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ABSTRACT

Doughnut is a popular snack in Malaysia prepared as a sweet snack in various forms that can be made homemade or bought in bakeries and food stalls. Frying techniques are the most popular method used to serve and consume the doughnut. This study is basically aimed to determine the optimum condition for frying doughnut via air frying technique and also to investigate the effect of air frying process on the texture and quality of doughnut compared with traditional deep fat frying. The doughnut was fried at a temperature of 130°C, 140°C and 150°C for 10, 12 and 14 minutes via air fryer technique while the temperature of 130°C for 10, 12 and 14 minutes via deep fryer technique. The quality of fried doughnut was analyzed based on moisture content, fat content, texture and colour. In this study, response surface methodology (RSM) was used to optimize the operating conditions (frying temperature and time) of the air fryer. The optimum operating conditions were found at a temperature of 130°C and time of 10 minutes for frying the doughnut. At this optimum condition, moisture content, fat content, texture and colour change were found to be 59.59%, 12.33%, 0.7278N and 2.80 respectively. Optimized air fried doughnut was compared with deep fried doughnut by sensory test to study the sensory acceptance of doughnut attributes. The sensory test indicates that panelist like and preferable the doughnut fried with deep frying method the most compared to air fried doughnut.

ABSTRAK

Donut adalah sejenis makanan ringan yang popular di Malaysia yang disediakan sebagai makanan ringan dalam pelbagai bentuk yang boleh dibuat sendiri atau dibeli di kedai roti dan gerai makanan. Teknik penggorengan adalah kaedah yang paling popular digunakan untuk menghidang dan memakan donat. Kajian ini pada dasarnya bertujuan untuk menentukan keadaan optimum untuk menggoreng donat melalui teknik penggorengan udara dan juga untuk mengkaji kesan proses penggorengan udara pada tekstur dan kualiti donat berbanding dengan penggorengan lemak dalam tradisional. Donat digoreng pada suhu 130°C, 140°C dan 150°C selama 10, 12 dan 14 minit melalui teknik penggorengan udara manakala suhu 130°C selama 10, 12 dan 14 minit melalui teknik penggorengan dalam. Kualiti donat goreng dianalisis berdasarkan kandungan lembapan, kandungan lemak, tekstur dan warna. Dalam kajian ini, metodologi permukaan tindak balas (RSM) digunakan untuk mengoptimumkan keadaan operasi (suhu dan masa menggoreng) penggorengan udara. Keadaan operasi optimum didapati pada suhu 130°C dan masa 10 minit untuk menggoreng donat. Pada keadaan optimum ini, kandungan lembapan, kandungan lemak, tekstur dan perubahan warna didapati pada 59.59%, 12.33%, 0.7278N dan 2.80 masing-masing. Donut goreng udara yang optimum dibandingkan dengan donat goreng yang mendalam dengan ujian deria untuk mengkaji penerimaan deria dari atribut donat. Ujian deria menunjukkan bahawa panelis suka dan lebih suka donat yang digoreng dengan kaedah penggorengan dalam berbanding dengan donat goreng udara.

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LIST OF SYMBOLS

M_{wet}	Mass of the sample before drying
M_{dry}	Mass of the sample after drying
W_1	Initial mass of aluminium cup
W_2	Final mass of the aluminium cup
W_s	Mass of the dried sample
ΔE	Colour change
L^*	Lightness of fried doughnut
a^*	Redness of fried doughnut
b^*	Yellowness of fried doughnut
L_0^*	Lightness of raw doughnut
a_0^*	Redness of raw doughnut
b_0^*	Yellowness of raw doughnut

CHAPTER 1

INTRODUCTION

1.1 Overview of the study

Nowadays, people of all ages really love to consume fried products because of their preparation is easy, fast and economical. For these reasons, in recent decades, frying processes have been generalized not only in fast food establishments but also in restaurants, food industries and homes. Among all commonly fried products, doughnuts are the most important due to their high consumption and production. The doughnut is a ring-shaped dessert that made of from sweet fried dough. It is popular in Malaysia and prepared as a sweet snack in various forms that can be made homemade or bought in bakeries and food stalls.

There are different frying techniques are being popular in the food industry. The deep-oil frying process is one of the oldest techniques of preparing food, which is highly appreciated by consumers due to the taste (Heredia et al., 2014). This process basically consists of an immersion of the product in hot vegetable oil, causing the egress of water and the ingress of oil, with the consequent changes in texture and colour properties.

Hot air frying is one of the modern methods besides other methods used to produce fried food with less amount of oil while maintaining their appearance and taste similar to deep fat fried foods (M. Arafat, 2014). In a kitchen air fryer, the hot air has direct contact with food and the oil droplets on its surface (Teruel et al., 2015). Frying with hot air has some advantages such as a reduction in oil absorption, keeping the oil-soluble vitamins through omission of oil as heat transporter fluid, and improvement of product quality since the issues of oil deterioration is avoided (Heredia et al., 2014).

Since there are no data found about air fryer application in the frying doughnut, the effectiveness response surface methodology (RSM) is used to optimize the processing condition of the air fryer. The independent variables are frying temperature and time, with a frying temperature of 130˚C to 150˚C and frying time of 10 to 14 minutes. The quality of the doughnut depends on the frying process conditions which are frying temperature and frying time. The desired quality such as lower moisture content, lower fat content and lower hardness are more significant in food frying. Colour is another key feature of the food product as it reveals the sensual attraction and the excellence of the foods. Hence, the process conditions should be most suitable to retain its best quality at the end.

Sensory analysis is being conducted after the optimization. The objective of this sensory analysis is to measure the acceptable and unacceptable of fried doughnut in terms of appearance, aroma, texture and overall acceptance. The samples of doughnuts rated based on how much it is liked or disliked by the 20 untrained panelists.

1.2 Problem statement

People nowadays love to consume healthy foods, but they do prefer food that is fried with oil because of its delicious taste and crispiness. However, the current method of frying food via deep fat fryer technique consists of a high amount of oil that is not healthy to consume. There will be a risk of spilling, splashing or accidentally touching hot oil. In fact, eating them regularly can give a high risk of developing diseases like diabetes, heart disease and obesity.

Therefore, air fried foods are touted as a healthy alternative to deep-fried foods because of their lower content of fat and calories. It is new frying equipment that has been developed with the uses of superheated air technology for frying, roasting, baking and grilling. Frying food with air fryer can be considered a healthier alternative to prepare food for consumption because it does not require oil during frying. Reducing the regular intake of unhealthful oils can promote weight loss. Besides, since there is no specific studies and published work in the literature about the frying doughnut in the air fryer, the optimum parameter of air fryer needs to be determined in order to get the best quality and texture of doughnuts.

Furthermore, it is important to find out if the taste of the doughnuts can be accepted and liked by the people or not. Basically, people's taste and perception are not the same when testing the foods. Hence, sensory analysis is needed to understand the panelists' requirements and acceptance.

1.3 Research objectives

The main objectives for this project are:

1. To determine the optimum condition for frying doughnut via air frying technique.
2. To investigate the effect of air frying process on the texture and quality of doughnut compared with traditional deep fat frying.

1.4 Scope of the study

The scope of this study consists of five chapters. Chapter 1 is about the introduction and overview of this research background, problem statements and objectives of this study. For Chapter 2, the literature review of the effect of frying on texture and quality of doughnut using air fryer. This chapter consists of background of doughnut, types of frying techniques, proximate analysis and optimization by response surface methodology. Chapter 3 is about the method used to conduct the experiment with the procedure and equipment used. This chapter consists of sample preparation, frying method, the proximate analysis method of fried doughnut, experimental design and statistical analysis, explanation about analysis of quality fried doughnut and lastly sensory analysis. Next, Chapter 4 is results and discussion of the experiment which contain figure, table and graph. The data of the experiment that have been analyzed are stated in this chapter. Lastly, the conclusion and recommendation of this research are stated in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of doughnut

A doughnut is a kind of fried dough or dessert food. It is popular at all time and prepared as a sweet snack in various forms that can be made homemade or bought in bakeries and food stalls. Doughnuts are tasty, sweet, and can be eaten at any time. Doughnuts are usually fried using deep fryer from a flour dough, typically in a ring-shaped or several shapes without a hole, and often filled, but can also be ball-shaped. Other types of batters and different types of toppings and flavorings, such as sugar, chocolate or maple glazing can also be used for making a doughnut. Once fried, it is possible to glaze doughnuts with a sugar icing, spread them on top with icing or chocolate, or top them with powdered sugar or sprinkles or fruit.

2.1.1 History of doughnut

The doughnut's history goes back centuries, long before the New World was discovered. According to the Oracle Think Quest Educational Foundation, in 1847, a 15-year-old boy has invented doughnuts by cutting his cake because he was tired of eating the soggy midsection of his cakes. He punched a hole at the center of the dough ball before frying. The hole can increase the area of the dough surface, exposure to hot oil, thus eliminating the uncooked center. Other versions of how the hole ended up in donuts are available. Some people say Captain Gregory wanted to steer both hands while enjoying his delicious delight, so he impaled his donuts on the steering wheel of the ship, creating a hole in the middle. Others say that in a dream sent by angels, the idea of the hole in the middle of donuts came to him (Lee, 2017).

Also, highly debated is the origin of the name "doughnut". Some say it refers to the nuts that were placed inside the dough ball to prevent the uncooked center while others say it refers to "dough knots" that were another popular olykoeks shape.

2.1.2 Nutrition of doughnut

Doughnuts are rich in carbohydrates as we are sure to have a full stomach after consuming three doughnuts. Furthermore, the sugar on the top of doughnut can give us the energy to do work for the whole day. But doughnut is not a healthy carb because plain doughnuts are high in sodium, sugar and trans fats that can increase the risk of heart disease. Therefore, we need to eat them in moderation and limiting trans fats as much as possible in our diet. Table 1 shows the nutrition information found in a fried doughnut.

Table 1: Nutrition information of fried doughnut (Tangkanakul et al., 1996)

Composition	Percentage (%)
Fat	23.63-59.40
Protein	3.68-63.69
Carbohydrate	0.68-62.18

The Food and Drug Administration (FDA) recommends only 2000 calories per day of a doughnut, with 65 g of fat, which should contain 20 g of saturated fat only. The FDA also suggests that only 300 mg cholesterol, 2400 mg sodium and 300 g carbohydrate should be ingested (Herman, n.d.).

2.2 Frying techniques

Frying of foods is a common and popular process utilized in the food industry due to its significant sales and a vast quantity of products. Fried products have unique sensorial properties, including flavor, crisp texture, juicy taste and brownish colour. The frying process is considered to have less effect on nutrient losses than other cooking methods (Kalogeropoulos, 2010). The types of frying are deep frying, pan frying, stir-frying and air frying. Thus, this study aims to investigate the effect of frying doughnuts using two major types of frying method which are air frying and deep fat frying (Ghaitaranpour et al., 2018).

2.2.1 Deep fat frying

Deep fat frying can be defined as the process of cooking foods by contacting it with hot oil at temperatures between 140°C to 180°C (Schwarzinger et al., 2012). It is widely used in the preparation of foods because consumers prefer the taste and appearance of fried food products. It is important that the deep fat fried products should satisfy both health and sensory aspects of consumer demand. High heat transfer rates are largely responsible for the development of desired sensorial properties in fried products (Farkas, 2017). Deep fat frying of donuts was conducted in a commercial batch fryer with 5 L of capacity and electrical resistors as a heating source (Vélez-Ruiz & Sosa-Morales, 2003). The vessel was filled with sunflower oil, and when the desired temperature was reached, raw donuts were introduced to the fryer; then the samples were taken periodically.

Based on Figure 1, a thin crust forms within a few seconds in the first phase, whose structure crucially affects the deep frying process and the quality of the food with regards to fat absorption and crispness (Schwarzinger et al., 2012). Many chemical reactions take place during the deep fat frying process. According to Sébédioa & Juanedab (2007), hydrolysis leads to the creation of fatty acids, monoglycerides and diglycerides while the existence of air and high temperatures leads to the creation of alteration products for heat and oxidation. Oxidation product may include monomeric, dimeric and oligomeric triglycerides and volatile elements.

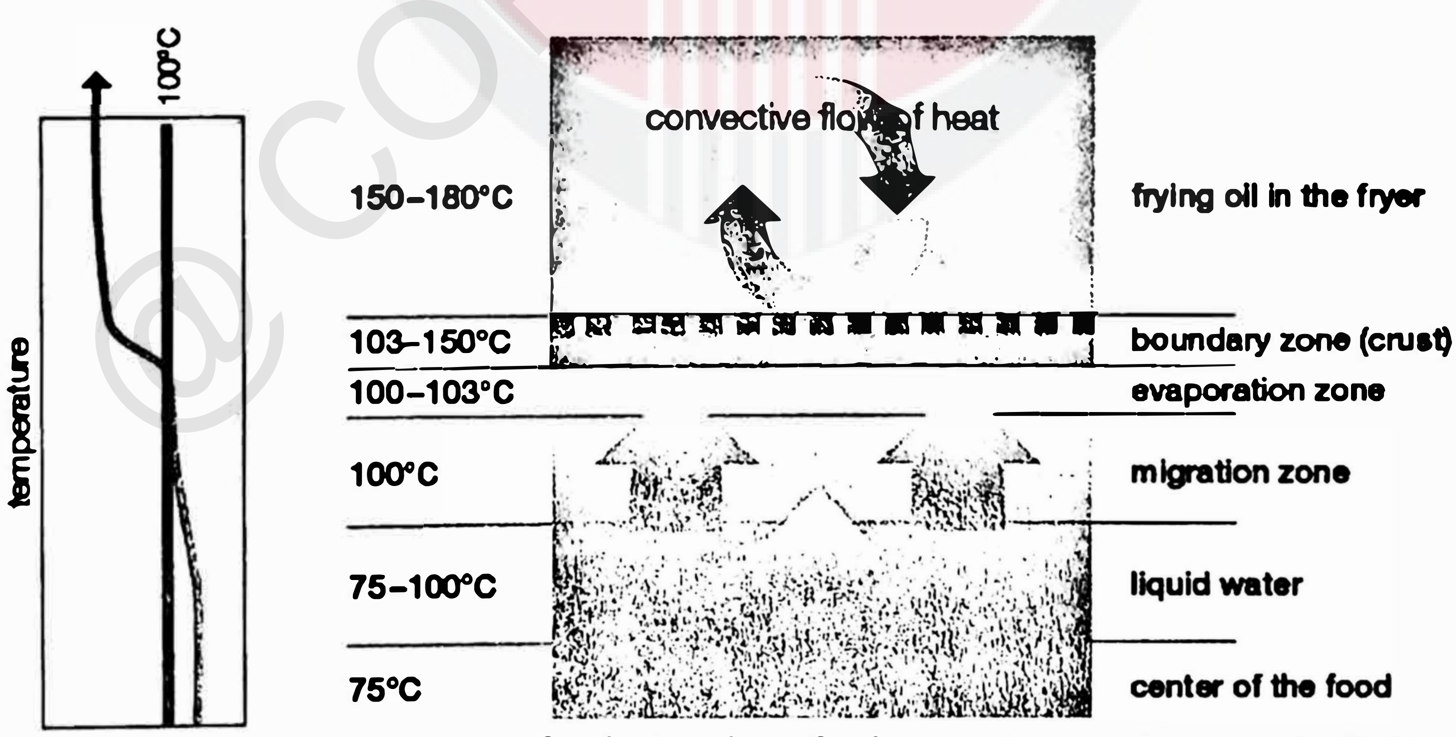


Figure 1: Heat and mass transfer during deep fat frying (Schwarzinger et al., 2012)

2.2.2 Air frying

According to Shaker (2015), air frying process is a new technique to get fried products through direct contact between an external emulsion of oil droplets in hot air and the product into a frying chamber. The air fryer looks like a large rice cooker and has a chunky tray which can be removed, filled with food and put back inside. It uses a grill and a fan to blast very hot air around the food at high speed rather than submerging the food in oil. The movement of air in the air fryer is shown in Figure 2.

