UNIVERSITI PUTRA MALAYSIA

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182189

A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD BACHELOR OF ENGINEERING (PROCESS AND FOOD)

DEPARTMENT OF PROCESS AND FOOD ENGINEERING

FACULTY OF ENGINEERING

UNIVERSITI PUTRA MALAYSIA

2019

ACKNOWLEDGEMENT

First of all, I would like to express our deepest appreciation to my project supervisor Dr. Mohd Salahuddin bin Mohd Basri for his useful ideas in improving my project, guidance and constant supervision as well as for providing necessary information regarding the project and also for his support in completing this project. His knowledges, advices and guidance has always been an inspiration. For that I would like to thank him gratefully, may his research in futuristic material finds fruitful conclusions. His guidance and advice have contributed to great part of the research.

Next, I have to appreciate both of the presentation examiners Dr. Azhari Samsu Baharuddin and Dr. Mohd Afandi P. Mohammed for the constructive comments and advices as well as all other lecturers that assists me in completing this project. I really appreciate your advicse and suggestions during the presentation of project proposal. I found them very helpful.

My thanks and appreciations also go to Mr Raman Morat, Mr Mohd Zahiruddin and Puan Siti Hajar binti Zakariain giving me permission and guidance to use all equipments required in this project and also for willingly helped me out with their expertise and abilities.

Last but not least, I would like to thank my parents Encik Mohd Jais bin Abdullah and Puan Latifah binti Khalid, siblings, best friends, and to all that provided us the possibility to complete this report. Without their abilities, help, cooperation and support, I would not be able to finish this project in a time frame. May all of you live long and prosper.

ABSTRACT

Dough stickiness is a significant problem in bakery production and is influenced by many factor. The formulation of cookie dough based on five different cup ratios of oat to flour was designed as 1:1, 1:1.25, 1:1.5, 1:1.75, and 1:2. Each formulation is kept for resting at five different resting time, which is 10, 20, 30, 40, and 50 minutes. The stickiness value was obtained using texture analyzer and the moisture content was evaluated using moisture analyzer. As results, the drop of stickiness value of dough composition of 1:1.75 and 1:2 for all resting times could be associated with the limited water availability in the dough complex. The moisture content was found to decrease over time for all dough composition. The study proved that Teflon (PTFE), silicon, stainless steel and parchment paper have lower stickiness value whick make it suitable to reduce the stickiness of the cookie dough. The study also showed that the using cookies shaping machine increase the production capacity by 47%. Dough with ratio 1:2 was found to be the most suitable cookie dough for the cookies shaping machine. In conclusion, the research proved that composition of oat and flour in cookie dough showed significant effect on the stickiness and moisture content properties of the dough. Using different materials for the cookie shaping machine helps to ease the process and increase the production capacity of the oat-based cookies as compared to the conventional method.

ABSTRAK

Kelekitan adunan adalah masalah besar dalam pengeluaran bakeri dan dipengaruhi oleh banyak faktor. Formulasi adunan berdasarkan lima jenis nisbah oat kepada tepung yang berbeza iaitu 1: 1, 1: 1.25, 1: 1.5, 1: 1.75 dan 1: 2 digunakan dalam kajian ini. Setiap formulasi disimpan untuk berehat dalam lima waktu yang berbeza iaitu 10, 20, 30, 40 dan 50 minit. Nilai kelekitan diperoleh menggunakan penganalisis tekstur dan kandungan kelembapan dinilai menggunakan penganalisis kelembapan. Penurunan nilai kelekitan bagi komposisi adunan 1: 1.75 dan 1: 2 untuk semua masa berehat boleh dikaitkan dengan ketersediaan air terhad di dalam adunan. Kandungan kelembapan didapati berkurang dari masa ke masa untuk semua komposisi doh. Kajian ini juga membuktikan bahawa Teflon (PTFE), silicon, keluli tahan karat dan kertas minyak mempunyai nilai kelekitan yang rendah dan sesuai untuk digunakan sebagai bahan pembuatan bahagian mesin pembentuk kukis. Kajian itu juga menunjukkan bahawa menggunakan mesin pembentuk kukis meningkatkan kapasiti pengeluaran sebanyak 47%. Kukis dengan nisbah 1:2 didapati sebagai adunan yang paling sesuai untuk mesin pembuatan kukis. Sebagai kesimpulan, kajian ini membuktikan bahawa komposisi oat dan tepung dalam adunan kukis menunjukkan kesan yang signifikan terhadap sifat kelekitan dan sifat kelembapan adunan. Menggunakan bahan yang berbeza untuk mesin pembentuk kukis membantu meningkatkan kapasiti pengeluaran kukis berasaskan oat berbanding dengan kaedah konvensional.

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CHAPTER 1: INTRODUCTION

1.1. Research background

In Malaysia, there is an increasing consumption pattern of ready-made or convenience food such as biscuits, bread and cake among Malaysian adults. According to the Malaysian Adult Nutrition Survey, biscuit and bread appeared in the list of top ten daily consumed food particularly. The survey also concluded that 16.3 percent of the local population consumed an average of five pieces of biscuits daily which showed that biscuits are one of favourite food in Malaysia (Norimah et al., 2008). Biscuits are among the well-known and highest consumed baked food in the world. The reason for such wide popularity is due to their ready to eat nature, affordable, good nutritional quality, available in different flavours and longer shelf life (Gandhi et al., 2001).

Between 2012 and 2016, the percentage of cookie sold in Malaysia increased, which subsequently increased the production capacity (Anonymous, 2018). In 2016, the sales value of manufactured biscuits and cookies in Malaysia was approximately 2.33 billion ringgit. This figure showed that the market demand for cookies are very high and therefore, keep increasing. In addition, it was found that there are different type of cookies flavours available in the market, and one of the most popular cookies is oat cookies with chocolate chip.

Oat-based cookies is a cookie that contains basic ingredients including butter, sugar, and additional ingredients which are oat, either rolled or instant oat and a large inclusion. Large inclusions are the additional ingredients added into the dough, including chocolate chips, almonds, raisins, cashew, and other type of nuts. The purpose of adding the large inclusion into the cookie dough is to produce the oat cookies with various flavour following the consumer preferences. Due to the addition of oat and large inclusions, the texture of the cookie dough is different as compared to that of the basic cookies dough which not has oat and large inclusions inside. As the texture differs, the dough properties such as stickiness and cohesiveness will significantly affect the production process of the cookie. Thus, a study on parameters affecting the properties of the cookie dough, including oat to flour ratio and resting time of cookie dough is unduly essential. By ensuring and determining the suitable oat-based cookie dough with suitable stickiness, the problem such as dough sticks on the machine surfaces may potentially be hindered.

Texture attributes, such as stickiness of grain-based food, is vital to consumers and manufacturers (McManuis, 2001). Texture evaluation is a crucial step in developing a new product or optimizing process variables (Meullenet et al., 1998). A descriptive method such as Texture Profile Analysis (TPA) is used in order to describe the textural properties of the cookie dough. By using TPA, the structure of the food can be emphasized.

Stickiness is the work or force necessary to overcome attractive forces between the surface of the product and the surface of the material (probe) in which the product comes in contact. It is the textural property commonly possessed by confectionery products, cooked pasta products, fresh bakery products, pharmaceutical patches and more obviously the adhesives. Dough stickiness can be defined as the adhesion of dough to the contact surface (Dobraszczyk, 1996; Hoseney and Smewing, 1999; Adhikari et al., 2001; Yildiz et al., 2012). Some authors described dough stickiness as the combination of cohesion which is the stickiness between particles, and adhesion which is defined as the stickiness between particle and wall or surface stickiness (Adhikari et al., 2001). Dough stickiness emerged as one of the significant problems in bakery and confectionary industries for decades ago. Today, modern bakery and confectionary industries apply dusting flour or oil method to reduce the dough stickiness. However, it does not significantly help in eliminating the problem. The negative effect due to the dough stickiness has long been proven to interrupt the production schedule and subsequently caused losses due to the low quality of the final products (Grausgruber et al., 2003).

Stickiness is a major problem in the food industry, especially in the baking and confectionery industries, where it can cause considerable difficulty during processing by causing interruptions in production, waste and contamination of machinery. Sticking of food to packaging materials or machinery is generally regarded as undesirable, resulting in possible packaging material damage, product loss and disfigurement of the product surface. It can be surmised that the extent to which this could generate adverse consumer reaction will depend on the extent of the sticking, type and cost of the product and availability of alternative product or packaging combinations.

Parameters resulted in dough stickiness and enhanced the dough stickiness had been reported in many research papers. According to research conducted by Grausgruber et al. (2003), several parameters influenced the dough stickiness such as overmixing of dough, over addition of water and uncontrollable intrinsic factors of the flour.

1.2. Problem statement

In any production line, waste product due to inaccurate process or malfunctioning machine should be hindered. In Malaysia, almost 98 percent of the business entities are the Small Medium Enterprise (SME). As the primary producer, they are highly particular in high yield production of their product. The oat-based cookies producer opts for the same situation. Their goals are to have high yield cookies product, uniform shape as well as maintain high quality and rich taste of the cookies. Currently, oat-based cookies produced manually have a high demand on the market, especially during festive seasons.

