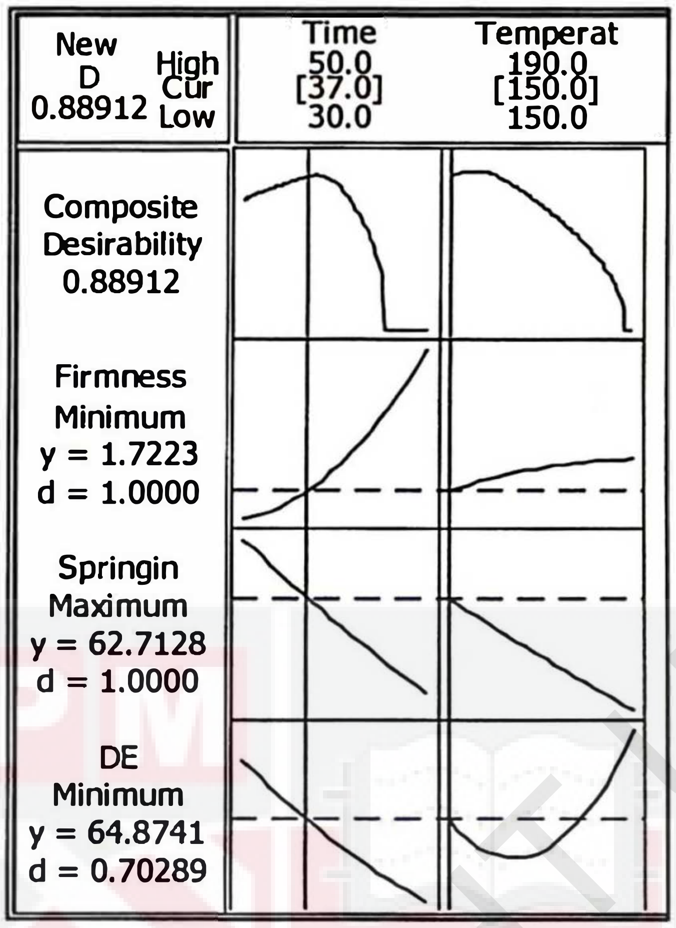


Figure 4.5: Optimization plot for optimum of baking time and temperature.

4.3 Experimental validation

Experimental validation is the final step in the modelling process and was used to verify the accuracy of thepredicted model (regression coefficient model). A validation experiment was carried out for three validation samples (SV1, SV2 and SV3) under the optimal conditions obtained form the optimization plot (Figure 4.5).

Table 4.3: Experiment validation.

Response variables	Sample	Actual	Predicted	Relative Deviation (%)
Firmness (N)	SV1	1.8845	1.7223	9.42
	SV2	1.9392	1.7223	12.59
	SV3	1.8272	1.7223	6.09
			Average	**9.37**
Springiness (%)	SV1	62.638	62.712	0.12
	SV2	62.362	62.712	0.56
	SV3	61.625	62.712	1.73
			Average	**0.80**
Colour change (ΔE)	SV1	61.976	64.874	4.47
	SV2	63.136	64.874	2.68
	SV3	64.897	64.874	0.04
			Average	**2.37**

As shown in Table 4.3, the average relative deviation for firmness, springiness and colour change were 9.37%, 0.80% and 2.37%, respectively. These shows that the percentages of error between the experimental (actual) and predicted values were less than 10%. This verified the predictability of the model with a comparison of the experimental (actual) values against the predicted figures (1.7223N, 62.712% and 64.874), implying that the RSM-based empirical model can adequately describe the relationship between the independent variables and the target response and therefore, succesfully reveal the optimum process conditions. Therefore, the model can be used to optimize the baking parameters for cake made from melted left-over ice cream.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

This chapter summarize the research work done. The main objective about this study is to optimize the baking time and temperature on cake made from melted left-over ice cream of physical quality. The physical characteristics of the cake textural properties (firmness and springiness) was identified with varying the baking time and temperature which significantly influence the texture of the cake. In addition, colour measurements were taken to determine the total colour change in the crust of the cakes. Not only that, but this chapter also includes recommendations for future work.

5.1 Conclusion

Leftover ice cream has a lot of potential as a value-added product in the form of a cake. Response surface methodology was successfully applied to optimize the baking parameters. Therefore, the analysis on the sample cakes was conducted to identify the textural profile and colour change.