Figure 2: Movement of air in the air fryer

The air fried product is thus dehydrated, gradually appearing the typical crust of fried products. The amount of oil used in the air fryer is lower than in deep-fat frying and very low fat products are produced. Today, it is possible to find, equipment designed from this principle to obtain low-fat fried products (M. Arafat, 2014). Frying with hot air has some advantages such as reduce the oil absorption, keeping the oil soluble vitamins through omission of oil as heat transporter fluid, and improve the product quality since the oil deterioration issues are avoided (Heredia et al., 2014).

2.3 Proximate analysis

The quality of fried doughnut that will be evaluated in term of moisture content, fat content, texture (hardness) and colour that may affect the product's shelf life. Frying temperature and frying time also play an important role for the quality of the doughnut.

2.3.1 Moisture analysis

Moisture content is the amount of water content dependent on the food. The moisture of food content is important to food manufacturers for a variety of reasons. Moisture in high amounts and inappropriate places is very damaging to the useful life of the food (Hagan, 1999). Water is an important component of many foods and each has its own characteristic. There are several methods to determine the moisture content such as vacuum oven method, microwave drying method, moisture analyzer and another method (Nielsen, 2010).

According to (Raihani, 2017), the drying oven is commonly used for commercial purposes. It is the established reference method for loss on drying. Approximately 8 g of each ground doughnut sample was placed into aluminium weighing boats and dried at 105°C in an oven (Melito & Farkas, 2013). A sample is weighed and subsequently heated in this procedure to allow moisture to be released. Following this, the sample is cooled in the desiccator before reweighing. The difference in wet and dry weight is calculated by the moisture content. Measuring accuracy and balance resolution is extremely important in this process. Also, careful consideration must be given to maintain the same conditions where temperature and duration are vital to produce accurate and reproducible results.

2.3.2 Fat analysis

Fat is important in the animal diet and can improve the quality of animal and can enhance productive performance in animals. It is a crucial component in animal food and the building blocks of fats are fatty acids, some of which animal require in their diet because their body cannot make them. There are several methods that can be used for fat determination such as Soxhlet, Goldfish, Mojonnier, and Babcock methods. Soxhlet method is usually used in food especially for solid food. A modern solvent extraction system, the Soxtec, is based on the classical Soxhlet method. Melito & Farkas (2013) conducted fat analysis of doughnuts by Soxhlet extraction. This method only can determine free fat. Total fat can be determined when mixes solvent likes chloroform-method is used in the right ratio (Nielsen, 2010).

For the gravimetric quantitation of fat and oil, the Soxtec provides a faster approach to solvent extraction. Typically, the Soxtec methods require only 20–25% of the time required for traditional Soxhlet extraction (Anderson, 2004). By definition, the procedure to determine crude fat is an empirical method in which the result is determined by the conditions of the procedure. Several aspects of the extraction process are explored, such as type of solvent, time and temperature. Many Soxtec applications are routinely used for measuring fats, oils, semi-volatiles, and another solvent extractable in food, feed, industrial, and environmental laboratories. This study will be limited mainly to crude fat extraction. Crude fat by solvent extraction is classified as an empirical method (Manual, n.d.). This means that the final result can be arrived at only according to the terms or variables of the method. Therefore, it becomes critical to strictly follow all aspects of the procedure.

2.3.3 Texture analysis

Texture is one of the main factors which determine the quality of any given food and plays an important role in the acceptance of food products by consumers (Sahin & Sumnu, 2006). The texture of food products is defined as all the rheological, mechanical and structural attributes of the product perceptible by means of mechanical, tactile, visual as well as auditory receptors. Because of its adaptability, texture analyzer has become commonplace throughout the food industry (Smewing, 2016). Texture Analyzer is easy to use, cost-effective solution to evaluate the textural properties of a wide range of products at all stages of manufacture. Mechanical texture analysis, with a software-operated calibrated texture test using fundamental algorithms, removes all subjectivity elements from the test. Tan & Mittal (2007) studied the physicochemical properties changes of doughnuts during vacuum frying compared to the conventional frying. The result shows that the force fluctuated of the doughnuts are in the range of 0.5–1.5 N.

2.3.4 Color analysis

Appearance is one of the most importantly fresh and processed food, products and their marketing attributes of sensory quality. The colour of the food surface is the first quality parameter evaluated by consumers, and it is critical to product acceptance. The first sensation that the consumer perceives and uses as a tool to either accept or reject food is the food appearance determined mostly by surface colour. Colour may be determined instrumentally using either colorimeters or spectrophotometers.

Colorimeters are a great way to capture color and do a basic evaluation for applications that don't require tight color control (Mouw, 2017). Colorimeters measure the colour of primary radiation sources, which emit light, and secondary radiation sources, which are those that reflect or transmit external light. Pathare & Opara (2013) studied that a tristimulus colorimeter has three main components which are a source of illumination, a combination of filters used to modify the energy distribution of the incident/reflected light and photoelectric detector that converts the reflected light into an electrical output. Therefore, colorimeters are the most commonly used instruments in the colour measurement of food and other products, presumably due to their ease of use and interpretation of colour data.

According to Vélez-Ruiz & Sosa-Morales (2003), the colour of the doughnut surface was measured by reflectance on a colorimeter with L^* (lightness), a^* (redness), and b^* (yellowness) parameters. Total color difference, ΔE, was calculated as:

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

This difference was calculated with respect to the raw dough, as the source of L_0^*, a_0^* and b_0^* parameters.

2.4 Optimization by response surface methodology (RSM)

Optimization is the most powerful design improvement tool, which is used to improve the performance of a process in order to achieve the maximum benefit from it. Response surface methodology (RSM) is defined as a statistical technique used to determine and simultaneously solve multivariate equations using quantitative data from the appropriate experimental design. RSM reduces the number and interactions of experimental trials needed to evaluate multiple parameters. Hence, it is an effective tool for optimizing complex processes and has been widely applied in the food industry (Lee & Yusof, 2006). In food engineering, many researchers have been performed to optimize frying conditions and find out an empirical model for the best quality of food product. Abd Rahman et al. (2017) applied the RSM to study the optimum conditions for frying sweet potato via hot air frying technique.

2.4.1 Advantage of RSM

In Design Expert Software, there are two most common and popular designs involved in RSM which are Central Composite Design (CCD) and Box-Behnken Design (BBD). The CCD is considered as most effective for uniform precision with lower runs required, chronological and it involves three classes of design such as rotatable, spherical and face-centered. The application if this design depends on the region of interest and region of operability. In face centered design as shown in Figure 3, the star points are at the center of each face of the factorial space, so $\alpha = \pm 1$. This variety requires 3 levels of each factor. Augmenting an existing factorial or resolution V design with appropriate star points can also produce this design (Anonymous, n.d.).

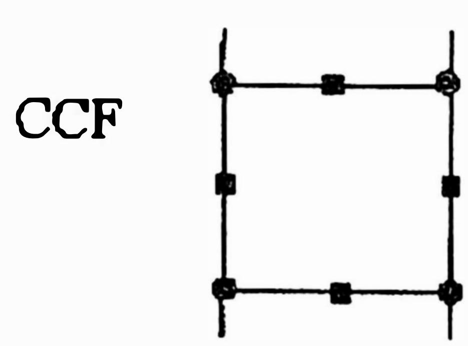


Figure 3: Face centered type of central composite design

2.4.2 Selection of the experimental design, prediction and model verification

The most common designs used for optimization are CCD and BBD. CCD is considered as most effective for uniform precision with lower run required, with a quadratic model was employed to study the combined effect of independent variables. The effect of these two variables x_1 and x_2 on the response (Y) was modeled using the second order polynomial response surface. The equation derived using RSM for the prediction of the response variables is shown in Equation 1:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2 \qquad \text{(eq. 1)}$$

where β_0 is constant, β_1 and β_2 are linear coefficients, β_{12} is interaction coefficient, and b_{11} and b_{22} are quadratic coefficients.

For the verification of model adequacy, several techniques are performed such as residual analysis, scaling residuals, prediction error sum of square (PRESS) residuals, and testing of the lack of fit. Myers et al. (2009) explained that the overall predictive capability of the model is commonly explained by the coefficient of determination (R^2), which is calculated from the PRESS. The predicted model equation can be acquired by the response surface plot and contour plot.

2.5 Sensory evaluation

Sensory evaluation is defined as the science of judging and evaluating the quality of food using the senses, which are taste, smell, sight, touch and hearing. Sensory testing was developed into an accurate, formal, structured methodology that is being continuously updated to refine existing techniques. The developed methods serve economic interests and can establish the worth or acceptance of a commodity.

Before a product reaches the market, it must pass through many tests to give a reasonable impression of how well the public will accept it. This is especially true in the food industry because of the many tastes and social preferences (Meilgaard et al., n.d.). There are many types of sensory analysis methods, the most popular being difference tests, descriptive analysis and consumer acceptance testing (Hildegarde & Lawless, n.d.). Consumer acceptance, preference, and hedonic tests are used to determine the degree of consumer acceptance for a product. It is also considered to be consumer tests since they should be conducted using untrained consumer panels.

CHAPTER 3

METHODOLOGY

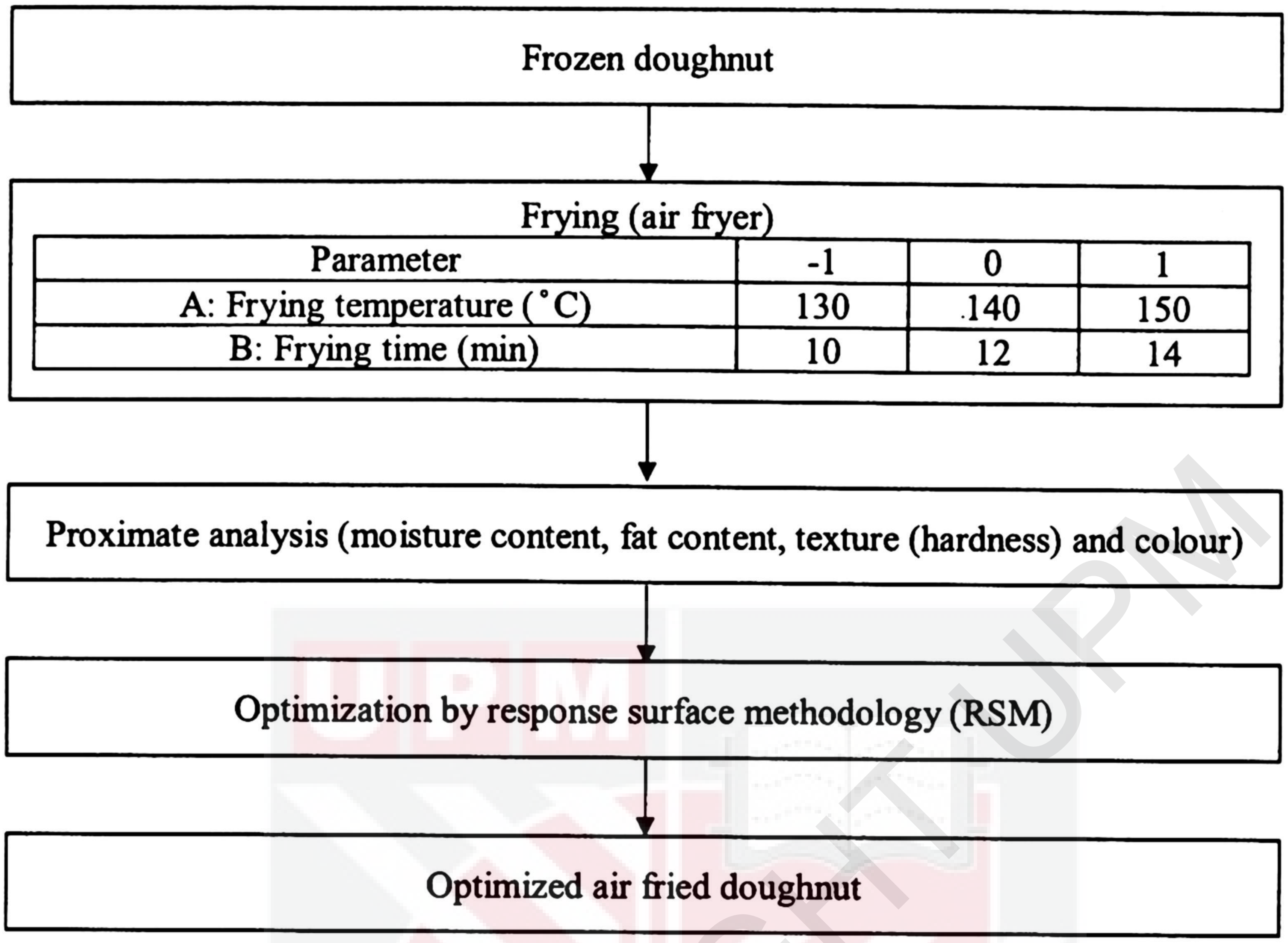
3.1 Sample preparation

Frozen doughnuts (Kart's) were purchased at a supermarket in Selangor, Malaysia and stored in the fridge at -18°C. The frozen doughnuts were taken out of the fridge and submerged (in packaging) in cold water maintained at 4°C and below to avoid microbial growth and to preserve its taste, texture and nutritional value. The water was replaced every 30 minutes by adding ice cubes, so it can continue to thaw.

3.2 Flow chart

Figure 4 shows the summary of the process flow of frying doughnut by using air fryer and deep fat fryer.