As of today, most of the oat-based cookies produced by SME companies are done manually. An only a small percentage of companies, which can afford to buy expensive machines, use them to fulfil the market demand. Although the oat-based cookies have substantial potential either in domestic or international markets, for SME companies, the production of the cookies remains low and therefore unable to meet the market demand. One of the reasons for this problem is due to the limited financial allocation to hire a high number of workers. Based on the responses from oat-based cookies producer, the most crucial process in making oat-based cookies is moulding. This process, when it is done manually, will yield an inconsistent cookie either its shape, size, or weight. Moreover, the production method is labour intensive, inefficient and time-consuming.

Therefore, by developing a suitable low-cost cookies machine and with an assistance of a thorough study on the stickiness and moisture content of the cookie dough, the daily production of oat-based cookies can be increased, and the problem regarding the stickiness can be minimized. On that note, it helps people in the SME industry to increase their production and quality of final products, thus increasing their chances in competing against other competitors locally and internationally.

1.3. Research objectives

The objectives of this research are:

1.3.1. To study the effect of different parameters on the stickiness of the cookie dough.

1.3.2. To study the stickiness behaviour of the cookie dough on different material surfaces.

1.3.3. To compare the effect of different dough composition on the cookies shaping machine.

1.4. Research scope

This research is divided into three main parts. The first part was to study the effect of different parameters on the dough stickiness, which are the resting time and oat to flour ratio. This result serves as an important guideline in producing cookie dough which is suitable for the newly developed cookies shaping machine while maintaining the quality, flavour and texture of the cookies.

The second part involved the study the stickiness behaviour of the cookie dough on different type of materials including polytetrafluoroethylene (PTFE) or known as Teflon, parchment paper, stainless steel and silicon. These materials are the component in fabricating the cookies shaping machine. Therefore, it is important to ensure that the material used for fabrication is suitable to be worked with different level of the stickiness of the cookie dough.

The third part included the evaluation of different dough composition on the cookies shaping machine. This part was performed to ensure that the yield of cookies produced by the shaping machine is high, which showed its effectiveness and efficiency.

CHAPTER 2: LITERATURE REVIEW

2.1. Cookie dough

Oat-based cookies are produced with a mixture of several ingredients such as butter, flour, baking soda, and oat. All of these ingredients will be mixed according to designated composition, shaped and baked in the oven at specific temperature and time. Duta and Culetu (2015) reported that oats are a healthy alternative for starch-based ingredients in gluten-free and regular diets; contain an outstanding high content of fibre, essential amino acids, unsaturated fatty acids, vitamins, minerals and bioactive compounds.

From a dietary perspective, the amount of ingredients in a recipe can enhance the quality of the cookies. Thus, it can be considered as a nutritional food to fulfil the special dietary needs. As stated by Škrbić & Cvejanov, (2011), the maintenance of a product's sensory attribute is one of the vital criteria in designing cookies with improved nutritional status.

According to Hoseney and Smewing, dough stickiness is caused by an interactive balance between adhesion and cohesion (Hoseney & Smewing, 1999). Dough stickiness or adhesion can be defined as the adhesion of dough to the contact surface (Dobraszczyk, 1996; Hoseney and Smewing, 1999; Adhikari et al., 2001; Yildiz et al., 2012).). Some authors described dough stickiness as the combination of cohesion which is the stickiness between particles, and adhesion which is defined as the stickiness between particle and wall or surface stickiness (Adhikari et al., 2001). There are many factors which have been suggested in enhancing the stickiness of the dough (Chen and Hoseney, 1995; Gore, 1997; Hoseney et al., 1990). However, the real factors remain unknown.

Dough stickiness emerged as one of the major problems in bakery and confectionary industries for decades ago. Today, modern bakery and confectionary industries apply dusting flour or oil method to reduce the dough stickiness. However, it significantly helps in eliminating the problem. The negative effect due to the dough stickiness has long been proven to interrupt the production schedule and subsequently caused losses due to the low quality of the final products (Grausgruber et al., 2003). Hence, it is important to ensure that the process and machines fulfil the specific requirement to facilitate the processing of the products.

The quality of food products is related to the dynamic viscoelastic properties of the dough. The viscosity and water holding capacity of oats are high, which makes the dough quite hard to handle during the pressing process of the dough through the nozzles. The hardness of the dough increases over time due to the interaction between proteins and starch by the hydrogen bonding (Inglett et al., 2015). Based on the geometrical properties of the cookies, the width, thickness and spread factor can be used as the parameters in determining the quality of the cookies. Therefore, solid concentration, starch types such as composition and structure, temperature, and gel preparation method are some of the other factors affecting the flow properties of starch pastes (Zhu, 2017).

2.2. Effect of different parameters of dough stickiness

2.2.1. Resting time

Resting time is a period before the final shaping process of the cookie dough. According to research by Cauvain (2003), it was found that the resting time has a big influenced on the rheological properties of the dough for the final moulding process. A higher changes on dough rheology occurred as the resting time increases. Resting time also important to ensure the final product is sufficiently soft and relaxed to allow optimum performance in the moulding stage (Cauvain, 2003).

Research conducted by Pyunk et al. (2007) on the effects of resting time on the fundamental rheological properties showed a conflicting result. Only two to three resting times were used in conducting the experiments. As a result, they found that the resting time was not influencing the textural parameters such as adhesiveness and cohesiveness of the dough. Hence, it is difficult to observe the trends and understand the effect of the resting time on the physiochemical properties of the dough. More intensive and systematic monitoring of this process is required, and proper experimental design should be prepared to study the effects of resting time on dough stickiness since the researched showed low variability.

Research conducted by Ahmad and Thomas (2018) on the stickiness and extensional properties of brown wheat flour/β-glucan composite doughs found that the stickiness value increase with resting time. However, no systematic trend of stickiness values on the resting time can be concluded.

2.2.2. Dough composition

In biscuit making, the main ingredients are flour, sugar and fat. The quality of the biscuit is governed by the nature and quantity of the ingredients used. Nevertheless, several authors have attempted to describe the effect of ingredients in a dough and formula balance on the final structure of the product (Chen and Hoseney, 1995).

High fibre ingredients exhibit many properties that influence the physiological functions of foods. Several workers have used fibre sources such as wheat bran, oat bran, corn bran, barley bran and psyllium husk, among others to prepare high fibre bread (Laurikainen, Ha¨rko¨nen, Autio, & Poutanen, 1998; Pomeranz, Shogren, Finney, & Bechtel, 1977; Sidhu, Suad, & Al-Saqer, 1999; Wang, Rosell, & Barber, 2002).

The addition of dietary fibre strengthens the structure of the dough at a limited level and modifies the textural properties of the dough (Sangnark & Noomhorm, 2004; Fendri et al. 2016). The study by Sundha et al. (2007) showed that the fibre or inclusion added into the dough formulation affect the rheological properties of the dough. Based on a research by Ahmad and Thomas (2018) on the stickiness and extensional properties of brown wheat flour/β-glucan composite doughs, results showed that dough stickiness is an important parameter that controls the dough handling. Other research conducted Wenjun et al. (2018) on the effect of oat to dough rheology showed that the dough stickiness increases as the oat substitution increase. Campbell et al. (2008) reported that the stickiness of the dough increases due to the higher content of soluble fibre (b-glucan). The excess water in that b-glucan and wheat gluten dough that is not bound by protein is responsible for the increased in stickiness value (Ahmed and Thomas, 2015).

In terms of the testing apparatus, texture analyzer with Chen-Hoseney Cell/Rig and Perspex probe is one of the currently available methods in measuring the dough stickiness (Tock et al., 2013). This study is focused on investigating the effect of oat to flour ratio and resting time on the dough stickiness of oat-based cookies using the Texture Analyzer with Chen-Hoseney Dough Stickiness Cell (A/DSC).

2.3. Different materials surfaces of the cookies shaping machine

Contact between dough and machine surfaces may last for several hours during production. Contact surface described as a material that is utilized in the baking industry as a surface material and came into contact with dough such are the conveyor belt, proofing tray and stainless steel. The Stable Micro System Chen–Hoseney Dough Stickiness Rig is an enhanced version of the scientific method developed and patented by Chen and Hoseney (1994) and is currently the most widely used measurement of dough stickiness. By using this method, a constant compression force is applied to the dough and force is recorded in the form of the force-versus-time curve to remove a specific cylinder probe from the dough surface. Texture analyzer is used to obtain the measurement of the separation force.

Typically, silicon (Figure 2.3.1) is used to prevent the food from sticking to the surface contact (Geueke, 2015). Silicon has been used in many food processing applications such as baking moulds and home cooking utensils due to their anti-slip properties, easy slip characteristics, inert, odourless and non-toxic, and able to tolerate high and low-temperature conditions (Food Processing & Packaging | Elkem Silicones, 2018).

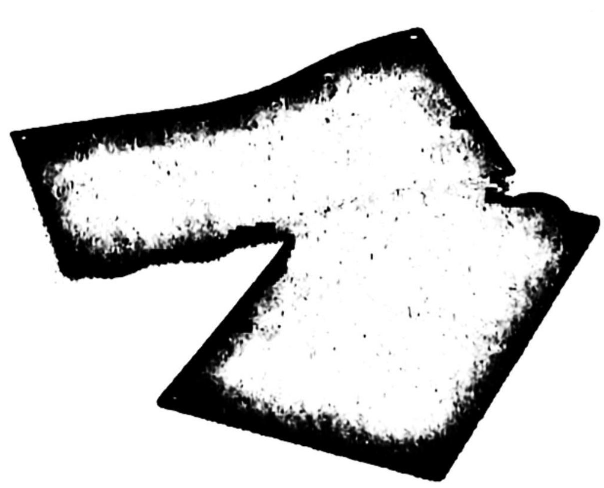

Figure 2.3.1: Example of silicone mould currently used in industry

Stainless steel is mostly used corrosion resistant materials in the chemical industry. The chromium content in stainless steel should be above 12 percents in order for it to resist corrosion. The higher the chromium content, the more resistant is the alloy to corrosion in oxidizing conditions. Nickel is added to improve the corrosion resistance in non-oxidizing environments. Molybdenum is added into stainless steel 316 to improve the corrosion resistance in reducing conditions, such as in dilute sulfuric acid, and, in particular, to solutions containing chlorides (Towler and Sinnot, 2013).