The objective was to optimize the baking parameters which are time and temperature. Baking conditions such as baking temperature and time have a significant effect on the quality of the cake (firmness, springiness and colour). Statistical analysis data using RSM, and CCD showed that baking temperature and time have significant effect (p-value < 0.05) on the firmness, springiness and colour of the cake made from left-over ice cream. The estimated regression coefficient, R^2, for each response (firmness, springiness and colour change) were 88.10%, 85.83% and 91.11%, respectively. Baking temperature between 170°C and 190°C, and within 30 and 35 minutes for baking time resulted in cake with high firmness. High region springiness was observed for baking time between 30- and 40 minutes, and within 150°C and 165°C for baking temperature. Also, high total colour change was observed for baking time between 35 minutes and 50 minutes, and within 175°C and 190°C for baking temperature. The optimized values for factors were time (V1) = 37 minutes and temperature (V2) = 150°C. The validation results showed the average relative deviation for firmness, springiness and colour change were 9.37%, 0.80% and 2.37%, respectively. Optimum baking parameters resulted in cake made from melted left-over ice cream with firmness of 1.8836 N, springiness of 62.208% and 63.336, respectively. The predicted model (regression coefficient model) thus developed was verified as highly accurate.

To summarise, the study objective is achieved, as evidenced by the high accuracy of the predicted model (regression coefficient model) in determining the optimum baking parameters.

5.2 Recommendations

There has been no other research on the conversion of ice cream manufacturing by-products into other food products that could result in a profit increase for the company. The characteristics of the cake made from melted leftover ice cream can be influenced by several factors.

For the future research, instead of varying the baking parameters using response surface methodology (RSM), the amount of melted left-over ice cream in the recipe can also be changed to improve the cake's taste and structure. Furthermore, the project can be improved by adjusting the mixing conditions to achieve the best baking conditions for a cake made from melted leftover ice cream. The nutritional value of a cake made from melted ice cream can also be added to ensure that the cake meets the needs of humans. Finally, other tests should be performed to obtain a specific result of an ice cream physical characteristic, such as the moisture content test, batter stickiness test, and fat globule size test. As a result, a few recommendations can be used to learn more about the characteristics of ice cream and cakes made from melted ice cream.

REFERENCES

Abbas Syed, Q. (2018). Effects of different ingredients on texture of ice cream. *Journal of Nutritional Health & Food Engineering*, *8*(6), 422–435. https://doi.org/10.15406/jnhfe.2018.08.00305

Al-Muhtaseb, A. H., McMinn, W., Megahey, E., Neil, G., Magee, R., & Rashid, U. (2013). Textural Characteristics of Microwave-Baked and Convective-Baked Madeira Cake. *Journal of Food Processing & Technology*, *04*(02). https://doi.org/10.4172/2157-7110.1000209

Anonymous (a). (n.d.). *Should Your Ice Cream Shop Stay Open This Winter?* Retrieved July 29, 2021, from https://www.webstaurantstore.com/blog/1826/should-you-close-your-ice-cream-stand-for-the-winter.html

Anonymous (b). (n.d.). *Butter Cake recipe| Simplehomerecipe.com*. Retrieved July 30, 2021, from https://web.archive.org/web/20150923003033/http://www.simplehomerecipe.com/butter-cake.html

Basri, M. S. M., Mustapha, F., Mazlan, N., & Ishak, M. R. (2020). Optimization of Rice Husk Ash-Based Geopolymers Coating Composite for Enhancement in Flexural Properties and Microstructure Using Response Surface Methodology. *Coatings 2020, Vol. 10, Page 165*, *10*(2), 165. https://doi.org/10.3390/COATINGS10020165

Cauvain, S. P., & Young, L. S. (2008). *Bakery Food Manufacture and Quality Water Control and Effects*. www.wiley.com/wiley-blackwell.