Part 1: Optimization



Part 2: Comparison between air fried doughnut and deep

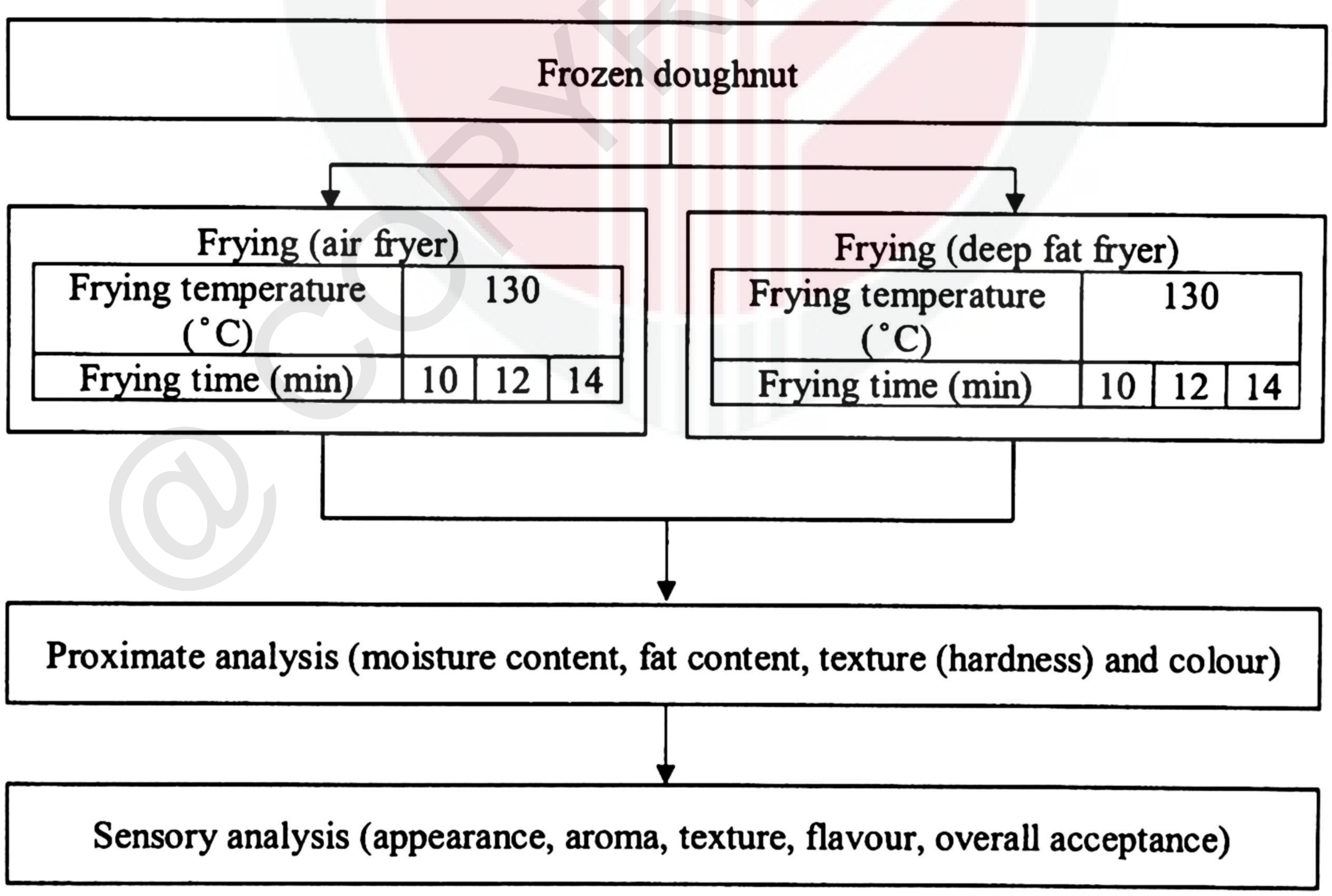


Figure 4: Summary of process flow of frying doughnut by using air fryer and deep fat fryer

3.3 Frying

The frying of doughnut has been performed by using two frying techniques which are air frying and deep fat frying. The deep fryer was turned on for two hours before the process begins and the air fryer was turned on for 20 minutes to reach thermal equilibrium (Ghaitaranpour et al., 2018). The frying temperature of foods usually was done between 120°C to 180°C depending on the final product desired (Costa & Oliveira, 1999). For each frying method, at least two replications were performed.

3.3.1 Air frying

Air fryer (Philips, United Kingdom) (Figure 5) was used for frying doughnut. The frying was selected at three different temperatures which are 130°C, 140°C and 150°C for 10, 12 and 14 minutes. There is no need to rotate the samples during air frying since hot air covered all parts of the sample's surface. At the end of the frying process and after reaching the ambient temperature, the samples were packaged in plastic bags (Ziploc) for further analysis.

Figure 5: Air fryer

3.3.2 Deep fat frying

The doughnuts were fried in a deep fat fryer (Faber) (Figure 6) containing 2 L of sunflower oil (Sun Lico) at a temperature of 130°C for 10, 12 and 14 minutes. The frying time was divided into two equal parts. The doughnuts were needed to rotate so that all parts of the sample's surface are fully cooked. Samples stayed for a few seconds in the adsorbent paper, allowing the elimination of extra oil and cooling at room temperature. Then, the samples were packaged in plastic bags (Ziploc) for further analysis.

Figure 6: Deep fat fryer

3.4 Determination of fried doughnut properties

3.4.1 Determination of moisture content

The moisture content of fried doughnut was determined using a convectional oven (Memmert, Germany) (Figure 7). The moisture content of the doughnut was analyzed by cutting the doughnut with 1 cm thickness and placed into the aluminium weighing boats. The mass of samples before drying, M_{wet} was recorded. The samples were dried in the oven at 105 °C for 24 hours. Mass of samples after drying, M_{dry} was recorded. Then, the moisture content of the samples was calculated from Equation 2:

$$\text{Moisture content (\%)} = \frac{M_{wet} - M_{dry}}{M_{dry}} \times 100\% \quad \text{(eq. 2)}$$

where M_{wet} and M_{dry} are the mass of samples before and after drying respectively.

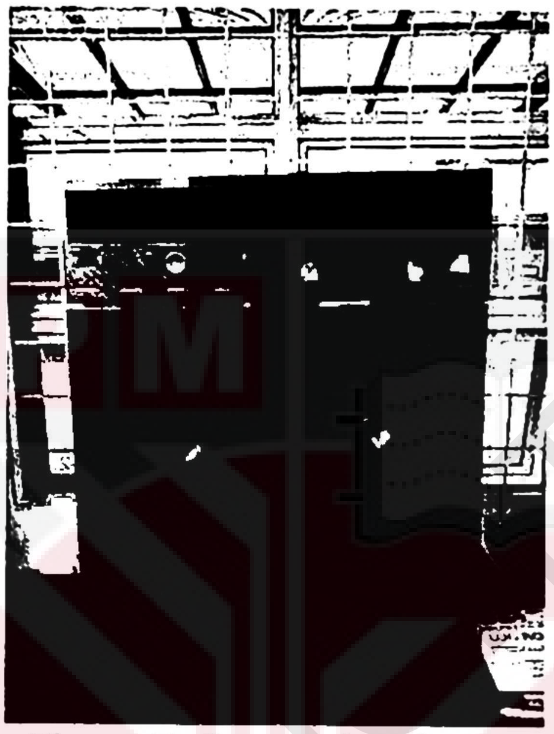


Figure 7: Convectional oven

3.4.2 Determination of fat content

The amount of fat in the fried samples was determined using Soxtec™ 2050 Automatic System (FOSS, Denmark) (Figure 8). Firstly, empty aluminum cups were dried in the convectional oven at 105 °C for 30 minutes and cooled down in the desiccator for 30 minutes. Mass of dried aluminum cups, W_1 were weighed. The samples were dried in the convectional oven at 50 °C for 24 hours. Then, the samples were meshed and ground using a grinder until the samples are homogenous. Approximately 1 g of each of the dried samples, W_S was weighed into the thimbles. The aluminium cups with samples inside were submerged into boiling hexane for 70 minutes. The cups were placed in the convectional oven again for 30 minutes and were left to cool in the desiccator for 30 minutes. After that, the mass of aluminimum cups with oil, W_2 was weighed. Then, the fat content of the sample was calculated using Equation 3:

$$\text{Fat content (\%)} = \frac{W_2 - W_1}{W_s} \times 100\% \qquad \text{(eq. 3)}$$

where W_1 and W_2 are the initial and the final mass of the aluminium cups respectively, while W_s is the mass of the dried sample.

Figure 8: Soxtec 2050 Automatic System

3.4.3 Determination of texture analysis (hardness)

Texture analysis of the fried doughnut was determined using texture analyzer (TA-XT2i, Stable Micro Systems, England) (Figure 9). The sample was placed on the base of the analyzer with a 2 mm cylindrical probe which was set to travel at a speed of 1 mm/s with 50% of their original height and trigger force 5 kg was selected. The penetration position of the doughnut was at the three points of the sample. The hardness of the sample was determined based on the maximum force (F_{max}) obtained from force vs frying times. The maximum compression force from the force-deformation curve generated indicated the hardness of the sample.

Figure 9: Texture analyzer

3.4.4 Determination of color measurement

Surface color analysis of the fried doughnut was measured using Color Reader CR-10 (Konica Minolta, Japan) (Figure 10) with L^* (lightness), a^* (redness), and b^* (yellowness) parameters. Colour change, ΔE^* is calculated using Equation 3:

$$\Delta E^* = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2} \qquad \text{(eq. 3)}$$

This difference was calculated with respect to the raw dough, as the source of L_0*, a_0* and b_0* parameters. The calibration was conducted using a standard white plate.

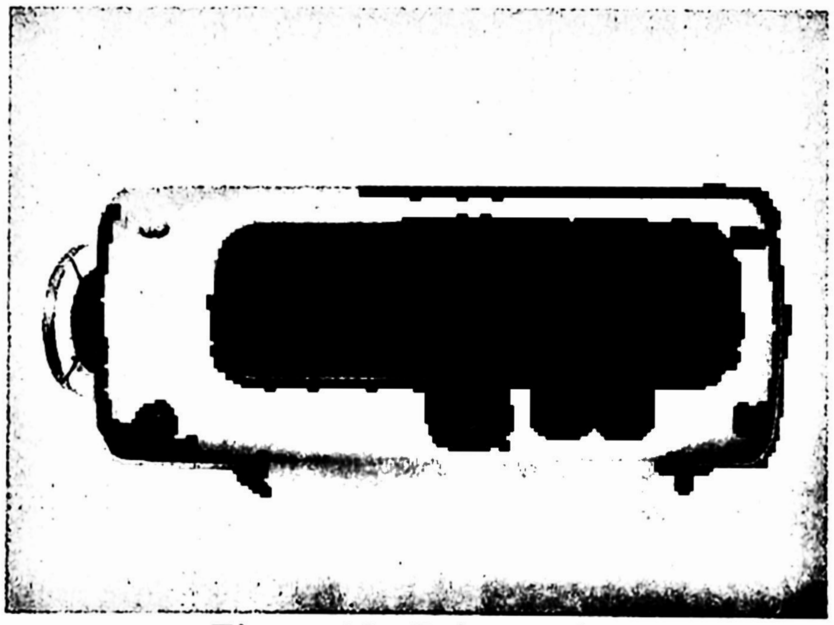


Figure 10: Color reader

3.5 Optimization by response surface methodology (RSM)

Optimization was performed using Design Expert software (Stat-Ease, Inc., Minneapolis, USA). A central composite design with two factors and four responses were used for the modeling of processing variables (frying temperature, and frying time), and the responses measured are moisture content, fat content, texture and colour. In this study, temperature (A) and time (B) were selected as independent variables. The ranges for these two variables were as follows:

1) Temperature: 130-150°C
2) Time: 10-14 minutes

Each independent variable was studied at three levels assigned as -1, 0, and +1 respectively as shown in Table 2.

Table 2: Level of independent variables in the experimental plan

Symbol	Variable	Code level		
		-1	0	1
A	Temperature (°C)	130	140	150
B	Time (min)	10	12	14

3.6 Sensory evaluation

A preference sensory test, based on a nine-point hedonic scale, was carried out with a sensory panel (Haque, et. al, 2015). Scores are based on a 9-point hedonic scale (1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much and 9=like extremely) for various quality characteristics. The sensory evaluation will be conducted between 20 untrained judges from students and staffs of Universiti Putra Malaysia (UPM). The sensory attributes studied are appearance, aroma, texture, flavor and overall acceptance obtained by the optimum process condition for fried doughnuts. The score sheet is shown in Appendices.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Optimization of air frying for doughnut by RSM

The air frying parameters were optimized for the best quality of fried doughnut using RSM. In order to obtain a proper model for the optimization of air frying condition, two factors (frying temperature and frying time) and four responses (moisture content, fat content, hardness, and colour) in a central composite design (CCD) were used to optimize the best quality of frying doughnut. According to CCD, thirteen runs have been carried out for the optimization of air frying parameters of frying doughnuts. The experimental data are tabulated in Table 3. These experimental data were used as raw data in the RSM program to generate a suitable predicted model and its statistical analysis.

Table 3: Central composite design obtained from RSM and experimental data of the responses of air fried doughnut for the required runs

	Factors		Responses			
Run	Frying temperature (°C)	Frying time (min)	Moisture content (%)	Fat content (%)	Hardness (N)	Colour (ΔE)
1	140	12	61.46	13.23	0.8919	8.55
2	140	12	58.42	13.32	0.8984	8.79
3	130	10	59.17	12.38	0.7277	2.74
4	150	10	59.40	14.25	0.9173	7.17
5	130	12	56.55	12.77	0.7488	3.63
6	140	12	61.45	13.19	0.8993	8.65
7	150	12	56.77	14.45	0.9202	9.62
8	140	12	60.81	13.22	0.8997	8.64
9	150	14	50.86	14.68	0.9409	10.88
10	140	12	59.58	13.62	0.8937	8.90
11	130	14	54.08	13.47	0.7683	4.24
12	140	10	66.62	13.01	0.8767	7.38
13	140	14	58.80	14.11	0.9112	9.05

The accuracy and fitness of the final predicted model were considered based on the results of the analysis of variance (ANOVA). ANOVA results of the quadratic model in Table 4 indicated that the model equation derived by RSM could adequately be used to describe the frying process under a wide range of operating conditions. As can be seen in Table 4, a *p*-value of less than 0.05 implies that the corresponding model term is significant. Values above 0.10 indicate that the terms of the model are not significant. Moreover, individual and interactive model terms also show the significance of the developed model.

The coefficient of variation (CV) is a measure of deviation from the mean values, which shows the reliability of the experiment. The obtained CV of this study is not greater than 10% and shows the reproducible nature and also indicate less variability and better reliability (Myers et al., 2009). From Table 5, the moisture content, fat content, texture and colour show low CV values (CV<4) and indicate that the models of the responses are highly reliable (Rezaul et al., 2016).

Adequate accuracy (AP) is a measure of comparison between the predicted values and the error of mean prediction. Manivannan & Rajasimman (2011) explains that AP>4 indicated that the consistency of the predicted model to describe the process. The response of moisture content, fat content, texture and colour show AP>4 which ensures that the predicted models are consistent with the air frying process. The lack of fit value was greater than 0.05 indicate that this value was not significant relative to the pure error, which was the most preferred. The PRESS values were considered to be a minimum to obtain a well accorded model.