Polytetrafluoroethylene (PTFE) or known as Teflon (Figure 2.3.3) will be resistant to corrosion, due to PTFE's ability to repel water and oil, and lubricated by the material to smoothly drive into whatever surface you are fastening to, with reduced friction, resulting in less wear on both the screw and the surface, and a longer-lasting, more secure finish. It is clear that longer lasting, higher-performance parts can add to the efficiency of any machinery, reduce the need to constantly acquire replacement parts, saving money and the time needed to fit the replacements, and reducing waste. This will also reduce maintenance needs as there are less likely to be faults with the equipment, and also greatly reduce, or even eliminate, any expensive manufacturing downtime due to faults or repairs (Anonymous, 2016).

Figure 2.3.2: PTFE or Teflon sheet

Parchment paper can be found in bleached or unbleached version. It is cellulose-based papers that have been treated or coated to make them non-stick and also heat resistant. Moreover, it is moisture and grease resistant. It is used in baking as a disposable non-stick surface. Primarily, parchment is used for lining baking pans. It eliminates greasing baking pans, so there is virtually no clean-up. Parchment-lined baking pans practically guarantee that food would not stick, which is helpful when baking cakes and sticky cookies, since they practically slide out of the pans. Parchment also help to ease pick up of an entire batch of cookies from the baking sheet and transfer them to a wire rack to cool without fumbling with hot pans and spatulas (no more misshapen cookies) (Anonymous, 2007).

2.4. Effect of moisture on dough stickiness

Mixing and handling of cookie dough influence the dough rheological properties (Osella et al., 2007). Moisture content is the amount of water dependent on plant, soil, and food. The moisture content of food is essential for food manufacturers due to various reasons. Water is an important component of many foods, and each has its characteristic. There are several methods to determine the moisture content such as forced draft method, vacuum oven method, rapid moisture analyzer and other methods (Nielsen et al., 2010). The important role of water during dough processing increase the interest of researchers to investigate the relationship between water mobility and functionality of dough using qualitative and quantitative analysis (Piazza and Schiraldi, 1997; Pronyk et al., 2007).

The addition of inclusion and brans in the cookie dough improving the water absorption (Sudha et al., 2007). Based on research conducted by Sai and Haridas (1999), it showed that the adhesiveness, as well as stickiness of the dough, is increased when the moisture content is higher. Furthermore, it also reported that the higher moisture content enhancing the stickiness of the dough (Mani et al. (1999); Gras et al. (2000) and Tseng & Lai (2002)).

CHAPTER 3: METHODOLOGY

3.1. Overview

Properties of food are changing overtimes, and when the food is processed or produced using machines, the food will not be as wanted due probably to clog or adhere as a precipitate on the material surfaces. Machines in the market are designed to operate for specific properties of food and certain purposes optimally. Therefore, changes in the properties of food may indirectly contribute to the operational problem of the machines. The problem can be minimized by conducting a study on the stickiness and moisture content properties of cookie dough based on two parameters, which are the oat to flour ratio and resting time (Figure 3.1.1).

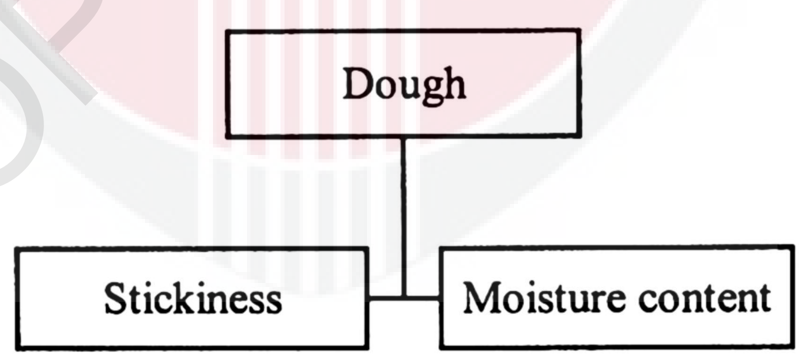

Figure 3.1.1: Properties of cookie dough

Effect of cookie dough properties on four type of materials in the cookies shaping machine was studied as well (Figure 3.1.2). The results obtained from this research will serve as a guideline in formulating the cookie dough that is suitable to be used in the cookies shaping machine.

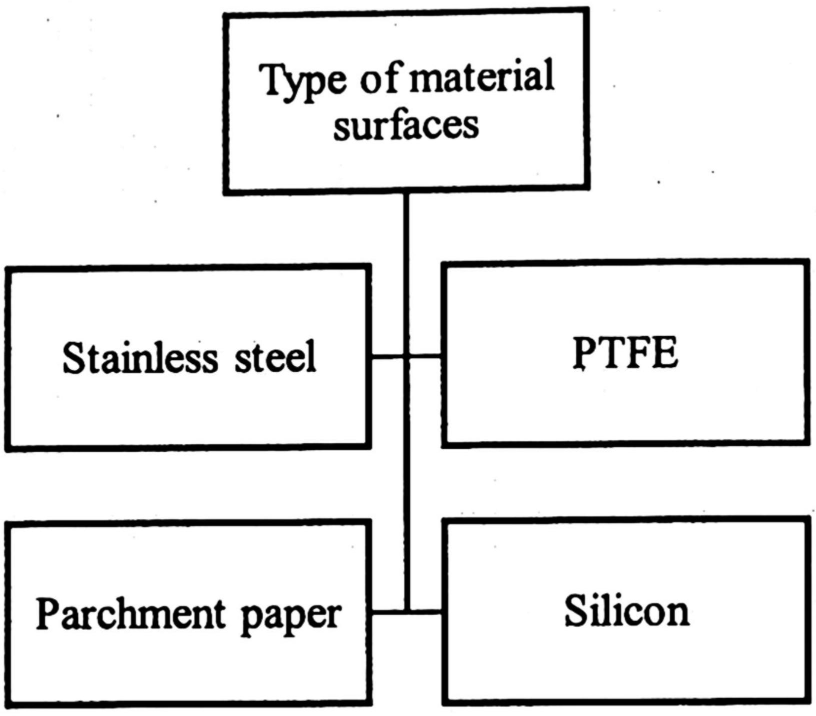

Figure 3.1.2: Material surfaces in the cookies shaping machine

3.2. Sample preparation

Basic mixture formulation used in this research is provided by one of the SME's cookies company who has experience for more than ten years in producing oat-based cookies. The basic mixture formulation of the cookie dough is measured in cup and weight for one cup of ingredient is shown in Table 3.2.1. This mixture formulation is for the one-time mixing process. For each mixing process, two cups of oat and 2.5 cups of flour were required, which makes up a total weight for oat and flour of 188 and 285 grams, respectively.

Table 3.2.1: Basic mixture formulation of the cookie dough

Ingredients	Quantity	Weight per 1 cup (g)
Oat	2 cups	94
Flour	2.5 cups	114
Brown sugar	0.75 cup	164
Castor sugar	0.5 cup	232
Chocolate chip	0.75 cup	178
Cashew nut	0.25 cup	140
Almond slice	0.5 cup	96
Egg	1 piece	-
Butter	250 gram	-
Soda bicarbonate	3 gram	-
Baking powder	8 gram	-

Since the basic mixture formulation was provided in cup measurement (Table 3.2.1) for most of the basic ingredients including oat and flour, oat to flour ratio was calculated based on the cup measurement throughout the research. Cup used to measure ingradient is shown in Figure 3.2.1. Prior to the experiments, samples were prepared at different oat to flour ratio, while other ingredients remained constant.

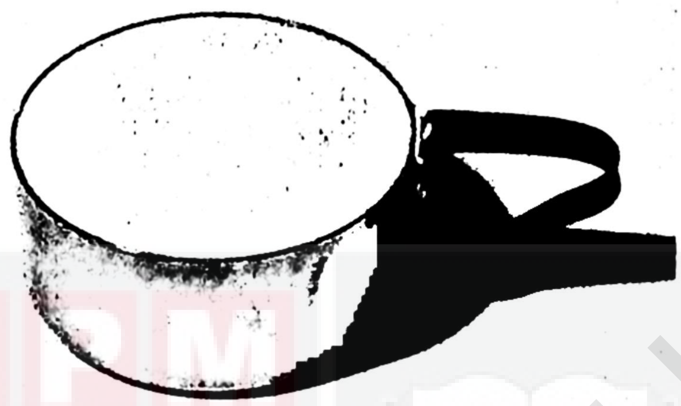

Figure 3.2.1: Cup used to weight the sample

Mixture formulation of cookie dough based on five different cup ratios are shown in Table 3.2.2. The ratio of 1:1.5 is the basic mixture formulation provided by the SME's cookies company. The calculated weight was rounded off to the nearest whole number. For example, for 1.8 cups of oat at ratio 1:1.5, the total weight required was 94 grams multiply by 1.8 cups, which equal to 169.2 grams. After rounded off to the nearest whole number, the weight required was 169 grams. The similar calculation method was used to calculate the weight of flour. For each oat to flour ratio, the total cup required for every mixing process was 4.5 cups.