Chiş, M. S., Păucean, A., Man, S. M., Mureşan, V., Socaci, S. A., Pop, A., Stan, L., Rusu, B., & Muste, S. (2020). Textural and sensory features changes of gluten free muffins based on rice sourdough fermented with Lactobacillus spicheri DSM 15429. *Foods*, *9*(3). https://doi.org/10.3390/foods9030363

Clarke, C. (2004). *The Science of Ice Cream.* The Royal Society of Chemistry, Thomas Graham House, Science Park, Milton Road, Cambridge CB4 OWF, UK. http://library1.nida.ac.th/termpaper6/sd/2554/19755.pdf

Czyrski, A., & Jarzebski, H. (2020). Response surface methodology as a useful tool for evaluation of the recovery of the fluoroquinolones from plasma-the study on applicability of box-behnken design, central composite design and doehlert design. *Processes*, *8*(4). https://doi.org/10.3390/PR8040473

Gan, H. E., Karim, R., Muhammad, S. K. S., Bakar, J. A., Hashim, D. M., & Rahman, R. A. (2007). Optimization of the basic formulation of a traditional baked cassava cake using response surface methodology. *LWT - Food Science and Technology*, *40*(4), 611–618. https://doi.org/10.1016/j.lwt.2006.05.005

Girotto, F., Alibardi, L., & Cossu, R. (2015). Food waste generation and industrial uses: A review. *Waste Management*, *45*, 32–41. https://doi.org/10.1016/J.WASMAN.2015.06.008

Goff, H. D. (n.d.). *The Ice Cream eBook.* Retrieved December 23, 2020, from https://www.uoguelph.ca/foodscience/book/export/html/2003

Goff, H. D., & Hartel, R. W. (2013). Ice Cream. In *Handbook on Natural Pigments in*

Food and Beverages: Industrial Applications for Improving Food Color. https://doi.org/10.1016/B978-0-08-100371-8.00009-9

Helstad, S. (2018). Corn sweeteners. In *Corn: Chemistry and Technology, 3rd Edition* (3rd ed.). Elsevier Inc. https://doi.org/10.1016/B978-0-12-811971-6.00020-6

Ho, L. H., Abdul Aziz, N. A., & Azahari, B. (2013). Physico-chemical characteristics and sensory evaluation of wheat bread partially substituted with banana (Musa acuminata X balbisiana cv. Awak) pseudo-stem flour. *Food Chemistry*, *139*(1–4), 532–539. https://doi.org/10.1016/j.foodchem.2013.01.039

Ice Cream - Wendell S. Arbuckle - Google Books. (n.d.). Retrieved June 26, 2021, from https://books.google.com.my/books?hl=en&lr=&id=_pAkBAAAQBAJ&oi=fnd&pg=PA1&dq=ice+cream&ots=j08pKNr_VE&sig=yePYlKXLMkshoTXPQCJ0BYhkNWA&redir_esc=y#v=onepage&q=ice cream&f=false

Im, J. S., Huff, H. E., & Hsieh, F. H. (2003). Effects of processing conditions on the physical and chemical properties of buckwheat grit cakes. *Journal of Agricultural and Food Chemistry*, *51*(3), 659–666. https://doi.org/10.1021/jf0259157

Jamaludin, N. S. (2020). *International Journal of Gastronomy and Food Science Innovation in gastronomy : Conversion of left-over ice cream into bakery product for food sustainability*.

Koxholt, M. M. R., Eisenmann, B., & Hinrichs, J. (2001). Effect of the fat globule sizes on the meltdown of ice cream. *Journal of Dairy Science*, *84*(1), 31–37. https://doi.org/10.3168/jds.S0022-0302(01)74448-7

Kwan, K. (2021). *Butter cake recipe (Complete guide- how to make in 8 simple steps).* https://tasteasianfood.com/butter-cake/

Leducq, D., Ndoye, F. T., Charriau, C., & Alvarez, G. (2015). Thermal protection of ice cream during storage and transportation. *Refrigeration Science and Technology*, 4614–4619. https://doi.org/10.18462/iir.icr.2015.0427

Marshall, R. T., Goff, H. D., Hartel, R. W., Marshall, R. T., Goff, H. D., & Hartel, R. W. (2003). Calculation of Ice Cream Mixes. In *Ice Cream*. https://doi.org/10.1007/978-1-4615-0163-3_5

Mior Zakuan Azmi, M., Taip, F. S., Mustapa Kamal, S. M., & Chin, N. L. (2019). Effects of temperature and time on the physical characteristics of moist cakes baked in air fryer. *Journal of Food Science and Technology*, *56*(10), 4616–4624. https://doi.org/10.1007/s13197-019-03926-z