Table 4: ANOVA evaluation of quadratic terms and coefficients for the prediction model of air fried doughnut

Variance source	**df**	**Moisture content**		**Fat content**		**Texture**		**Colour**	
		Sum of squares	*P*-value	Sum of squares	*P*-value	Sum of squares	*P*-value	Sum of squares	*P*-value
Model	5	159.91	0.0013	5.36	<0.0001	0.060	<0.0001	73.57	<0.0001
Linear									
A	1	1.28	0.4669	3.78	<0.0001	0.047	<0.0001	48.51	<0.0001
B	1	76.68	0.0006	1.14	0.0003	1.624E-003	<0.0001	7.89	<0.0001
Interaction									
AB	1	2.98	0.2790	0.11	0.0835	7.7225E-005	0.0741	1.22	0.0033
Square									
A^2	1	74.80	0.0006	0.13	0.0631	9.570E-003	<0.0001	11.29	<0.0001
B^2	1	1.98	0.3707	0.077	0.1332	9.435E-007	0.8174	0.51	0.0252
Residual	7	15.12		0.19		1.149E-004		0.45	
Lack of fit	3	8.15	0.3305	0.063	0.6138	6.424E-005	0.3053	0.37	0.0516
Pure error	4	6.97		0.12		5.054E-005		0.077	
Cor Total	12	175.03		5.55		0.060		74.01	
R-Squared		0.9136		0.9662		0.9981		0.9940	
Adj R-Squared		0.8519		0.9421		0.9967		0.9896	
Pre R-Squared		0.5990		0.8630		0.9897		0.9479	
Adeq Precision		13.697		22.129		76.581		46.459	
PRESS		70.19		0.76		6.238E-004		3.85	
C.V.		2.50		1.21		0.47		3.35	

N.B.: *p*-value <0.05 is significant at α=0.05; Lack of fit is not significant at *p*-value >0.05. A= Frying temperature, B= Frying time.

4.1.1 Correlation of predicted vs. experimental values of the responses

In general, it is important to ensure that the fitted model shows an adequate approximation of the actual values. If the model does give a suitable fit, the optimization of the fitted response surface is likely to show poor or misleading results (Fang et al., 2012). However, the model suitability can be investigated based on the results of fitted-line plots of predicted versus experimental as shown in Figure 11 to Figure 14. The diagnostic line plot signifies the closeness or relationship between the predicted and experimental values for these responses.

It can be seen from Figure 11 to Figure 14, the rectangular points are the experimental values that shown in Table 3 are very close to the linear regression line, which shows that the experimental values are fitted to the regression line. The fitted line plot of the responses suggests that there has adequate consistency between the experimental and predicted data. Furthermore, high R^2 values such as, R^2=0.9136 for moisture content, R^2=0.9662 for fat content, R^2=0.9981 for texture and R^2=0.9940 for colour, were obtained, which suggests that the models are highly compatible. This is because, for a good fit model, R^2 value should be at least 0.8, indicates 80% of response data is around of its mean (Myers et al., 2009).

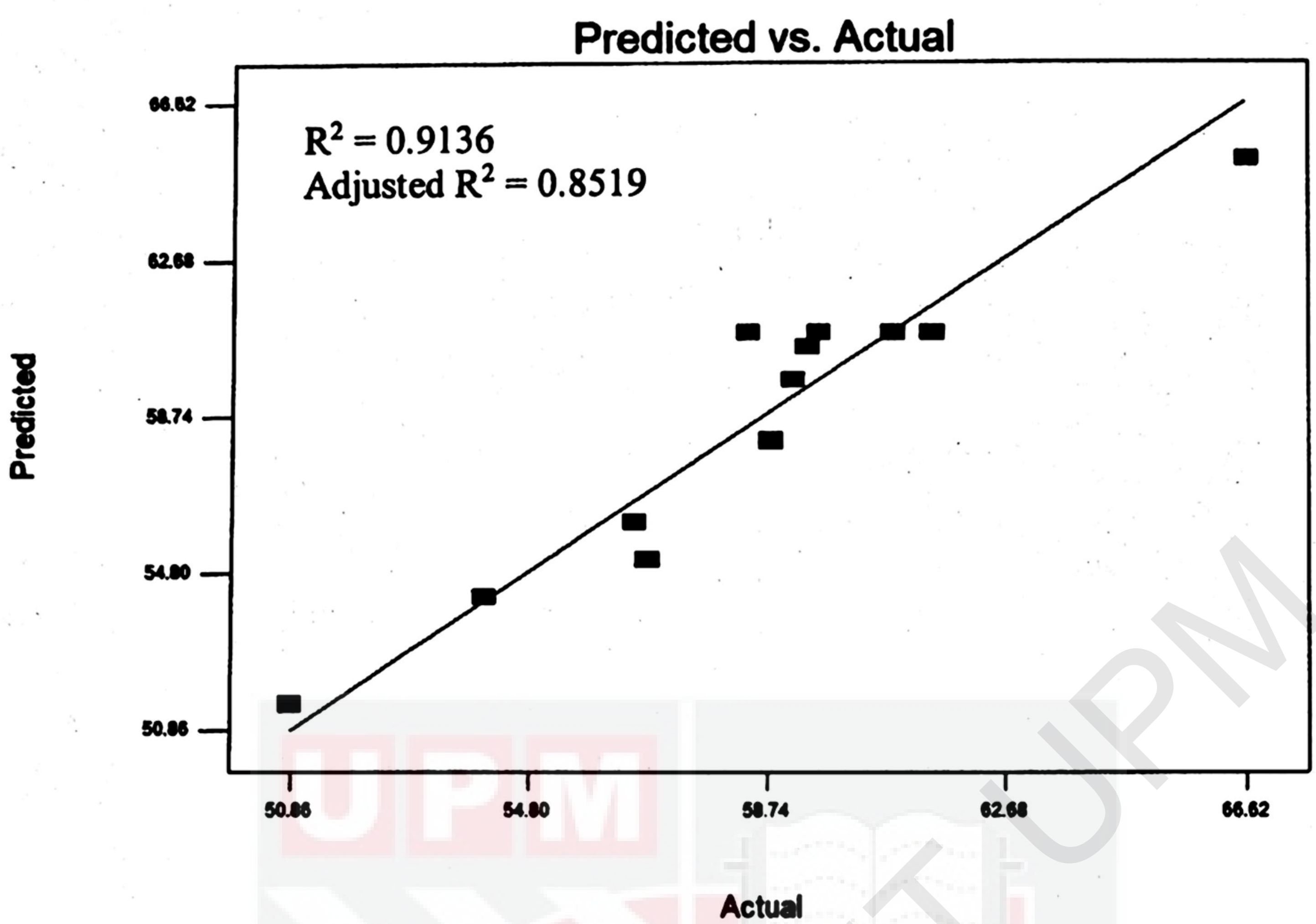


Figure 11: The fitted line plot signifying the closeness between predicted values and experimental values for moisture content

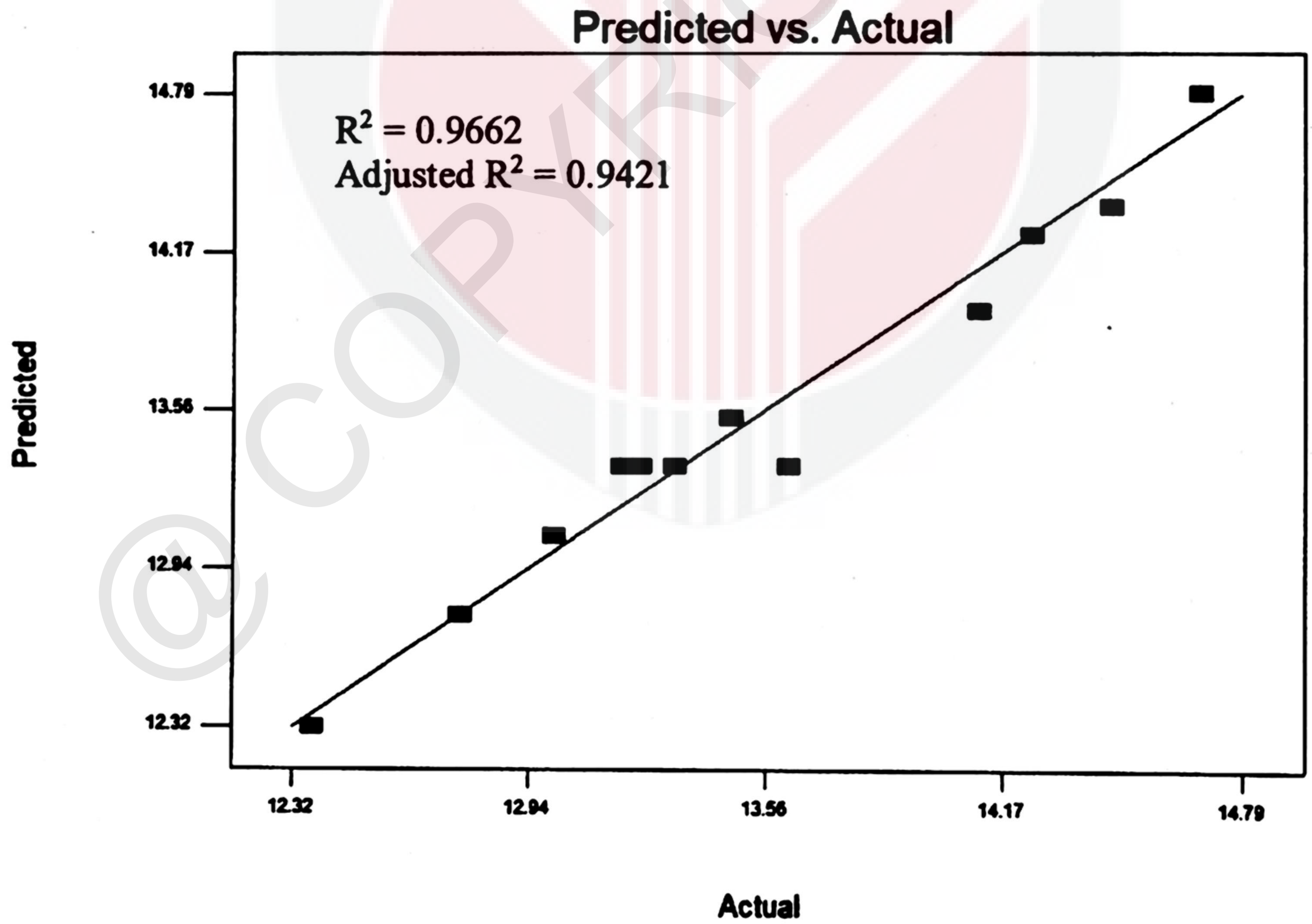


Figure 12: The fitted line plot signifying the closeness between predicted values and experimental values for fat content

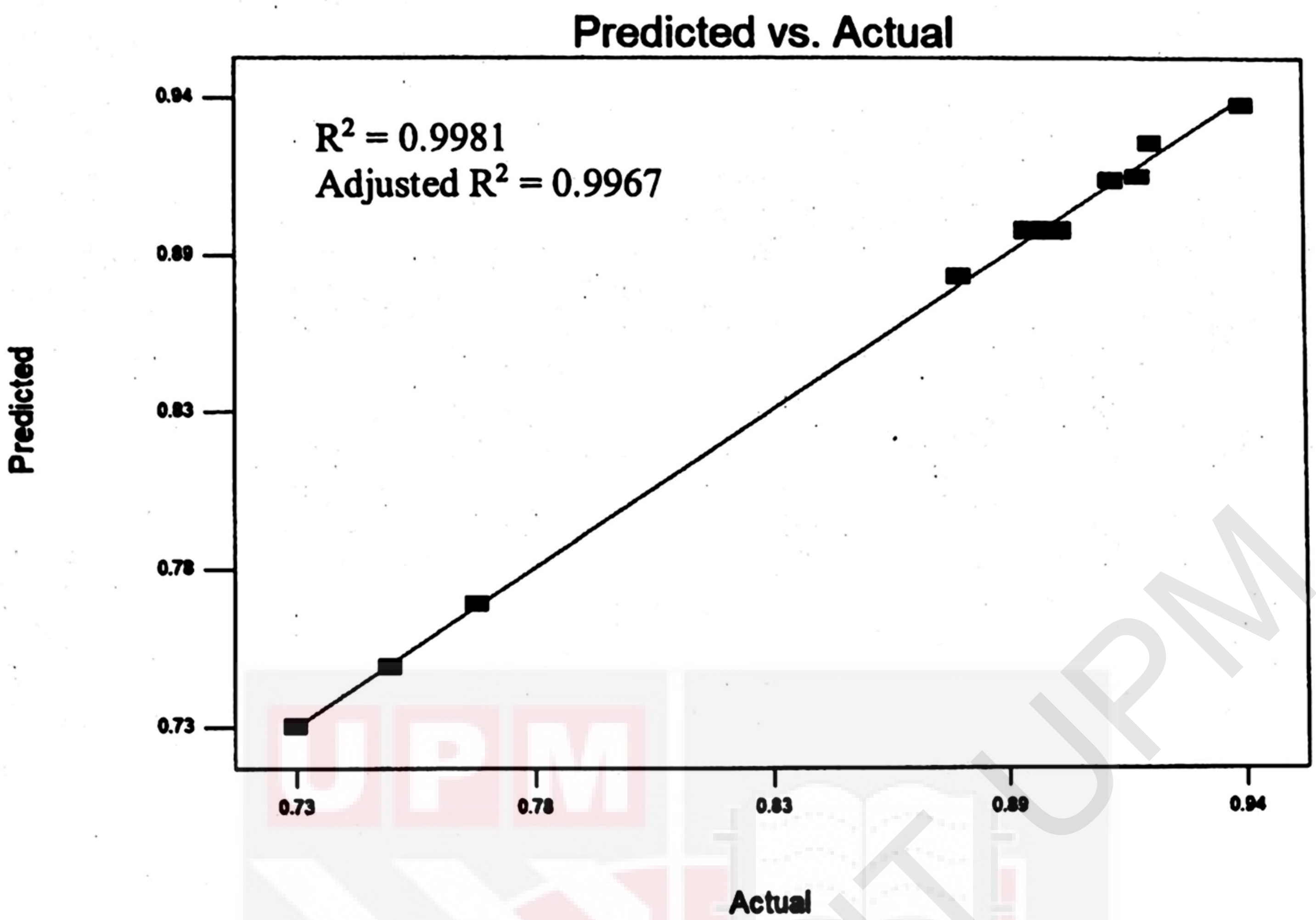


Figure 13: The fitted line plot signifying the closeness between predicted values and experimental values for texture