Table 3.2.2: Mixture formulation of cookie dough for different oat to flour ratio

Measurement	Oat to flour ratio	Oat	Flour	Total
Cup	1 : 1	2.25	2.25	4.50
	1: 1.25	2.00	2.50	4.50
	1: 1.5	1.80	2.70	4.50
	1: 1.75	1.64	2.86	4.50

	1: 2	1.50	3.00	4.50
Weight (g)	1 : 1	212	257	469
	1: 1.25	188	285	471
	1: 1.5	169	308	477
	1: 1.75	154	326	480
	1: 2	141	342	483

The dough was prepared using heavy duty mixer (Model 5K5SS, KitchenAid, St. Michigan, USA) as shown in Figure 3.2.2. First, butter, castor and brown sugars were placed inside the mixing bowl and mixed using the mixer. The mixing time and speed were kept constant at 11 minutes and 6 rpm, respectively. Then, the egg was added into the mixture and was mixed for another 2 minutes at 6 rpm. The mixing product was a soft white-yellowish batter as in Figure 3.2.3.

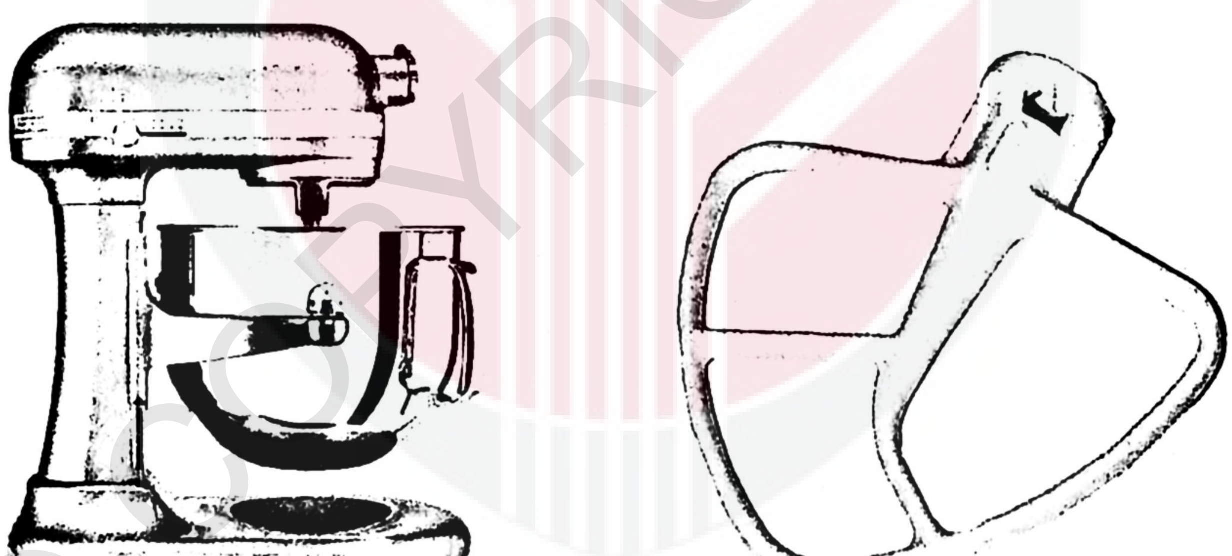

Figure 3.2.2: Mixer (left) and blade (right) used to mix the ingredients

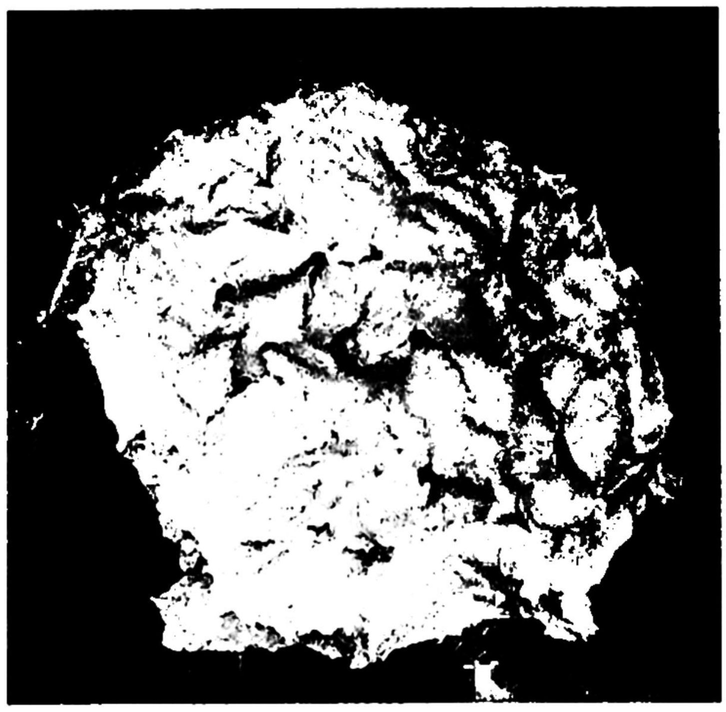

Figure 3.2.3: Soft white-yellowish butter

At the same time, the remaining ingredients were mixed manually in another bowl following the proper ratio as shown in Table 3.2.1. The batter was mixed with the remaining ingredients for 2 minutes until the mixture was well-mixed (Figure 8). The mixing process was repeated for all oat to flour ratio.

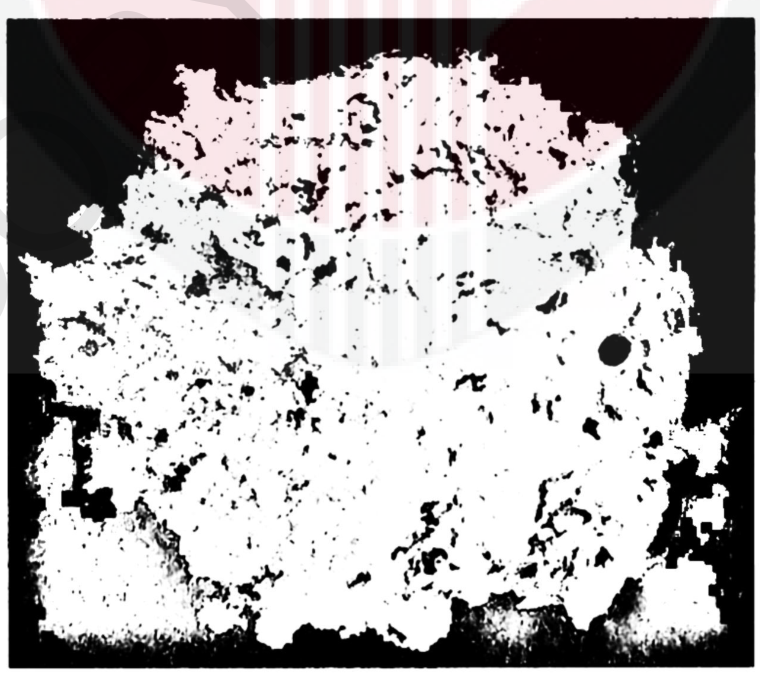

Figure 3.2.4: Well mixed cookie dough

Prior to testing, the well-mixed cookie dough was divided into five equal parts (Figure 3.2.5) and stored in a closed container and labelled as in Table 3.2.2. The dough was rested at five different resting times, which were 10, 20, 30, 40, and 50 minutes. Since samples were tested on different days, the dough was rested inside an incubator at controlled room temperature approximately 27-degree celsius with 85 to 90 percent relative humidity. The mixing process and testing apparatus are located near to each other to minimize inaccuracy in data collection due to difference in temperature and relative humidity.