Mohamad, R. A., Taip, F. S., Kamal, S. M. M., & Bejo, S. K. (2015). Color and Volume Development of Cake Baking and Its Influence on Cake Qualities. *Journal of Applied Science and Agriculture*, *10*(January), 63–68. www.aensiweb.com/JASA

Mundt, S., & Wedzicha, B. L. (2007). A kinetic model for browning in the baking of biscuits: Effects of water activity and temperature. *LWT - Food Science and Technology*, *40*(6), 1078–1082. https://doi.org/10.1016/j.lwt.2006.07.011

Myers, R. H., Montgomery, D. C., & Anderson-Cook, C. M. (2015). *Response Surface Methodology: Process and Product Optimization Using ... - Raymond H. Myers, Douglas C. Montgomery, Christine M. Anderson-Cook - Google Books.*

https://books.google.com.my/books?hl=en&lr=&id=T-BbCwAAQBAJ&oi=fnd&pg=PR13&dq=response+surface+methodology&ots=O2hePned5R&sig=LtUTLhjbXKEF6zHgbjoI9Z2ippE&redir_esc=y#v=onepage&q=response surface methodology&f=false

Nazaruddin, R., Syaliza, A. S., & Wan Rosnani, A. I. (2008). The effect of vegetable fat on the physicochemical characteristics of dates ice cream. *International Journal of Dairy Technology*, *61*(3), 265–269. https://doi.org/10.1111/J.1471-0307.2008.00413.X

Purlis, E. (2010). Browning development in bakery products - A review. *Journal of Food Engineering*, *99*(3), 239–249. https://doi.org/10.1016/j.jfoodeng.2010.03.008

Pyler, E. ., & Gorton, L. A. (2014). Baking Science & Technology. In *Conventional and Advanced Food Processing Technologies* (Vol. 9781118406). https://doi.org/10.1002/9781118406281.ch8

Racca, A. (2020). *Method For Using Lefover Ice-Cream by Mixing The Ice-Cream with Flour and Yeast, and Bakery products having Various Flavours Obtained with Said Mixtures.pdf.*

Şakıyan, Ö. (2015). Optimization of formulation of soy-cakes baked in infrared-microwave combination oven by response surface methodology. *Journal of Food Science and Technology*, *52*(5), 2910–2917. https://doi.org/10.1007/s13197-014-1342-6

Sani, N. A., Taip, F. S., Kamal, S. M. M., & Aziz, N. A. (2014). Effects of temperature and airflow on volume development during baking and its influence on quality of cake. *Journal of Engineering Science and Technology*, *9*(3), 303–313.

Sherman, P. (1966). *The Texture of Ice Cream 3. Rheological Properties of Mix and Melted Ice Cream*.

Tabaraki, R., & Nateghi, A. (2011). Optimization of ultrasonic-assisted extraction of natural antioxidants from rice bran using response surface methodology. *Ultrasonics Sonochemistry*, *18*(6), 1279–1286. https://doi.org/10.1016/j.ultsonch.2011.05.004

Tharp, B. W., & Young, L. S. (n.d.). *THARP & YOUNG ON ICE CREAM An Encyclopedic Guide to Ice Cream Science and Technology*.

Turabi, E., Sumnu, G., & Sahin, S. (2008). Optimization of baking of rice cakes in infrared-microwave combination oven by response surface methodology. *Food and Bioprocess Technology*, *1*(1), 64–73. https://doi.org/10.1007/s11947-007-0003-4

Yolmeh, M., & Mahdi Jafari, S. (1947). *Applications of Response Surface Methodology in the Food Industry Processes*. https://doi.org/10.1007/s11947-016-1855-2

APPENDICES

6.1 Appendix A1

Table 6.1: Design matrix and response value for the firmness, springiness and colour change test.