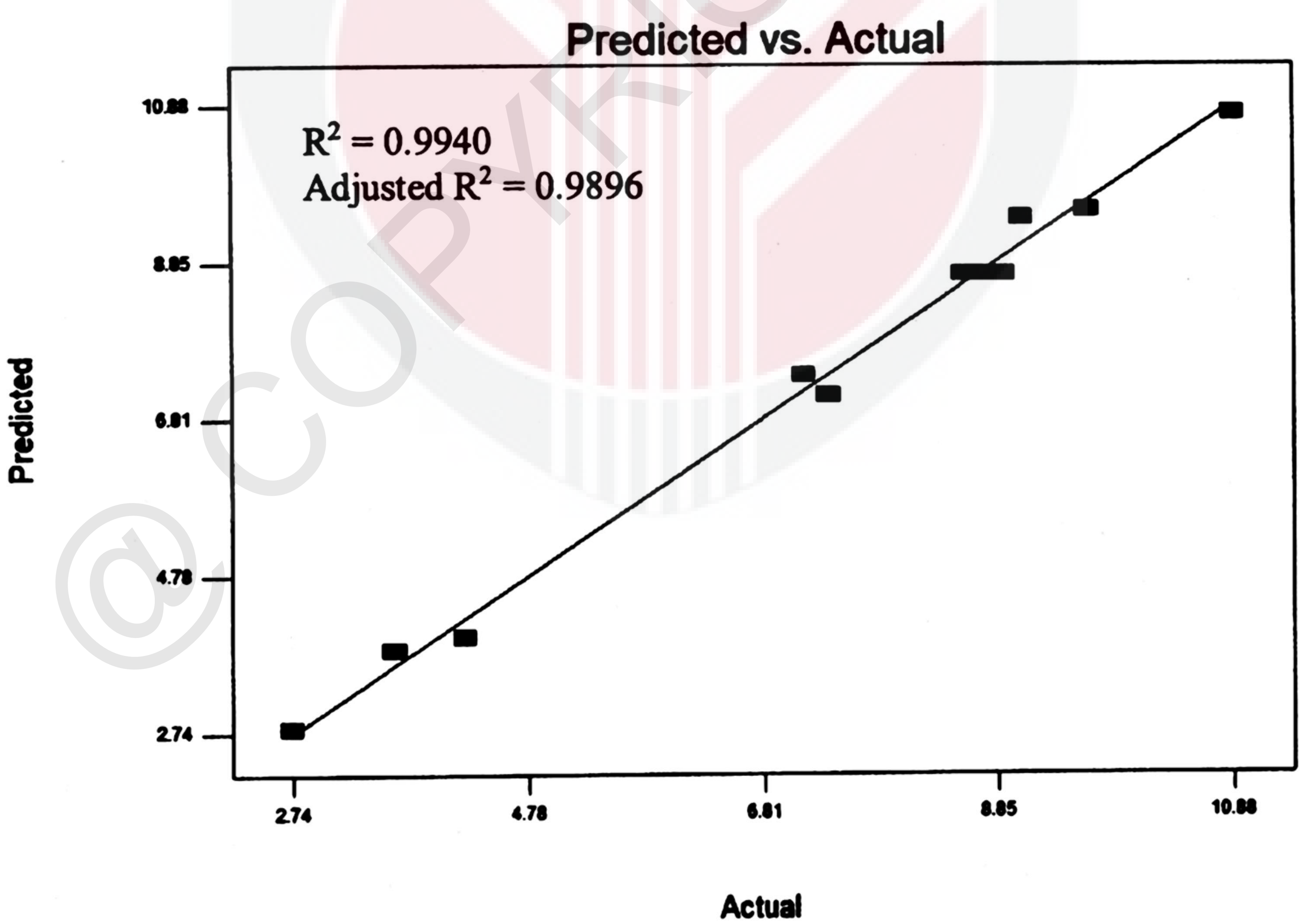


Figure 14: The fitted line plot signifying the closeness between predicted values and experimental values for colour change

4.1.2 Effect of the temperature and time on the moisture content of air fried doughnut

Moisture content is the most important property and is intimately associated with the entire quality and long shelf life of the food product. Figure 15 shows the plot of temperature and time against the moisture content of the air fried doughnut. The variation of the frying temperature in the range 130˚C to 150˚C was investigated during frying the doughnut in the air fryer. The optimal measure of temperature was found to be 150˚C, representing the optimal moisture content with the highest of moisture content 59.40%. When the temperature value was adjusted to 140˚C, the moisture content of the air fried doughnut was 66.62%. Meanwhile, a further decrease in temperature down to 130˚C decrease the moisture content of fried doughnut to 59.17%.

The effect of time on the moisture content of air fried doughnut was also investigated in this study. The frying time of doughnut in air fryer was carried out at a time ranging from 10 to 14 minutes. Based on the result, the moisture content decreased with increasing time. According to the result, it can be concluded that the higher temperature with time will decrease the moisture content of doughnut.

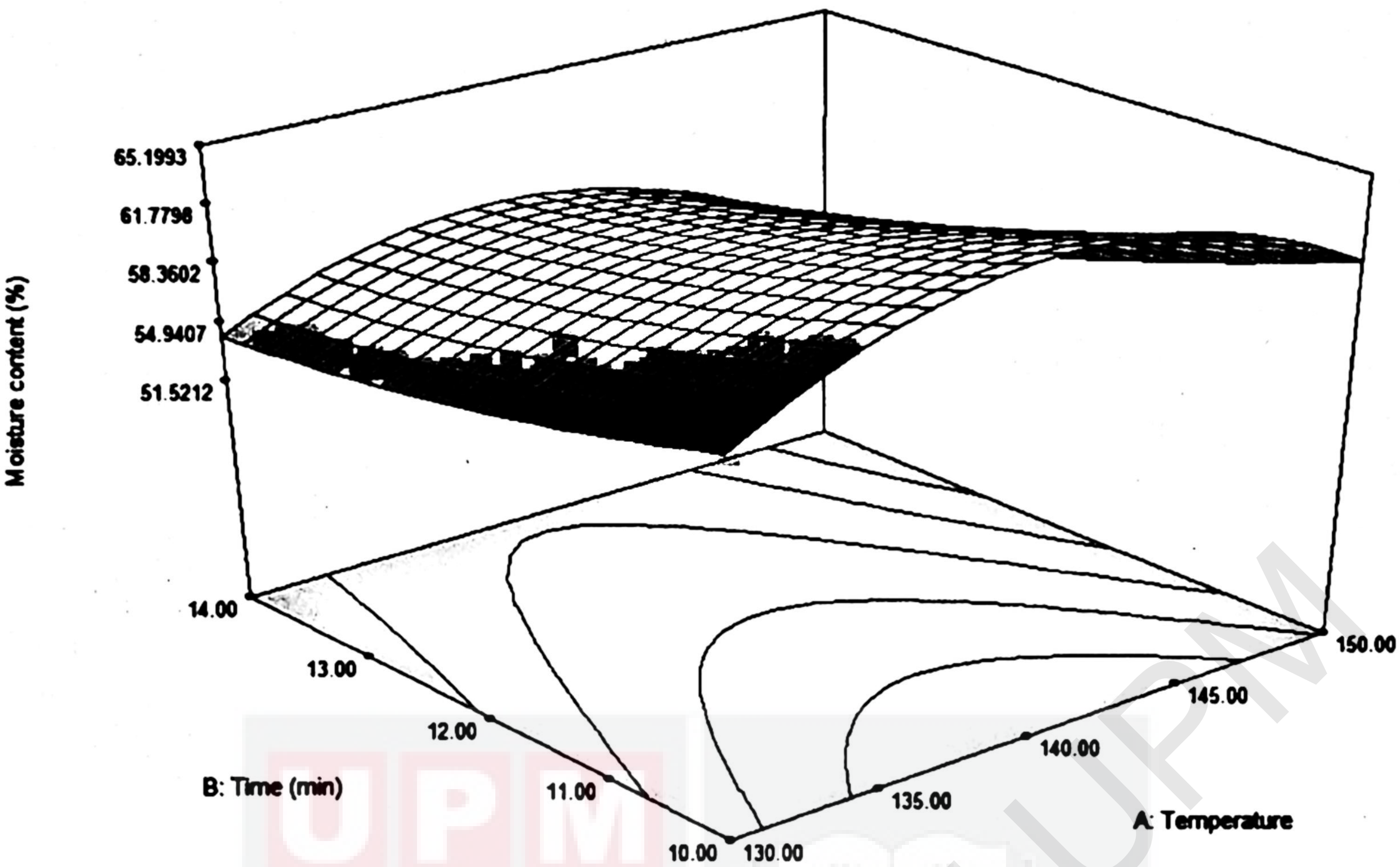


Figure 15: Response surface for moisture content of air fried doughnut as a function of frying temperature and time

4.1.3 Effect of the temperature and time on the fat content of air fried doughnut

Figure 16 shows the plot of temperature and time against the fat content of the air fried doughnut. The variation of the frying temperature in the range 130°C to 150°C was investigated during frying the doughnut in the air fryer. The optimal measure of temperature was found to be 150°C. representing the optimal moisture content with the highest of fat content 14.68%. When the temperature value was adjusted to 140°C, the fat content of the air fried doughnut was 13.62%. Meanwhile, further decrease in temperature down to 130°C increase the fat content of fried doughnut to 13.47%.

The effect of time on the fat content of air fried doughnut was also investigated in this study. The frying time of doughnut in air fryer was carried out at a time ranging from 10 to 14 minutes. Based on the result, the fat content increased with increasing time. According to the result, it can be concluded that the higher temperature with time will increase the fat content of doughnut.

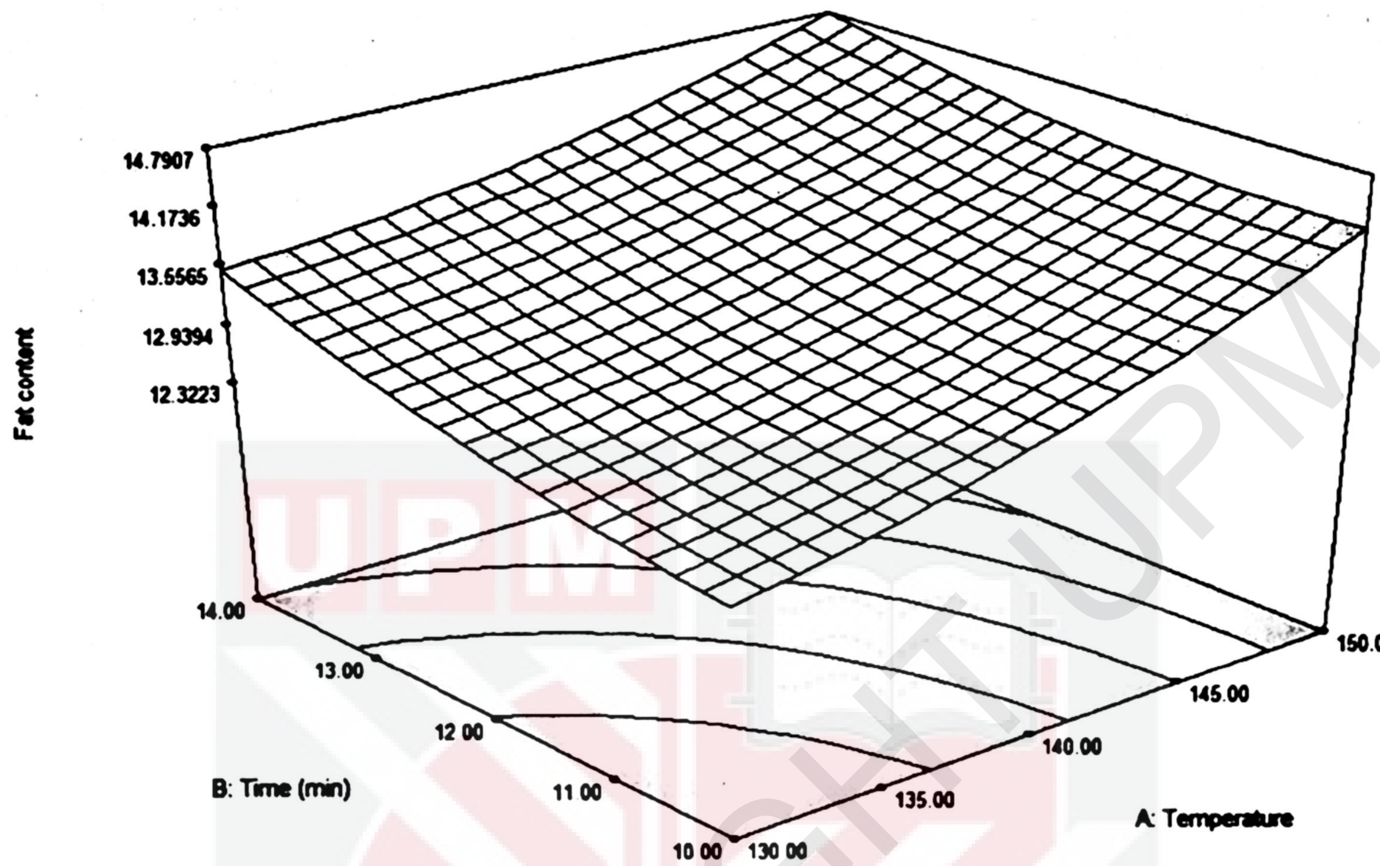


Figure 16: Response surface for the fat content of air fried doughnut as a function of frying temperature and time

4.1.4 Effect of the temperature and time on texture (hardness) of air fried doughnut

Figure 17 illustrates the effect of the frying temperature and time on the textural quality of hardness for the doughnut. Based on this figure, it showed that the higher frying temperature in the air fryer will produce a higher hardness of the fried doughnut. At the higher temperature which is 150°C, the hardness of the fried doughnut is 0.9408N. When the temperature value was adjusted to 140°C, the hardness value decreases to 0.9112N. Meanwhile, further decrease in temperature to 130°C had to decrease the hardness of the fried doughnut to 0.7683N.

The effect of time on the hardness of air fried doughnut was also investigated in this study. The frying time of doughnut in air fryer was carried out from 10 to 14 minutes. Based on the result, the hardness increased with increasing time. Chakkaravarthi et al. (2014) studied that the increasing in frying time will the failure force as the soft batter material transforms into a semi-solid mass and finally into a brittle solid with a desirable crisp texture. The number of fractures reflects the doughnut's brittleness or crispy features. The desirable crisp texture of the doughnut is indicated by a large number of fractures. According to the result, it can be concluded that the higher temperature with time will increase the hardness of doughnut.

The moisture content also affects the hardness of the fried doughnut. The decreasing of moisture content in fried doughnut will increase the hardness which caused the force that required to break the fried doughnut increased considerably at texture profile analysis. Interaction between temperature and time in fried doughnut was important because it can influence the physical structure of products by determining the freshness of the product (Sahin & Sumnu, 2006).