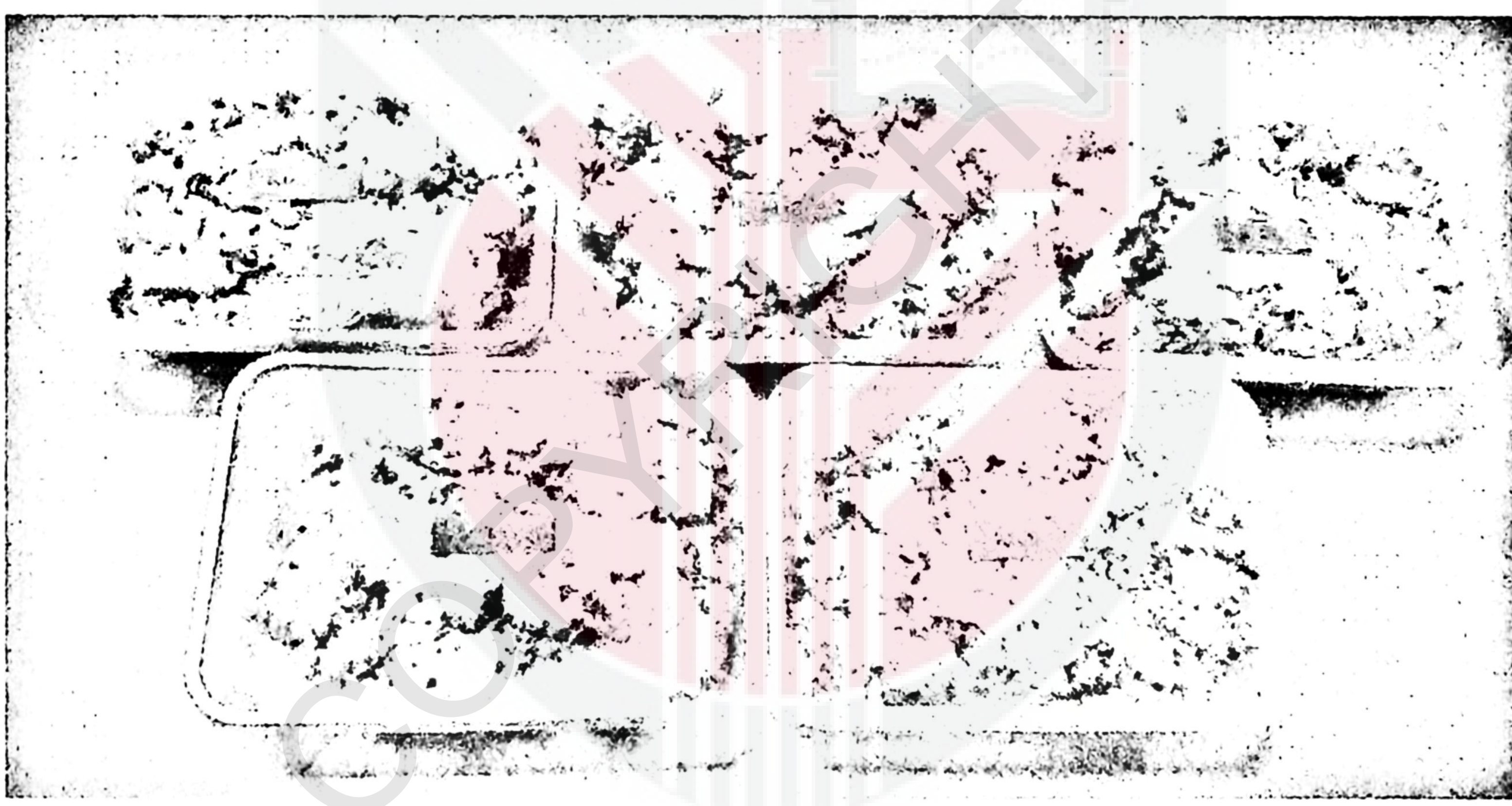

Figure 3.2.5: Five equal parts of the well-mixed dough for different oat to flour ratio

Experimental design

The experiment was first designed based on two parameters, which are the oat to flour ratio and resting time, as shown in Table 3.2.2. Each sample was labelled based on their parameters. For example, a sample prepared based on a ratio of 1:1 and 10 minutes resting time, the sample was labelled as R10010. With three replications were considered for each part, there are 75 samples in total.

Table 3.2.3: Labelled for each parameter on the dough studied

		Oat to flour ratio				
		1 : 1	1 : 1.25	1 : 1.5	1 : 1.75	1 : 2
Resting time (min)	10	R10010	R12510	R15010	R17510	R20010
	20	R10020	R12520	R15020	R17520	R20020
	30	R10030	R12530	R15030	R17530	R20030
	40	R10040	R12540	R15040	R17540	R20040
	50	R10050	R12550	R15050	R17550	R20050

Experiments were conducted in two phases. The first phase involved the determination of stickiness, cohesiveness, and moisture content properties of different cookie dough mixture formulation based on oat to flour ratio and resting time. Texture and moisture analyzer were used in the first phase. The second phase focusing on the stickiness properties of cookie dough on different material surfaces, including polytetrafluoroethylene (PTFE) or known as Teflon, silicon, stainless steel, and parchment paper. For the second phase, only good and poor samples, obtained in the first phase based on the properties, were tested. Figure 3.2.6 shows the experimental flowchart of the research.

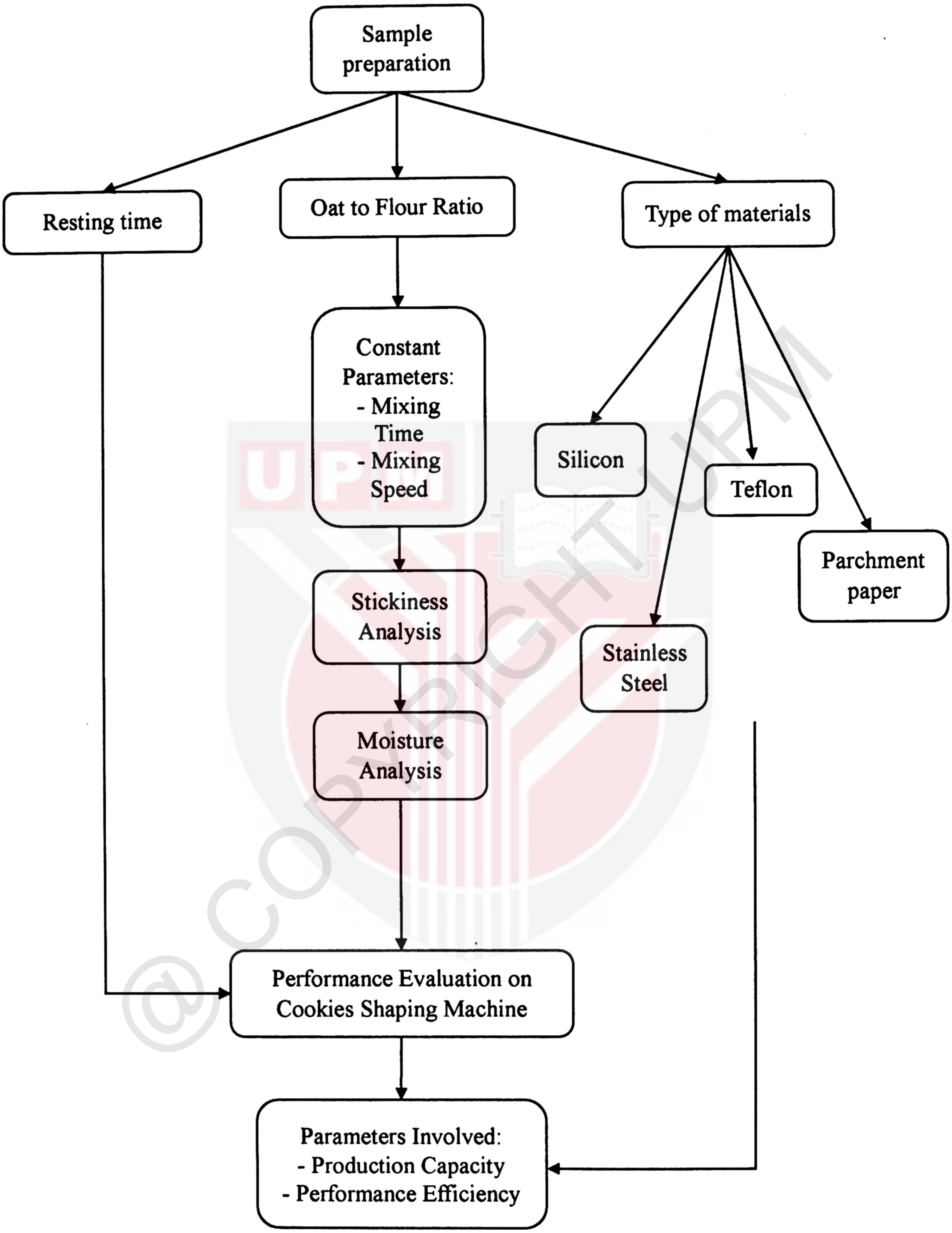

Figure 3.2.6: Experimental flow chart of the reseach

Experimental procedure

3.2.1. Texture analyzer

The value of adhesiveness and stickiness were studied using the texture analyzer (TA.XT PLUS, Stable Micro Systems, Surrey, U.K.) with a 75 mm diameter cylinder probe (P/75P) under the following settings, Pre-Test Speed: 0.5 mm/s, Test Speed: 0.5 mm/s, Post-Test Speed: 10.0 mm/s, Return Distance: 5 mm, Applied Force: 5 g, Contact Time: 0.1s, Trigger Type: Auto – 5 g (Chen and Hoseney, 1995). The measurement was performed on triplicate samples from each condition, and three measurements were performed on each replicate. Dough stickiness data were documented as a force-versus-time curve (Figure 3.2.1.1). The dough stickiness measured the maximum positive force (N). Balestra (2009) defined the highest positive peak from the positive region of the graph as the stickiness measurement.