Sample	Coded factor		Uncoded factor		Response		
	V1	V2	V1	V2	Firmness (N)	Springiness (%)	Colour change (ΔE)
S1	-1	-1	35	160	3.2884	55.655	62.3146
S2	1	-1	45	160	2.8441	55.183	61.3537
S3	-1	1	35	180	2.3954	54.484	62.6835
S4	1	1	45	180	3.1040	59.400	62.3601
S5	-2	0	30	170	4.2759	52.524	64.7288
S6	2	0	50	170	2.3569	59.459	63.0499
S7	0	-2	40	150	2.5582	59.786	62.3320
S8	0	2	40	190	1.9883	54.062	72.3396
S9	0	0	40	170	2.9835	58.425	60.5186
S10	0	0	40	170	2.4809	56.525	62.0142
S11	0	0	40	170	4.0489	52.463	64.5762
S12	0	0	40	170	1.9078	51.542	77.5115
S13	0	0	40	170	2.6542	59.004	62.1774
S14	-1	-1	35	160	2.2879	59.320	62.5104
S15	1	-1	45	160	2.5043	54.413	63.5097
S16	-1	1	35	180	3.3779	55.894	62.1662

S17	1	1	45	180	3.0555	57.289	62.4386
S18	-2	0	30	170	2.6417	52.583	61.4332
S19	2	0	50	170	2.8743	55.759	62.2207
S20	0	-2	40	150	1.9288	54.430	70.6480
S21	0	2	40	190	2.5314	55.731	63.0272
S22	-1	0	40	170	2.1405	59.666	63.4545
S23	0	0	40	170	2.3037	55.106	59.5322
S24	0	0	40	170	2.1882	52.398	65.0388
S25	0	0	40	170	1.9973	50.140	73.3102
S26	0	0	40	170	2.0065	50.297	73.9153
S27	-1	-1	35	160	3.3849	50.531	64.2502
S28	1	-1	45	160	3.3261	51.033	64.9656
S29	-1	1	35	180	2.6361	54.525	63.0663
S30	1	1	45	180	4.0042	52.870	64.1561
S31	-2	0	30	170	2.3898	54.513	61.3423
S32	2	0	50	170	3.3744	56.041	62.0376
S33	0	-2	40	150	2.1070	54.104	62.1393
S34	0	2	40	190	3.3138	49.144	65.2756
S35	0	0	40	170	2.4466	54.615	62.6979
S36	0	0	40	170	1.9778	54.249	71.8769
S37	0	0	40	170	2.3567	56.593	63.0635

S38	0	0	40	170	2.1707	59.804	62.8733
S39	0	0	40	170	2.3526	55.217	61.9637

6.2 Appendix B1

Response Surface Regression: Firmness (N) versus Time, Temperature

The analysis was done using coded units.

Estimated Regression Coefficients for Firmness (N)

Term	Coef	SE Coef	T	P
Constant	2.47859	0.05467	45.339	0.000
Time	0.15596	0.03801	4.104	0.000
Temperature	-0.11018	0.03801	-2.899	0.007
Time*Time	0.27765	0.02750	10.095	0.000
Temperature*Temperature	-0.05819	0.02750	-2.116	0.042
Time*Temperature	-0.62521	0.06583	-9.498	0.000

S = 0.228036 PRESS = 2.43715
R-Sq = 88.10% R-Sq(pred) = 83.10% R-Sq(adj) = 86.30%

Analysis of Variance for Firmness (N)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	12.7063	12.7063	2.54126	48.87	0.000
Linear	2	1.3127	1.3127	0.65636	12.62	0.000
Time	1	0.8757	0.8757	0.87569	16.84	0.000
Temperature	1	0.4370	0.4370	0.43703	8.40	0.007
Square	2	6.7030	6.7030	3.35148	64.45	0.000
Time*Time	1	6.4702	5.2990	5.29900	101.90	0.000
Temperature*Temperature	1	0.2328	0.2328	0.23278	4.48	0.042
Interaction	1	4.6906	4.6906	4.69063	90.20	0.000
Time*Temperature	1	4.6906	4.6906	4.69063	90.20	0.000
Residual Error	33	1.7160	1.7160	0.05200		
Lack-of-Fit	3	0.9071	0.9071	0.30235	11.21	0.000
Pure Error	30	0.8090	0.8090	0.02697		
Total	38	14.4223				