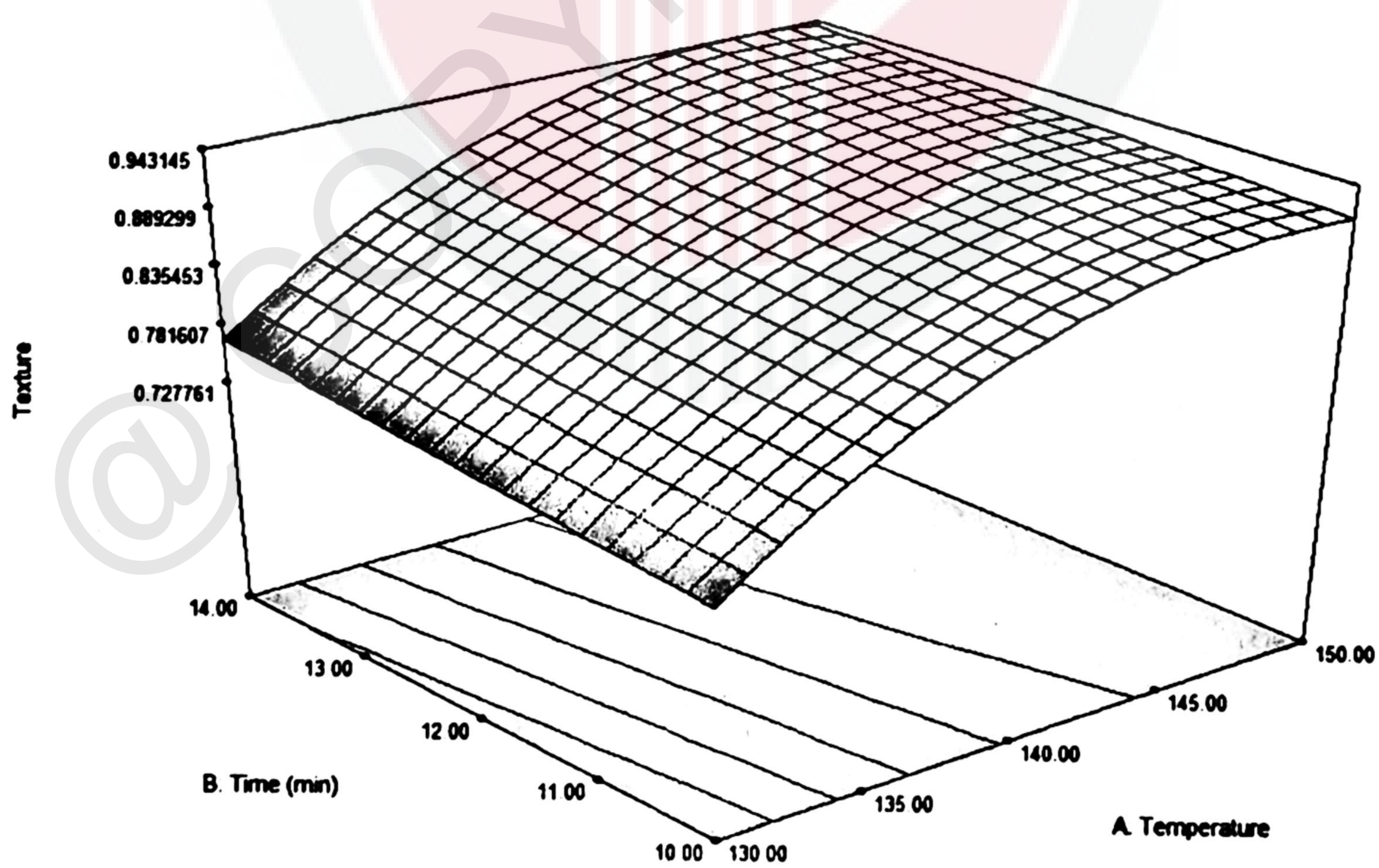


Figure 17: Response surface for texture of air fried doughnut as a function of frying temperature and time

4.1.5 Effect of the temperature and time on the colour change of air fried doughnut

Figure 18 illustrates the plot of temperature and time against the colour of the air fried doughnut. The variation of the frying temperature in the range 130°C to 150°C was investigated during frying the doughnut in the air fryer. The optimal measure of temperature was found to be 150°C. representing the optimal colour change with the highest of colour change 10.88. When the temperature value was adjusted to 140°C, the colour change of the air fried doughnut was 9.05. Meanwhile, a further decrease in temperature down to 130°C decreases the colour change of fried doughnut to 4.24.

The effect of time on the colour of air fried doughnut was also investigated in this study. The frying time of doughnut in air fryer was carried out at a time ranging from 10 to 14 minutes. Based on Figure 18, not much different in colour as the time increased. According to the result, it can be concluded that the higher temperature with time will increase the colour change of doughnut.

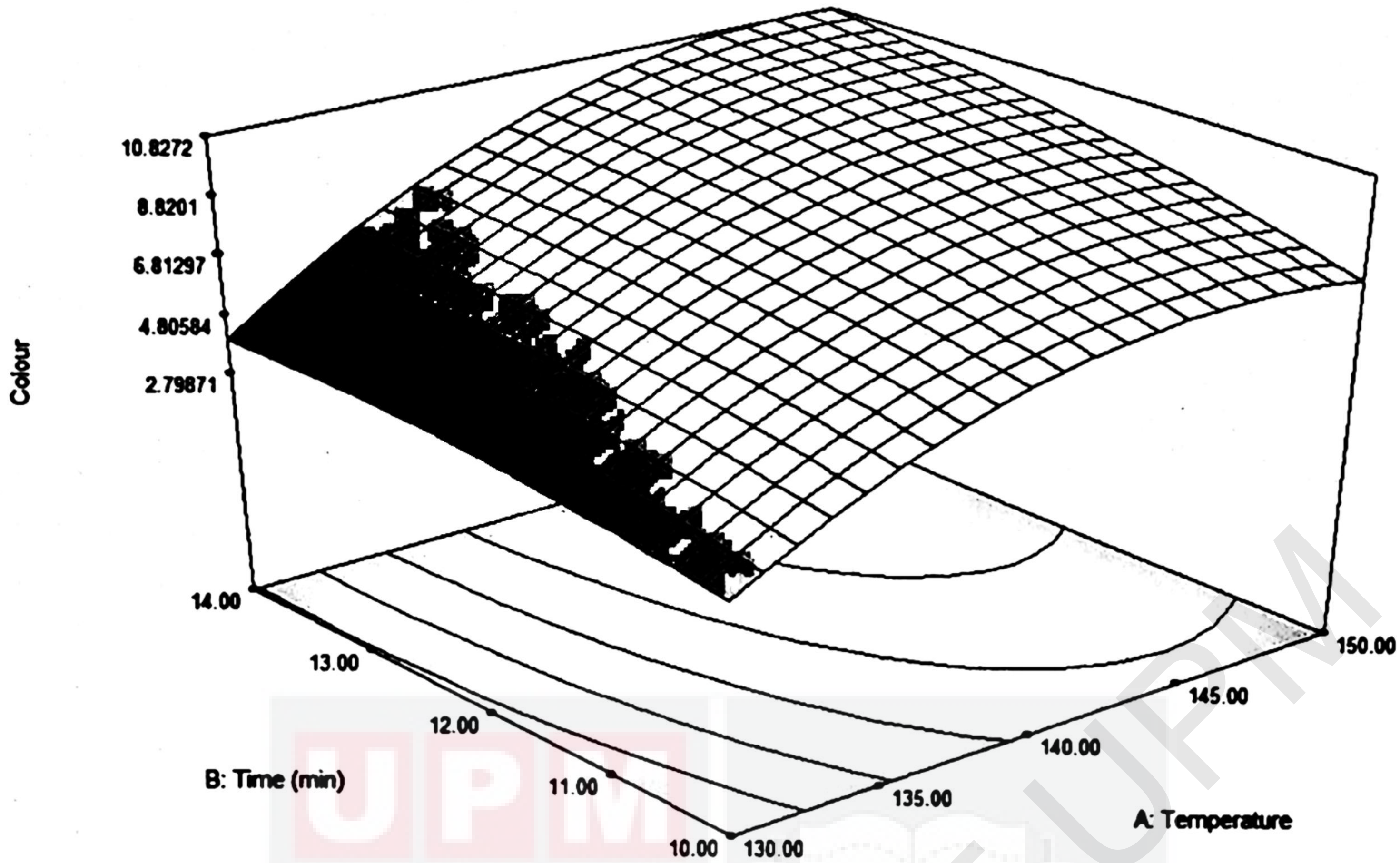


Figure 18: Response surface for colour change of air fried doughnut as a function of frying temperature and time

4.1.6 Optimization of the air frying process

In the field of food engineering, optimization is considered as a key element to maximize the process efficiency with increased throughput. The aim of this investigation was to discover the best process factors for minimum fat content with low moisture content, hardness and color. The doughnut must be prepared and fried properly at a suitable optimum condition to prevent overcooking which consequently affect the quality of foods.

For optimization, the desirability function was generated after limiting the preferred goal of factors by minimizing the frying temperature and frying time as it can save frying cost and time. Similarly, limiting the responses by minimizing the moisture content, fat content, hardness and colour in order to obtain the desired quality of doughnut as shown in Table 5.

Table 5: Criteria of the numerical optimization for the air fried doughnut

Term	Goal	Lower limit	Upper limit	Lower weight	Upper weight	Importance
A: Temperature	Minimize	130°C	150°C	1	1	3
B: Time	Minimize	10 min	14 min	1	1	3
R1: Moisture	Minimize	50.86	66.62	1	1	3
R2: Fat	Minimize	12.38	14.68	1	1	3
R3: Texture	Minimize	0.7277	0.9409	1	1	3
R4: Colour	Minimize	2.74	10.88	1	1	3

According to the desirability function, the predicted optimum condition was at frying temperature 130°C and 10 minutes of frying time. Table 6 shows the optimum condition and the predicted and experimental values of doughnuts based on desirability function. At these optimum values, moisture content, fat content, texture and colour change were found to be 59.59%, 12.33%, 0.7278N and 2.80 respectively.

Validation of the RSM model was verified by the good agreement between the experimental and the predicted values of doughnut. Compared with the value predicted by Design Expert software, the results showed that the predicted value was very close to the experimental results. This indicated that the optimization is reliable in the present study.

Table 6: Optimum conditions and the predicted and experimental value of response at the optimum conditions

	Temperature (°C)	Time (min)	Moisture content (%)	Fat content (%)	Hardness (N)	Colour change, ΔE
Predicted value	130	10	59.59	12.33	0.7278	2.80
Experimental value	130	10	59.17	12.38	0.7277	2.74

4.2 Effect of frying temperature and time on doughnuts

4.2.1 Effect of frying temperature and time on moisture content

Moisture content was the main parameter of food products which influences the storage time. Values of moisture content of doughnut during the frying are shown in Figure 19. The result shows that the values of moisture content of doughnuts fried using a deep fryer at a temperature 130°C are 41.90%, 40.01% and 39.14% for 10, 12 and 14 minutes respectively. Next, the moisture content of doughnuts fried at a temperature 130°C using air fryer is 59.17%, 56.55% and 54.08% at frying time 10, 12 and 14 minutes respectively. Shaker (2015) studied that the significant differences in the moisture content of fried potato strips between deep frying and air frying process at 180°C for 40 minutes were recorded 30.51% and 35.25% respectively. From this, it is clear that these findings are in agreement with those explained by Shaker (2015) who reported that the air frying process significantly has more moisture content than deep fat frying.

The value of moisture content for both frying methods is decreasing with the increasing of frying time. It is obvious that the moisture content of deep fried doughnut is lower than air fried doughnut because the loss of moisture allows the oil to enter and fill the pores created in the doughnut (Chakkaravarthi et al., 2014). In contrast, oil uptake increased when frying time increased, and exhibited an inverse relation as a function of the process temperature (Vélez-Ruiz & Sosa-Morales, 2003).

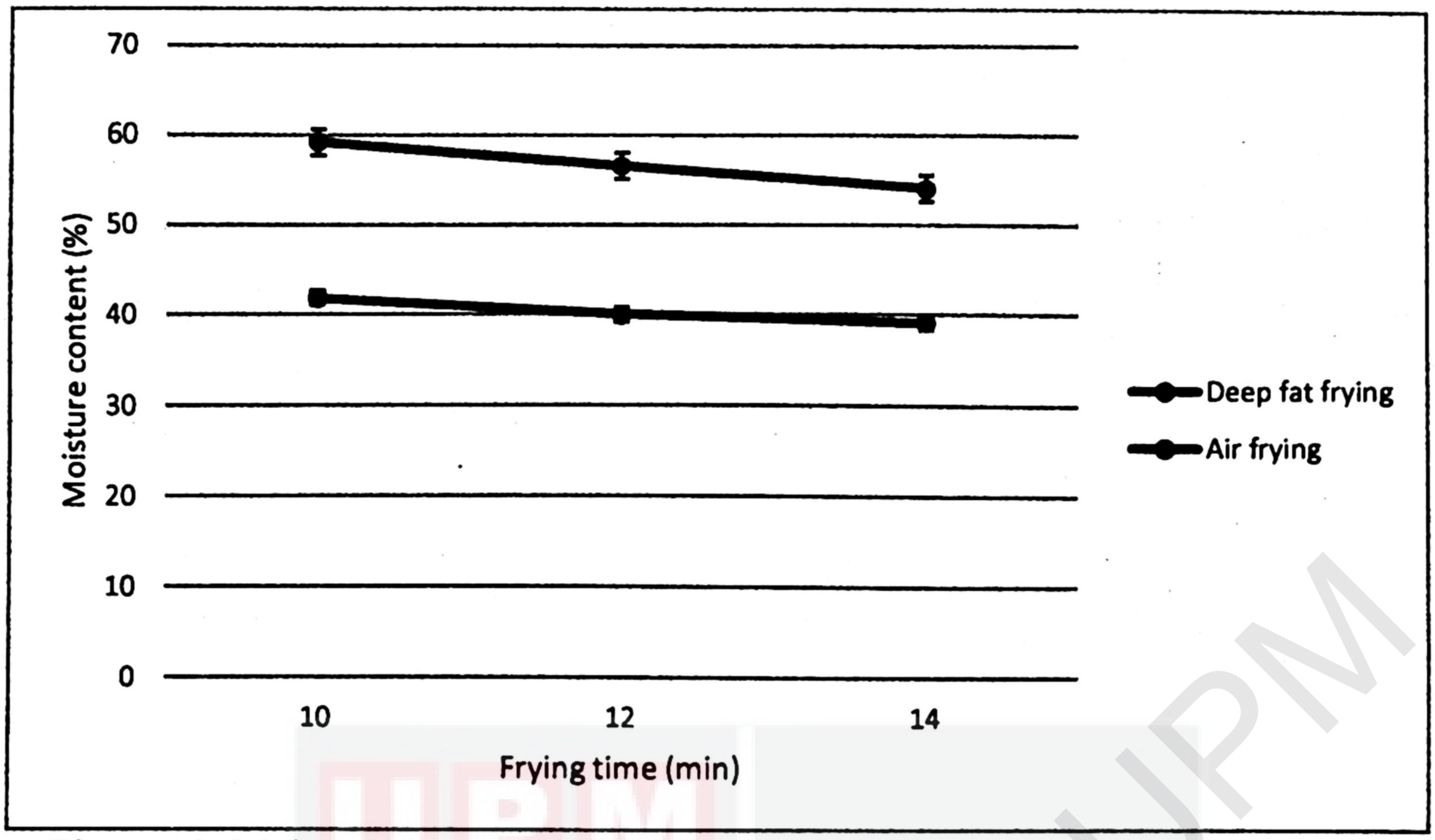


Figure 19: Moisture content of doughnut in both processes at frying temperature 130˚C

4.2.2 Effect of frying temperature and time on fat content

The difference between fat content is due to the type of frying medium employed. Figure 10 shows the fat content of deep fat fried doughnut and air fried doughnut fried at a fixed temperature of 130˚C. The fat content of deep fat fried doughnuts is 33.47%, 35.89%, and 37.97% while fat content of air fried doughnuts is 12.38%, 12.77% and 13.47% for frying time 10, 12, and 14 minutes. The result for the fat content of deep fried doughnut is in the range of 23.63-59.40% according to the studies by Tangkanakul et al. (1996).