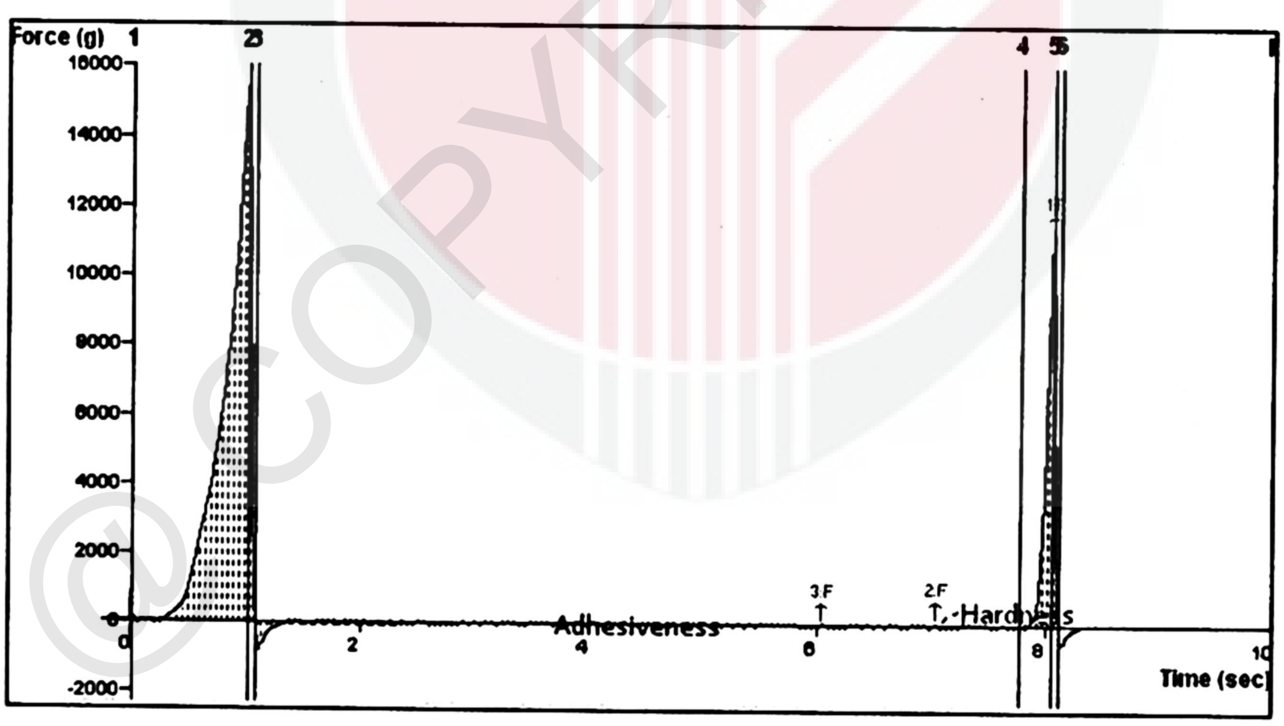

Figure 3.2.1.1: Illustrated force versus time curve for dough stickiness test

3.2.2. Scanning Electron Microscope (SEM)

Doughs with different composition were observed using an SEM in Institute of Bioscience, Universiti Putra Malaysia. The doughs were mounted on an SEM stub by a double-sided tape. The samples were coated with gold and placed in the SEM (JSM-IT100 InTouchScope, Hitachi, Japan) chamber.

3.2.3. Moisture analyzer

The moisture content of the cookie dough was examined using Moisture Analyzer (Model MB45, Othaus, US) as shown in Figure 3.3.1. A total of 2 grams of the sample was placed in the tray. The starting temperature is 105℃, and end temperature is 120℃. The accuracy is set to medium. Each testing was repeated three times and the average of all replications was calculated and recorded.

3.3. Performance evaluation of the cookies shaping machine

Performance evaluation is conducted to identify the suitability of different dough composition on the cookies shaping machine based on the production capacity and other related parameters.

3.3.1. Determination of production capacity of the cookie dough

$$\text{Production capacity} = \frac{\textit{Number of cookie dough filled in the mould}}{\textit{Time (hr)}} \quad (1)$$

3.3.2. Determination of performance efficiency of the cookies shaping machine

$$\text{Performance efficiency} = \frac{\textit{Number of cookie dough fall into the tray}}{\textit{Total of sample}} \times 100\% \quad (2)$$

CHAPTER 4: RESULTS AND DISCUSSION

4.1. Effect of the dough composition and resting time on dough stickiness

In the baking industry, dough stickiness is an important parameter that controls the dough handling (Ahmed & Thomas, 2018). The effect of dough composition on the dough stickiness after five different time intervals are presented in Table 4.1.1.

Table 4.1.1: Stickiness value for different dough compositions over resting time

Dough composition	Resting time (min)				
	10	20	30	40	50
1:1	1926	2575	3111	3476	2500
1:1.25	4470	5950	6132	6557	5797
1:1.5	5093	6254	6601	6925	6529
1:1.75	2867	3803	3603	4304	3866
1:2	1220	1888	1838	2509	1682

Content of flour in the dough composition of 1:2 is higher as compared to that of the dough composition of 1:1. According to research by Yildiz (2012), on determination of stickiness values on different flour combinations, it was found that the stickiness values decrease as the flour content increase. This is also supported by Hana and Fadi (2011) where the dough stickiness decreases as the flour content increase. Fustier et al. (2009) said that dough stickiness is generally associated with the development of gluten and the interaction with other ingredients in the formula (sugar, fat and water).

From Table 4.1.1, after a resting time of 10 minutes, the stickiness value increase from 1926 to 4470 and 5093 N for dough composition of 1:1, 1:1.25 and 1:1.5, respectively. This is because the dough become more fluid over resting time. As time goes, the cooperation between the dough and the material increase as the dough can go through deeper into the materials and create a bigger contact area between the dough and material (Ghorbel and Launay, 2014). The increasing of stickiness value indicates could be explained by increasing contact area over time (Laukemper, Jekle, and Becker, 2019).

Further addition of flour resulted in a drop of stickiness value to 2867 and 1220 N for dough composition of 1:1.75 and 1:2, respectively. It can be seen that the trend is similar for other resting times. The findings were in agreement with (Yildiz, 2012) where the dough become stickier as the resting time increasing. Same finding also reported by Ahmed and Thomas, in which reported that the stickiness value increase with the resting time, however, they found no systematic trend of stickiness values on the resting time (Ahmed and Thomas, 2018).

According to Hoseney and Smewing, dough stickiness is caused by an interactive balance between adhesion and cohesion (Hoseney and Smewing, 1999). A higher stickiness value for dough composition of 1:1.25 and 1:1.5 as shown in Figure 13 could be influenced by the presence of excess water that is not bound by proteins (Ahmed and Thomas, 2018). The gluten present in the flour absorbed water to induce protein interactions that play a critical role in dough stickiness as well (Van Velzen et al., 2003). Similar results were obtained by Tang and Liu, which concluded that as the protein increase, the hydration of protein resulted in higher surface adhesion and subsequently higher dough stickiness (Tang and Liu, 2017).

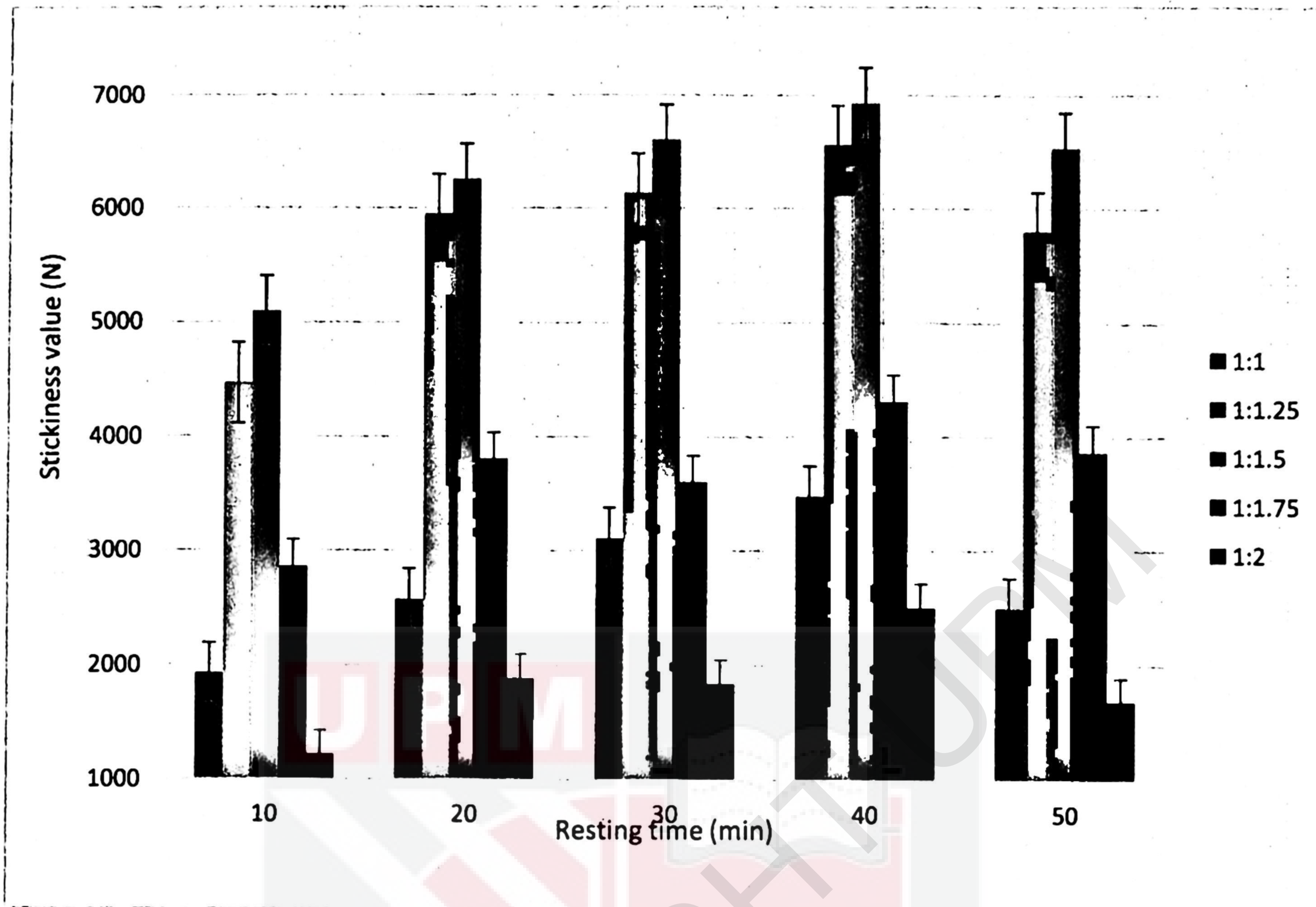

Figure 4.1.1: Stickiness value of oat-based cookies with different composition over resting time

The results obtained was supported by Sandoval et al. which claimed that the surface tension between the dough surface and the surface that is in contact with the dough is produced by a mixture of water and the water-soluble materials, which are dissolved in it (Rodriguez-Sandoval, Franco, & Manjarres-Pinzon, 2014). It is also opined that if the doughs were made by mixing non-sticky dough flour with sufficient amount of water-soluble fibre then dough stickiness would increase (Chen and Hoseney, 2002). The drop of stickiness value of dough composition of 1:1.75 and 1:2 for all resting times could be associated with the limited water availability in the dough complex. The hydration capability and complexing with constituents might play an important role to impart the stickiness in the dough (Ahmed and Thomas, 2018).