Obs	StdOrder	Firmness (N)	Fit	SE Fit	Residual	St Resid
1	28	3.288	3.589	0.093	-0.301	-1.44
2	22	2.844	2.479	0.055	0.366	1.65
3	38	2.395	2.479	0.055	-0.083	-0.38
4	5	3.104	3.277	0.117	-0.173	-0.89
5	19	4.276	3.901	0.117	0.375	1.92
6	1	2.357	2.027	0.093	0.330	1.58
7	7	2.558	2.466	0.117	0.092	0.47
8	30	1.988	2.119	0.093	-0.130	-0.63
9	18	2.983	3.277	0.117	-0.294	-1.50
10	25	2.481	2.479	0.055	0.002	0.01
11	32	4.049	3.901	0.117	0.148	0.76
12	34	1.908	2.025	0.117	-0.118	-0.60
13	33	2.654	2.466	0.117	0.188	0.96
14	20	2.288	2.466	0.117	-0.178	-0.91
15	35	2.504	2.479	0.055	0.026	0.12
16	2	3.378	3.589	0.093	-0.211	-1.01
17	31	3.055	3.277	0.117	-0.222	-1.13
18	23	2.642	2.479	0.055	0.163	0.74
19	26	2.874	2.479	0.055	0.396	1.79
20	4	1.929	2.119	0.093	-0.190	-0.91
21	13	2.531	2.479	0.055	0.053	0.24

22	14	2.140	2.027	0.093	0.113	0.54
23	10	2.304	2.479	0.055	-0.175	-0.79
24	39	2.188	2.479	0.055	-0.290	-1.31
25	8	1.997	2.025	0.117	-0.028	-0.14
26	21	2.007	2.025	0.117	-0.019	-0.10
27	16	3.385	3.057	0.093	0.328	1.57
28	3	3.326	3.057	0.093	0.269	1.29
29	9	2.636	2.479	0.055	0.158	0.71
30	6	4.004	3.901	0.117	0.103	0.53
31	37	2.390	2.479	0.055	-0.089	-0.40
32	15	3.374	3.589	0.093	-0.215	-1.03
33	36	2.107	2.479	0.055	-0.372	-1.68
34	29	3.314	3.057	0.093	0.257	1.23
35	12	2.447	2.479	0.055	-0.032	-0.14
36	17	1.978	2.119	0.093	-0.141	-0.68
37	11	2.357	2.479	0.055	-0.122	-0.55
38	27	2.171	2.027	0.093	0.144	0.69
39	24	2.353	2.479	0.055	-0.126	-0.57

6.3 Appendix B2

Response Surface Regression: Springiness (%) versus Time, Temperature

The analysis was done using coded units.

Estimated Regression Coefficients for Springiness (%)

Term	Coef	SE Coef	T	P
Constant	54.7773	0.2846	192.456	0.000
Time	-0.9394	0.1979	-4.748	0.000
Temperature	-2.3703	0.1979	-11.979	0.000
Time*Time	0.1776	0.1432	1.240	0.224
Temperature*Temperature	0.0575	0.1432	0.402	0.691
Time*Temperature	1.9477	0.3427	5.683	0.000

S = 1.18726 PRESS = 64.8968
R-Sq = 85.83% R-Sq(pred) = 80.23% R-Sq(adj) = 83.68%

Analysis of Variance for Springiness (%)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	281.730	281.730	56.346	39.97	0.000
Linear	2	234.037	234.037	117.019	83.02	0.000
Time	1	31.772	31.772	31.772	22.54	0.000
Temperature	1	202.265	202.265	202.265	143.49	0.000
Square	2	2.172	2.172	1.086	0.77	0.471
Time*Time	1	1.945	2.168	2.168	1.54	0.224
Temperature*Temperature	1	0.227	0.227	0.227	0.16	0.691
Interaction	1	45.521	45.521	45.521	32.29	0.000
Time*Temperature	1	45.521	45.521	45.521	32.29	0.000
Residual Error	33	46.516	46.516	1.410		
Lack-of-Fit	3	20.581	20.581	6.860	7.94	0.000
Pure Error	30	25.935	25.935	0.864		
Total	38	328.246				