Figure 20 illustrates that the fat content of deep fried doughnut is higher than air fried doughnut because of the oil usage in deep fat frying method. The fat content values increase as the frying time increase because the doughnut absorbs more oil. According to Teruel et al. (2015), it is known that 64% to 90% of oil absorption occurs at the end of deep frying due to the condensation of water vapor inside the doughnut caused by the fall in temperature below the boiling point of water, which creates a suction pressure gradient between surface and inner structure of the doughnut.

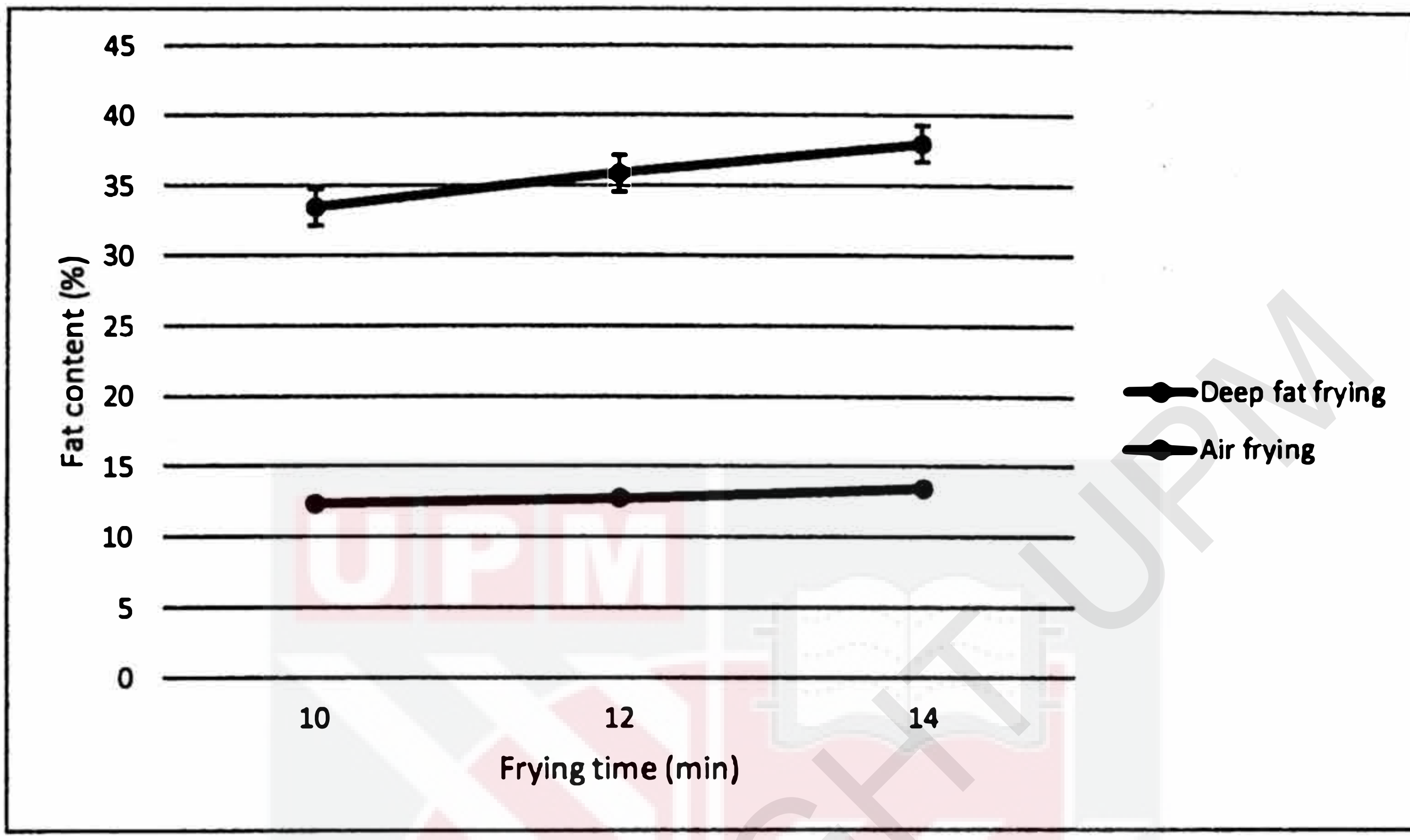


Figure 20: Fat content of doughnut in both processes at frying temperature 130°C

4.2.3 Effect of frying temperature and time on texture (hardness)

Figure 21 illustrates that the values of the hardness of doughnuts fried using a deep fryer at a temperature 130˚C were 0.5105N, 0.5793 N and 0.6001N for 10, 12 and 14 minutes respectively. Next, the moisture content of doughnuts fried using air fryer at a temperature 130˚C for 10, 12 and 14 minutes were 0.7277N, 0.7488N and 0.7683N respectively. It can be concluded that the higher frying time, the hardness of doughnut will increase. The hardness of doughnuts is fit with the result reported by Tan & Mittal (2007) because the force fluctuated was in the range of 0.5–1.5 N. The deep fried doughnut has a lower hardness compared to air fried doughnut. Melito & Farkas (2013) proves that increased oil uptake during frying would result in a relatively result in the softer crust. During the frying process, the loss of surface moisture causes crust dehydration, leading to increased food hardness.

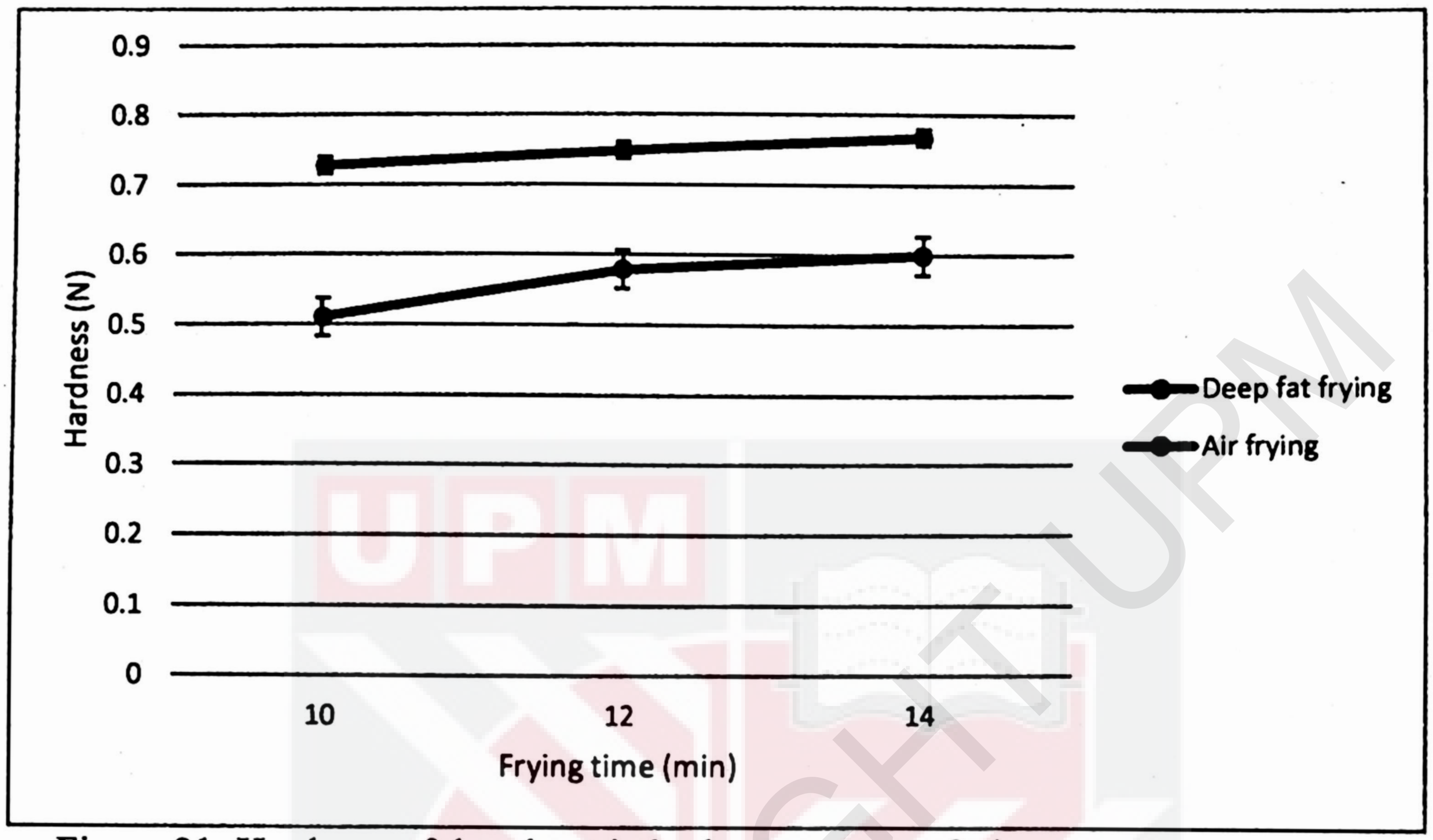


Figure 21: Hardness of doughnut in both processes at frying temperature 130°C

4.2.4 Effect of frying temperature and time on colour change

The colour change is important to colour property which shows the colour change between the sample and the fried doughnut. Based on Figure 22, the colour change of deep fat fried doughnut and air fried doughnut fried at a fixed temperature of 130˚C are shown. The colour of the doughnut varied with different frying time. The result shows that the colour change of deep fat fried doughnuts is 8.48, 10.41 and 11.86 while a colour change of air fried doughnuts is 2.74, 3.63 and 4.24 for frying time 10 min, 12, min and 14 min. As the frying time increase, the colour change increase too. The color change gets more intense at higher frying time. The air fried doughnut had the least colour change compared to air fried doughnut. Through the existing cracks and splits, the oil easily penetrated the donuts during the frying. During the frying process, donuts with low moisture content absorbed more oil, which could have resulted in more expansion and darkening (Tan & Mittal, 2007).

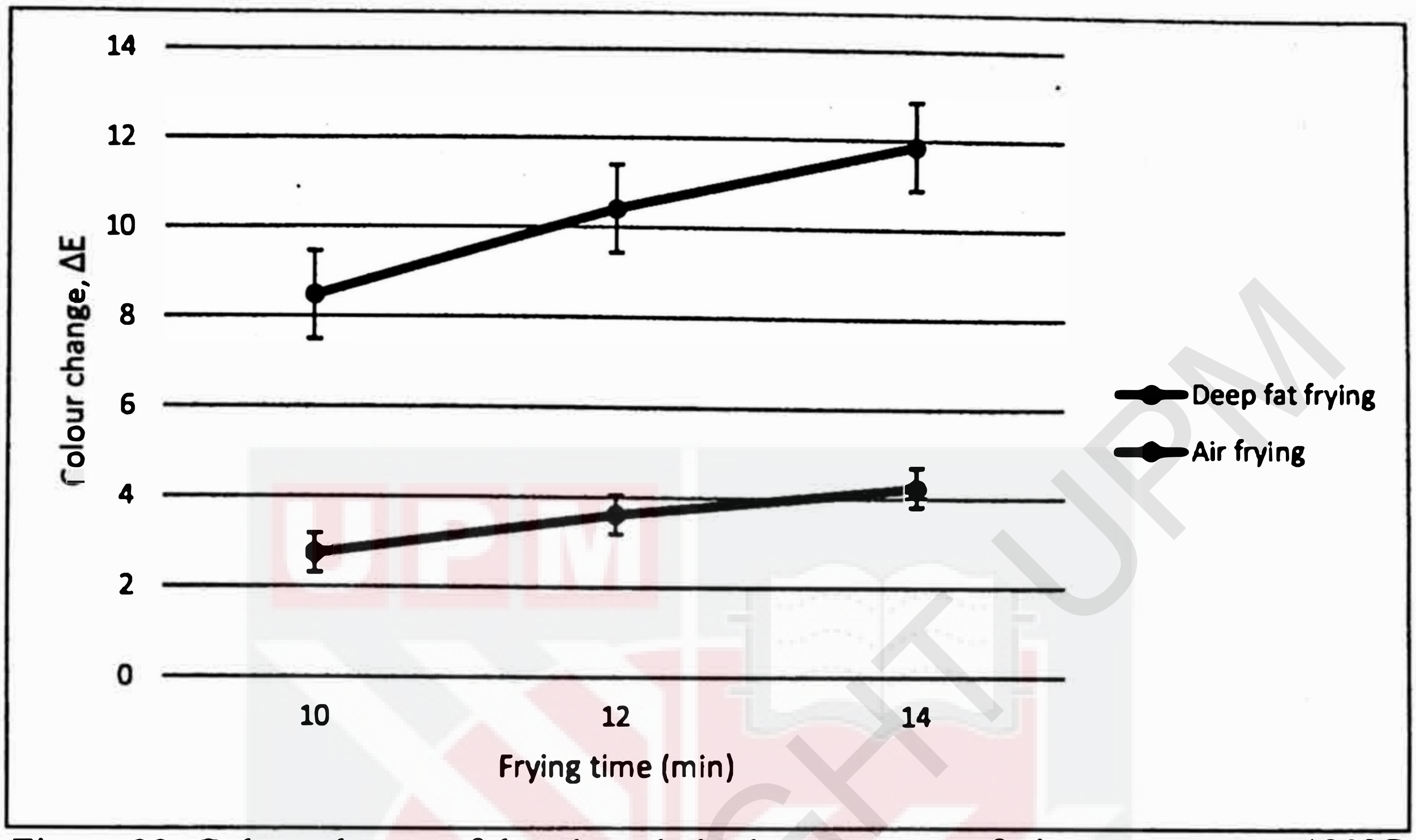


Figure 22: Colour change of doughnut in both processes at frying temperature 130°C

4.3 Sensory evaluation between deep fried doughnut and optimized air fried doughnut

The objective of the sensory evaluation was to measure the acceptable and unacceptable of the deep fried doughnut and air fried doughnut samples in terms of appearance, aroma, texture, flavor and overall acceptance. Based on the sensory evaluation conducted by 20 untrained panelists, sensory attributes of deep fried doughnuts are comparable to optimized air fried doughnuts as shown in Figure 23. The samples of doughnuts rated based on how it is liked or disliked by the panelist.

From this sensory test, panelist gave a higher score on the appearance, texture, flavor and overall acceptance for the deep fried doughnut while higher score on the aroma for the air fried doughnut. This indicates that panelist like and preferable the doughnut fried with deep frying method the most compared to air fried doughnut.