Dough properties changed over time (Laukemper, Jekle & Becker, 2019). The dough tends to become more fluid as time increases. This is because of the structural relaxation (Kim et al., 2008) and network degradation caused by the activity of the enzyme after longer resting time (Wu and Hoseney, 1989).

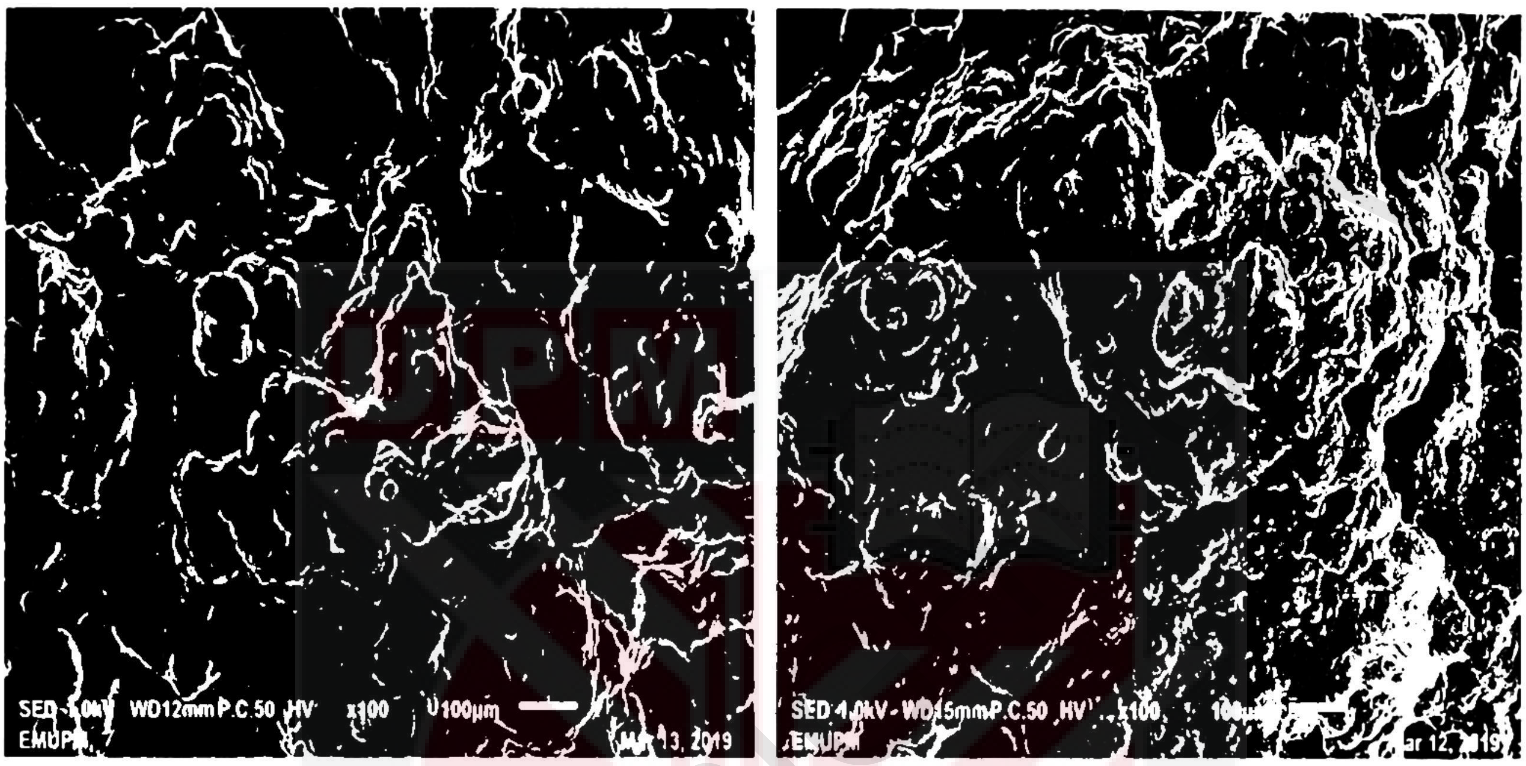

Figure 4.1.2: (a) SEM for dough with ratio 1:1.5 with highest stickiness value (left) and (b) SEM for dough with ratio 1:2 with lowest stickiness value (right)

Figure 4.1.2 shows the micrograph of the surface of the cookie dough with the highest and lowest stickiness values at 100x magnification after 50 minutes of resting time. It can be observed that starch granules were distributed in the protein matrix. The findings were in accordance with Dachana et al., which stated that a thin sheet representing protein matrix along with small and large starch granules embedded in it can be observed in cookie dough (Dachana et al., 2010). In addition, the granules which are almost entirely covered by a thin layer protein film were melted and re-solidified fat (BRITES et al., 2018).

In Figure 4.1.2(a), which is the micrograph of the surface of cookie dough with the highest stickiness value, starch granules were partially embedded in the protein matrix due to the surface adhesion induced by the protein. Hollows and ditches were observed on the dough surface which indicates that the continuity of the gluten matrix has been disrupted by the protein (Tang and Liu, 2017). Figure 4.1.2(a) has more holes compared to Figure 4.1.2(b). Hence, the surfaces in Figure 4.1.2(b) is smoother than surfaces in Figure 4.1.2(a). This structure resulted in difficulty in handling the dough due to high stickiness properties. Figure 4.1.2(b) shows the micrograph of the cookie dough with lower stickiness value as compared to that of Figure 4.1.2(a). It can be seen that the starch granules were mostly covered with thin protein film which was responsible for network formation and thus resulted in low stickiness properties and good handling of dough (Sarabhai and Prabhasankar, 2015; Dachana et al., 2010).

4.2. Effect of dough composition and resting time on dough moisture content

The moisture content of cookie dough was studied using moisture analyzer and the results were shown in Table 4.2.1. The dough composition of 1:1 contained a lower quantity of flour as compared to that of the dough composition of 1:2. The moisture content decrease over time for all dough composition. Except for the dough composition of 1:1, all dough composition showed the highest moisture content after 10 minutes of resting time and decreased gradually over a period of 50 minutes. As time goes, the water content become lower. This is due to evaporation of the water from the cookie dough which is depending on the environment. Although water is a minor component in cookie batter formula, the rheological behaviour and the machinability of cookie batter are largely influenced by the water content and its distribution within the batter (Agyare et al., 2005; Assifaoui et al., 2006; Lee and Inglett, 2006).

Table 4.2.1: Moisture content of oat-based cookies with different compositions over time

Dough composition	Resting time (min)				
	10	20	30	40	50
1:1	11.21	11.44	11.15	11.14	10.73
1:1.25	11.62	11.49	11.33	11.18	10.90
1:1.5	11.96	11.58	11.36	11.14	10.74
1:1.75	11.99	11.72	11.40	10.74	10.45
1:2	12.15	11.70	11.16	10.63	10.39

Effect of resting time and dough composition on the moisture content is presented in Figure 4.2.1. The difference can be seen at two parts which are before and at 30 minutes, and after 30 minutes of resting time. At 10 minutes of resting time, dough composition of 1:2 with the lowest stickiness value (Figure 4.2.1) have the highest moisture content. Its moisture content dropped significantly after 10 minutes onwards and the dough composition of 1:2 had the lowest moisture content at 50 minutes of resting time. Higher content of flour has a higher surface area and tend to absorb more moisture in the first 20 minutes. Increase in surface area of starch leads to higher water absorption (Hazelton, DesRochers, and Walker, 2004). However, the increase in surface area of starch granules and protein matrix resulted in higher moisture loss. According to Bushuk, the water bound to the flour constituents is distributed as follows: 46% is bound to the starch, 31% to the proteins, and 23% to the pentosans; an additional 15% water is required to develop the gluten network (Bushuk, 1966).