Obs	StdOrder	Springiness (%)	Fit	SE Fit	Residual	St Resid
1	28	55.655	54.496	0.482	1.159	1.07
2	22	55.183	54.777	0.285	0.406	0.35
3	38	54.484	54.777	0.285	-0.293	-0.25
4	5	59.400	57.367	0.609	2.033	2.00
5	19	52.524	53.609	0.609	-1.085	-1.06
6	1	59.459	60.270	0.482	-0.811	-0.75
7	7	59.786	59.748	0.609	0.038	0.04
8	30	54.062	53.650	0.482	0.412	0.38
9	18	58.425	57.367	0.609	1.058	1.04
10	25	56.525	54.777	0.285	1.748	1.52
11	32	52.463	53.609	0.609	-1.146	-1.12
12	34	51.542	50.267	0.609	1.275	1.25
13	33	59.004	59.748	0.609	-0.744	-0.73
14	20	59.320	59.748	0.609	-0.428	-0.42
15	35	54.413	54.777	0.285	-0.364	-0.32
16	2	55.894	54.496	0.482	1.398	1.29
17	31	57.289	57.367	0.609	-0.078	-0.08
18	23	52.583	54.777	0.285	-2.194	-1.90
19	26	55.759	54.777	0.285	0.982	0.85
20	4	54.430	53.650	0.482	0.780	0.72
21	13	55.731	54.777	0.285	0.954	0.83

22	14	59.666	60.270	0.482	-0.604	-0.56	
23	10	55.106	54.777	0.285	0.329	0.29	
24	39	52.398	54.777	0.285	-2.379	-2.06	R
25	8	50.140	50.267	0.609	-0.127	-0.12	
26	21	50.297	50.267	0.609	0.030	0.03	
27	16	50.531	51.634	0.482	-1.103	-1.02	
28	3	51.033	51.634	0.482	-0.601	-0.55	
29	9	54.525	54.777	0.285	-0.252	-0.22	
30	6	52.870	53.609	0.609	-0.739	-0.73	
31	37	54.513	54.777	0.285	-0.264	-0.23	
32	15	56.041	54.496	0.482	1.545	1.42	
33	36	54.104	54.777	0.285	-0.673	-0.58	
34	29	49.144	51.634	0.482	-2.490	-2.29	R
35	12	54.615	54.777	0.285	-0.162	-0.14	
36	17	54.249	53.650	0.482	0.599	0.55	
37	11	56.593	54.777	0.285	1.816	1.58	
38	27	59.804	60.270	0.482	-0.466	-0.43	
39	24	55.217	54.777	0.285	0.440	0.38	

R denotes an observation with a large standardized residual.

6.4 Appendix B3

Response Surface Regression: Colour change (ΔE) versus Time, Temperature

The analysis was done using coded units.

Estimated Regression Coefficients for Colour change (ΔE)

Term	Coef	SE Coef	T	P
Constant	62.7057	0.3154	198.831	0.000
Time	0.9389	0.2193	4.282	0.000
Temperature	3.0248	0.2193	13.796	0.000
Time*Time	0.2206	0.1587	1.390	0.174
Temperature*Temperature	1.5947	0.1587	10.050	0.000
Time*Temperature	1.9360	0.3798	5.098	0.000

S = 1.31552   PRESS = 81.7810
R-Sq = 91.11%   R-Sq(pred) = 87.26%   R-Sq(adj) = 89.76%

Analysis of Variance for Colour change (ΔE)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	584.947	584.947	116.989	67.60	0.000
Linear	2	361.127	361.127	180.564	104.34	0.000
Time	1	31.738	31.738	31.738	18.34	0.000
Temperature	1	329.389	329.389	329.389	190.33	0.000
Square	2	178.840	178.840	89.420	51.67	0.000
Time*Time	1	4.032	3.345	3.345	1.93	0.174
Temperature*Temperature	1	174.808	174.808	174.808	101.01	0.000
Interaction	1	44.979	44.979	44.979	25.99	0.000
Time*Temperature	1	44.979	44.979	44.979	25.99	0.000
Residual Error	33	57.110	57.110	1.731		
Lack-of-Fit	3	20.505	20.505	6.835	5.60	0.004
Pure Error	30	36.604	36.604	1.220		
Total	38	642.056				