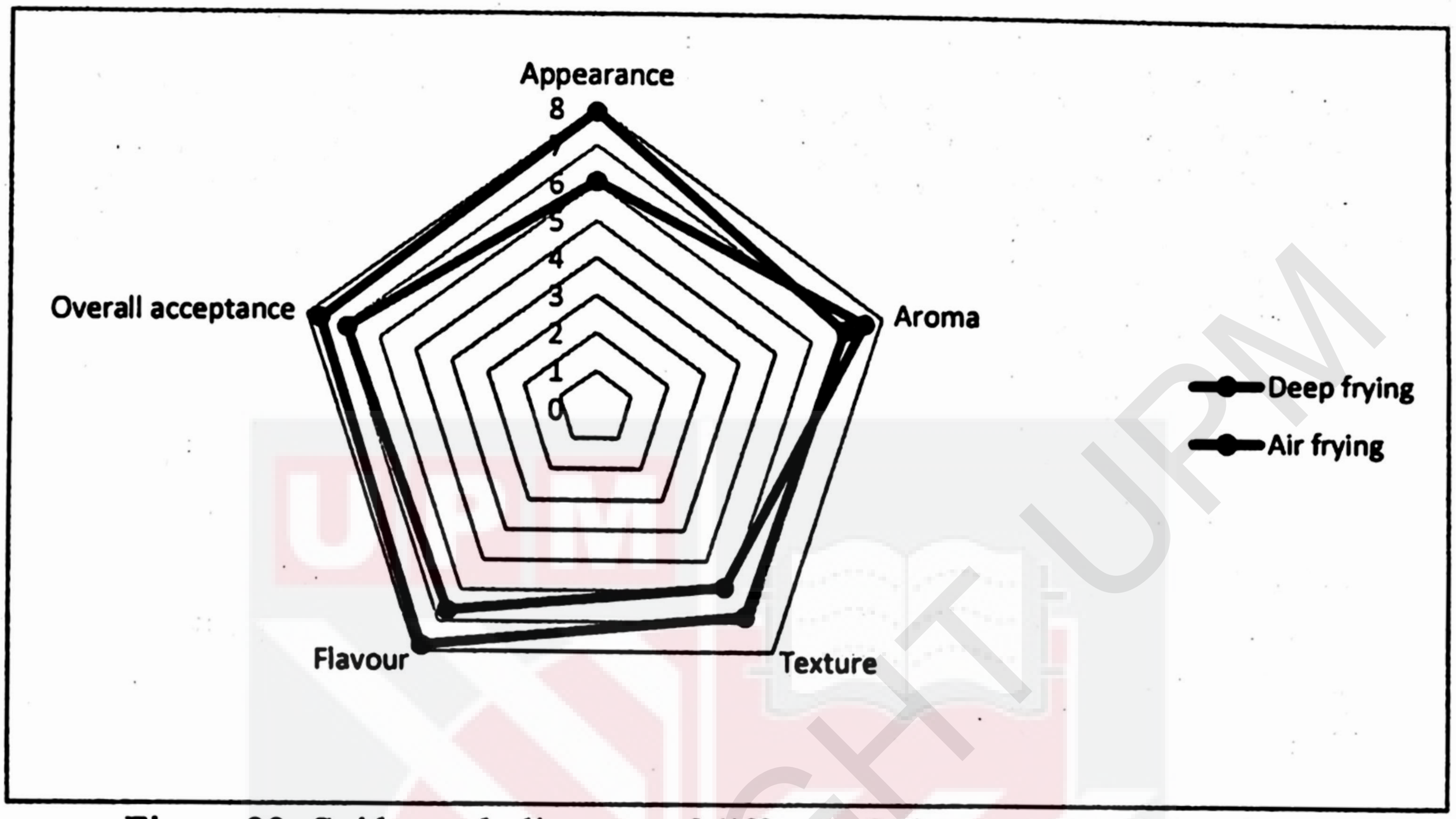


Figure 23: Spider web diagram of different frying method of doughnuts

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

The effect of air frying and deep frying method on the texture and quality of doughnut was evaluated in this study. The results showed that the moisture content of doughnut decreased as the frying temperature and time increase. Fat content, texture and colour of doughnut increased when the frying temperature an time increased. Based on the study that has done, thirteen different runs according to Central Composite Design (CCD) was used to study the optimum condition for frying Malaysian snack via air frying technique. Analysis of variance (ANOVA) has shown that the effects of all the process variables including frying temperature and frying time were statistically significant. Second-order polynomial models were obtained for predicting moisture content, fat content, texture and colour change. From the RSM analysis, the optimum condition for frying doughnut is at frying temperature 130°C and frying time 10 minutes. At these optimum values, moisture content, fat content, texture and colour change were found at 59.59%, 12.33%, 0.7278N and 2.80 respectively. The sensory test indicates that panelist like and preferable the doughnut fried with deep frying method the most compared to air fried doughnut.

The recommendation for this study is people should generally limit their intake of fried food. Frying food via air frying technique doesn't mean that it is healthier than any other food. Be sure to include other cooking methods for optimal health in regular dietary routines such as oven roasting, grilling, baking and pan-searing foods. Maintaining a variety of foods and methods of cooking will help people to get a healthier diet. Next, a technologic suggest an intermediate period between frying and cooling. As the oil absorption takes place from the adhered surface oil when the product is removed from fryer it would be of interest to make an intermediate period in order to decrease the oil content. It is believed that a combination of vacuum and hot air, behind effective shaking can decrease drastically the final oil content of the fried product.

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APPENDICES

Figure 24. Kart's frozen doughnut

Figure 25: Sun Lico sunflower seed oil

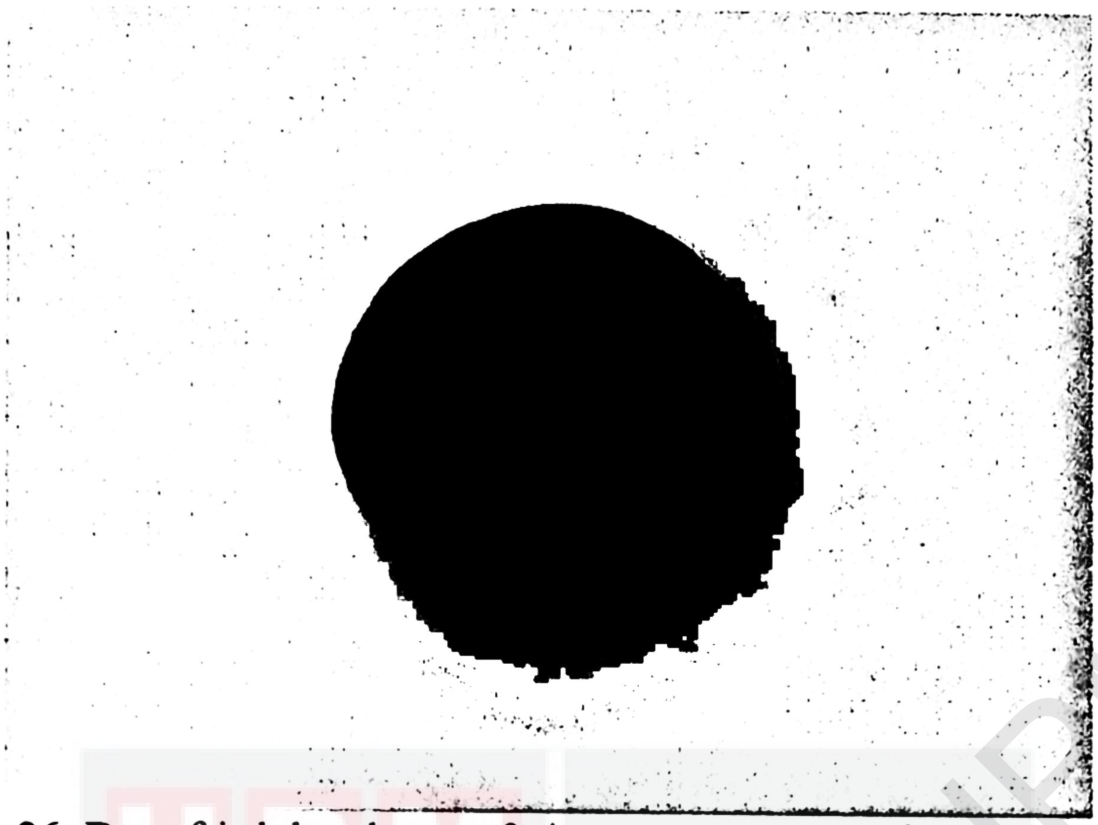

Figure 26: Deep fried doughnut at frying temperature 130˚C for 10 minutes

Figure 27: Air fried doughnut at frying temperature 130˚C for 10 minutes

Table 7: Raw data for moisture analysis of air fried doughnut

Temp (°C)	Time (min)	Run	Mass of empty aluminium boat (g)	Mass before drying, M_{wet} (g)	Mass after drying, M_{dry} + aluminium boat (g)	Mass after dying, M_{dry} (g)	Moisture content (%)	Avg.
140	12	1	0.3270	1.2626	1.0931	0.7661	64.81	61.46
		2	0.3185	1.5974	1.3288	1.0103	58.11	
140	12	1	0.3251	1.2634	1.1047	0.7796	62.06	58.42
		2	0.3183	1.5792	1.3386	1.0203	54.78	
130	10	1	0.3377	1.7278	1.4090	1.0713	61.28	59.17
		2	0.3534	1.9741	1.6103	1.2569	57.06	
150	10	1	0.3493	1.5439	1.3209	0.9716	58.90	59.40
		2	0.3588	1.569	1.3400	0.9812	59.91	
130	12	1	0.3109	1.6529	1.3906	1.0797	53.09	56.55
		2	0.3022	1.3350	1.1365	0.8343	60.01	
140	12	1	0.3219	1.2634	1.0984	0.7765	62.70	61.45
		2	0.3190	1.6027	1.3195	1.0005	60.19	
150	12	1	0.3538	1.4898	1.3036	0.9498	56.85	56.77
		2	0.3674	1.4916	1.3194	0.9520	56.68	
140	12	1	0.3254	1.2593	1.0928	0.7674	64.10	60.81
		2	0.3186	1.5839	1.3241	1.0055	57.52	
150	14	1	0.3254	1.6214	1.4019	1.0765	50.62	50.86
		2	0.3270	1.6442	1.4152	1.0882	51.09	
140	12	1	0.3126	1.2651	1.0957	0.7831	61.55	59.58
		2	0.3194	1.5795	1.3216	1.0022	57.60	
130	14	1	0.2939	1.8480	1.5269	1.2330	49.88	54.08
		2	0.3058	1.4908	1.2477	0.9419	58.28	
140	10	1	0.3510	1.4543	1.2137	0.8627	68.58	66.62
		2	0.3749	1.5411	1.3108	0.9359	64.67	
140	14	1	0.3244	1.4145	1.2353	0.9109	55.29	58.80

2	0.3305	1.2807	1.1195	0.789	62.32

Table 8: Raw data for fat analysis of air fried doughnut

Temp (°C)	Time (min)	Run	Mass of initial aluminium cup, W_1 (g)	Mass of dried sample, W_S (g)	Mass of aluminium cup + oil, W_2 (g)	Fat content (%)	Avg.
140	12	1	44.9358	1.0918	45.0714	12.42	13.23
		2	46.3690	1.0705	46.5194	14.05	
140	12	1	44.9367	1.0925	45.0724	12.42	13.32
		2	46.3684	1.0783	46.5218	14.23	
130	10	1	46.2342	1.0565	46.3661	12.48	12.38
		2	46.3670	1.0664	46.4978	12.27	
150	10	1	46.2335	1.0880	46.3865	14.06	14.25
		2	46.3650	1.0649	46.5187	14.43	
130	12	1	44.9399	1.0545	45.0733	12.65	12.77
		2	46.3723	1.0473	46.5072	12.88	
140	12	1	44.9296	1.0927	45.0729	13.11	13.19
		2	46.3651	1.0713	46.5072	13.26	
150	12	1	46.2782	1.0577	46.4335	14.68	14.45
		2	44.8762	1.0884	45.0310	14.22	
140	12	1	44.9438	1.0923	45.0728	11.81	13.22
		2	46.3616	1.0707	46.5182	14.63	
150	14	1	46.2356	1.0470	46.4046	16.14	14.68
		2	46.3680	1.0231	46.5033	13.22	
140	12	1	46.2781	1.0272	46.4035	12.21	13.62
		2	44.8772	1.0691	45.0379	15.03	
130	14	1	46.2825	1.0532	46.4188	12.94	13.47
		2	44.8817	1.0060	45.0225	14.00	

140	10	1	44.9293	1.0921	45.0718	13.05	13.01
		2	46.3714	1.0708	46.5103	12.97	
140	14	1	44.9363	1.0818	45.0840	13.65	14.11
		2	46.3671	1.0054	46.5136	14.57	

Table 9: Raw data for texture (hardness) of air fried doughnut

Temp (°C)	Time (min)	Hardness sample 1 (N)			Hardness sample 2 (N)			Avg.
		1	2	3	1	2	3	
140	12	0.9094	0.9002	0.8912	0.8808	0.8859	0.8838	0.8919
140	12	0.8953	0.9028	0.8912	0.8926	0.9032	0.9051	0.8984
130	10	0.7180	0.7348	0.6719	0.7475	0.7659	0.7279	0.7277
150	10	0.9276	0.9359	0.9059	0.8992	0.9305	0.9045	0.9173
130	12	0.7127	0.7425	0.7691	0.7475	0.7749	0.7463	0.7488
140	12	0.9015	0.8984	0.9027	0.9025	0.8926	0.8982	0.8993
150	12	0.9186	0.9287	0.9478	0.8939	0.9401	0.8921	0.9202
140	12	0.9016	0.8957	0.9012	0.8983	0.8985	0.9026	0.8997
150	14	0.9636	0.9605	0.9362	0.9366	0.8833	0.9645	0.9408
140	12	0.8895	0.9002	0.9012	0.8893	0.8906	0.8911	0.8937
130	14	0.7314	0.7628	0.7862	0.7674	0.7526	0.8093	0.7683
140	10	0.9467	0.7303	0.9771	0.8202	0.8861	0.8995	0.8767
140	14	0.9346	0.9223	0.8977	0.8984	0.9017	0.9122	0.9122

Table 10: Raw data for colour measurement of air fried doughnut

Raw doughnut					
		L_0	a_0	b_0	
		28.2	10.3	35.6	

Fried doughnut					
Temp (˚C)	Time (min)	L*	a*	b*	Colour change, ΔE
140	12	21.7	13.3	30.9	8.55
140	12	21.6	13.4	30.7	8.79
130	10	26.6	11.4	33.7	2.74
150	10	23.3	13.0	31.2	7.17
130	12	25.7	11.9	33.5	3.63
140	12	21.7	13.4	30.8	8.65
150	12	20.8	12.8	30.1	9.62
140	12	21.6	13.3	30.9	8.64
150	14	19.9	12.6	29.0	10.88
140	12	21.5	13.5	30.7	8.90
130	14	25.1	12.5	33.8	4.24
140	10	22.5	13.0	31.8	7.38
140	14	21.2	13.3	30.7	9.05

SCORE SHEET
QUESTIONNAIRE FOR HEDONIC SCALE

PANEL NO.: ____________________ DATE: _______________
PRODUCT: Doughnut

Instruction:
Please taste these coded samples and indicate how much you like or dislike the products' attributes using the scale provided. Rinse your mouth with water in between samples.

SCALE	DESCRIPTION
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like or dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

Sample Attributes	Sample Code	
	A1	A2
Appearance		
Aroma		
Texture		
Flavor		
Overall acceptance		

Comment:
____

Thank you for your kind participation.