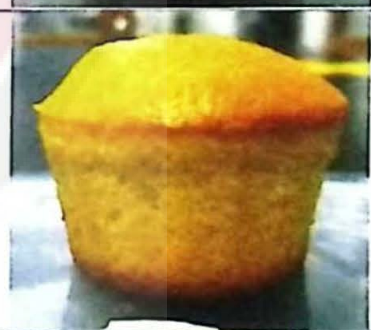
Obs	StdOrder	Colour change (ΔE)	Fit	SE Fit	Residual	St Resid	
1	28	62.315	60.499	0.534	1.816	1.51	
2	22	61.354	62.706	0.315	-1.352	-1.06	
3	38	62.684	62.706	0.315	-0.022	-0.02	
4	5	62.360	61.710	0.675	0.650	0.58	
5	19	64.729	65.466	0.675	-0.737	-0.65	
6	1	63.050	62.493	0.534	0.557	0.46	
7	7	62.332	63.035	0.675	-0.703	-0.62	
8	30	72.340	70.421	0.534	1.919	1.60	
9	18	60.519	61.710	0.675	-1.192	-1.06	
10	25	62.014	62.706	0.315	-0.692	-0.54	
11	32	64.576	65.466	0.675	-0.890	-0.79	
12	34	77.512	75.134	0.675	2.377	2.11	R
13	33	62.177	63.035	0.675	-0.857	-0.76	
14	20	62.510	63.035	0.675	-0.524	-0.46	
15	35	63.510	62.706	0.315	0.804	0.63	
16	2	62.166	60.499	0.534	1.667	1.39	
17	31	62.439	61.710	0.675	0.728	0.65	
18	23	61.433	62.706	0.315	-1.273	-1.00	
19	26	62.221	62.706	0.315	-0.485	-0.38	
20	4	70.648	70.421	0.534	0.227	0.19	

21	13	63.027	62.706	0.315	0.321	0.25	
22	14	63.454	62.493	0.534	0.961	0.80	
23	10	59.532	62.706	0.315	-3.174	-2.48	R
24	39	65.039	62.706	0.315	2.333	1.83	
25	8	73.310	75.134	0.675	-1.824	-1.62	
26	21	73.915	75.134	0.675	-1.219	-1.08	
27	16	64.250	64.671	0.534	-0.421	-0.35	
28	3	64.966	64.671	0.534	0.295	0.25	
29	9	63.066	62.706	0.315	0.361	0.28	
30	6	64.156	65.466	0.675	-1.310	-1.16	
31	37	61.342	62.706	0.315	-1.363	-1.07	
32	15	62.038	60.499	0.534	1.539	1.28	
33	36	62.139	62.706	0.315	-0.566	-0.44	
34	29	65.276	64.671	0.534	0.605	0.50	
35	12	62.698	62.706	0.315	-0.008	-0.01	
36	17	71.877	70.421	0.534	1.456	1.21	
37	11	63.063	62.706	0.315	0.358	0.28	
38	27	62.873	62.493	0.534	0.380	0.32	
39	24	61.964	62.706	0.315	-0.742	-0.58	

R denotes an observation with a large standardized residual.

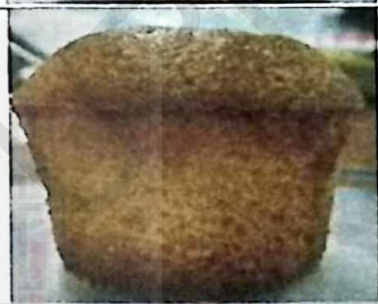
6.5 Appendix C1

Table 6.2: Sample of cakes at different baking time and temperature.

Sample	Coded factor		Uncoded factor		Figure
	V1	V2	V1	V2	
S1	-1	-1	35	160	
S2	1	-1	45	160	
S3	-1	1	35	180	
S4	1	1	45	180	
S5	-2	0	30	170	
S6	2	0	50	170	

S7	0	-2	40	150	
S8	0	2	40	190	
S9	0	0	40	170	
S10	0	0	40	170	
S11	0	0	40	170	
S12	0	0	40	170	
S13	0	0	40	170	

S14	-1	-1	35	160	
S15	1	-1	45	160	
S16	-1	1	35	180	
S17	1	1	45	180	
S18	-2	0	30	170	
S19	2	0	50	170	
S20	0	-2	40	150	

S21	0	2	40	190	
S22	-1	0	40	170	
S23	0	0	40	170	
S24	0	0	40	170	
S25	0	0	40	170	
S26	0	0	40	170	
S27	-1	-1	35	160	

S28	1	-1	45	160	
S29	-1	1	35	180	
S30	1	1	45	180	
S31	-2	0	30	170	
S32	2	0	50	170	
S33	0	-2	40	150	
S34	0	2	40	190	

S35	0	0	40	170	
S36	0	0	40	170	
S37	0	0	40	170	
S38	0	0	40	170	
S39	0	0	40	170