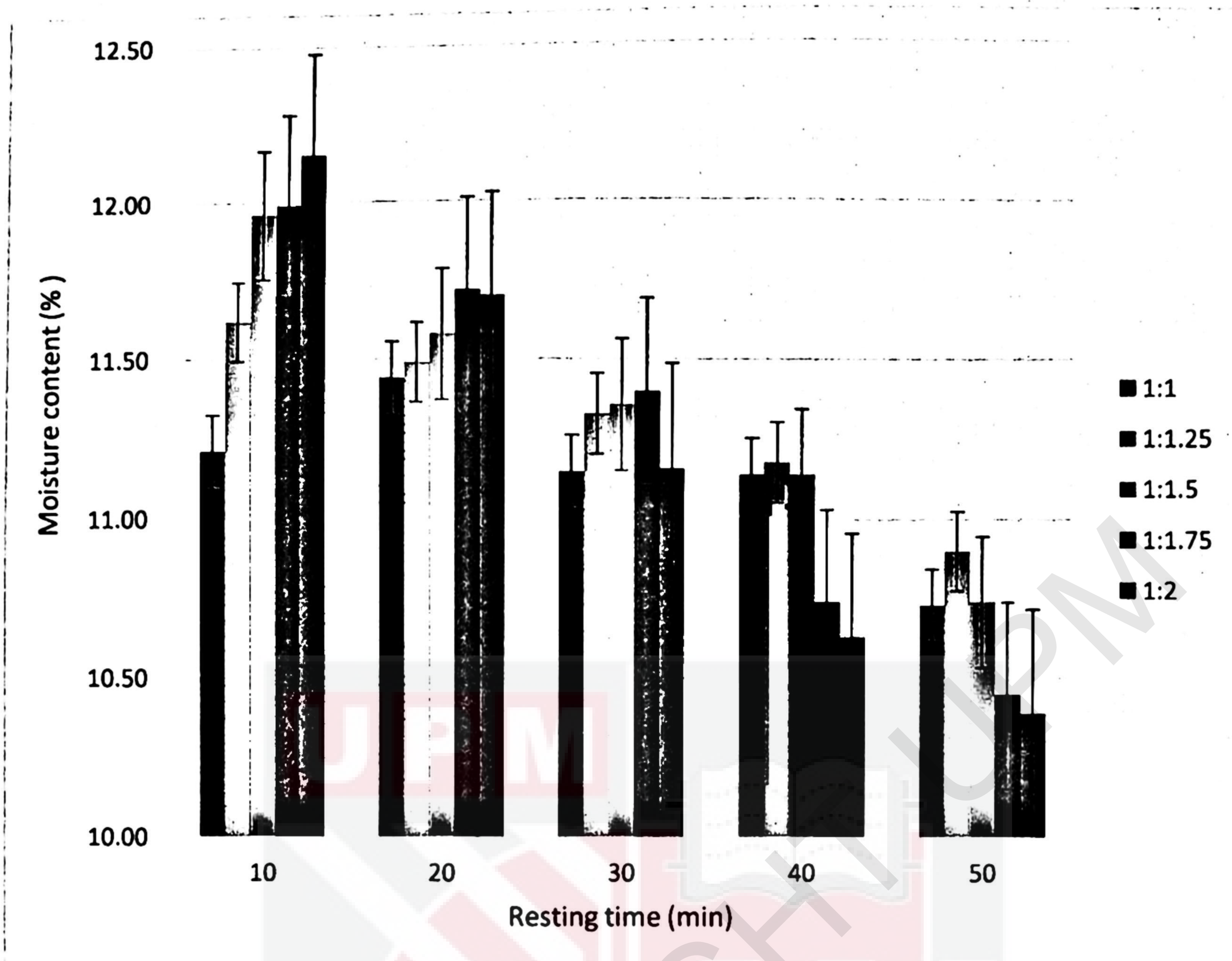

Figure 4.2.1: Moisture content analysis for different composition of oat-based cookies over time

At 30, 40, and 50 minutes of resting time, dough composition with high stickiness value (sample with 1:1.5 ratio) contained high moisture and vice versa. Based on this trend, it can be said that the lower the moisture content of the cookie dough, the lower the stickiness value as obtained by Dokic, Nikolic,& Radosavljevic (2013) in rheological and textural properties of cookie dough research. This result is in agreement with with other researchers which concluded that higher water absorption provided better wetting properties and the dough surface is in better contact with the surface of the probe. Thus, it gives higher surface adhesion and subsequently increases dough stickiness (Chen & Hoseney, 1995; Collar & Bollaín, 2005; Ghodke, Ananthanarayan, & Rodrigues, 2009; Yi, Kerr, & Johnson, 2009). Moisture absorption ability of the flour was found to be directly proportional to the protein level. An increase in protein level does not only raise water absorption but the stickiness values as well (Van Velzen et al., 2003). Water has a marked influence not only during batter preparation but also in the end product during storage of cookies (Cornillon and Salim 2000).

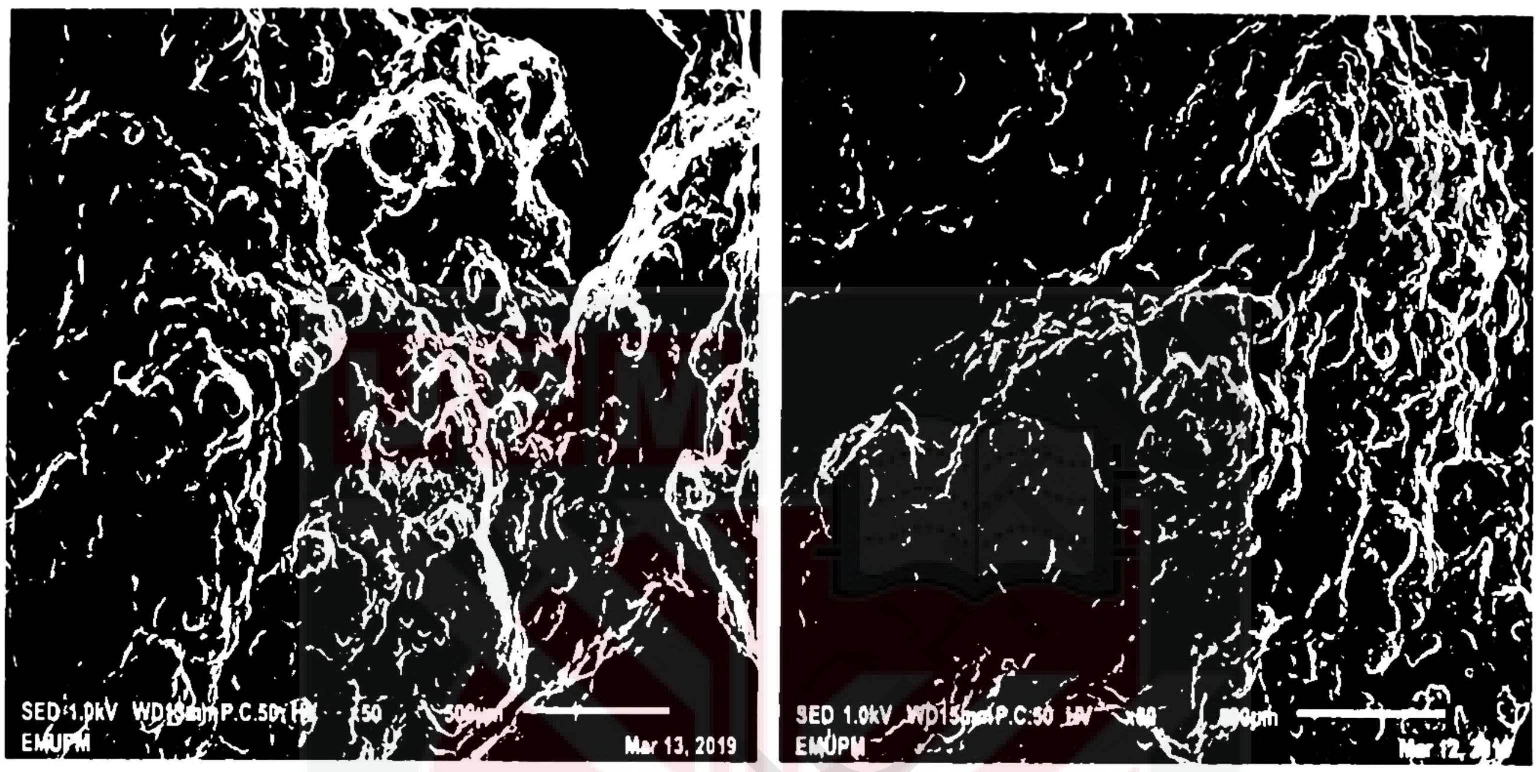

Figure 4.2.2: (a) 1:1.25 highest moisture content (left), (b) 1:2 lowest moisture content (right)

Figure 4.2.2 shows the microscopic images of cookie dough with the highest and lowest moisture content. Samples were tested after 50 minutes of resting time. The starch granules in Figure 4.2.2(a) were completely covered with the protein matrix due to high moisture content while in Figure 4.2.2(b), the starch granules were not completely covered with the protein matrix due to less moisture content. This was in agreement to research by Ltang, Piau and Verdier, (1999) who reported that less hydrated cookie dough has less visible starch granules. The dough with high moisture content as shown in Figure 16(a) entailed a highly aggregated protein phasewhich is scattered, clustered and less interconnected. The signal revealed less incorporated starch granules which is in accordance with Letang et al., (1999), who stated that starch granules are less visible in highly hydrated dough than in hydrated dough due to a covering of continuous film. The micrograph in Figure 4.2.2(b) with the lowest water content exhibits a slightly clustered, though interconnected network of protein filaments. Between the protein strands some still empty areas can be detected but on the other hand the proteins are more compact compared with micrograph in Figure 4.2.2(a). This means that the protein network is not evenly distributed. Bonds are responsible for the integrity of the dough's protein film.

4.3. Dough stickiness behavior on different material surfaces

The stickiness behaviour of the cookie dough on different materials was studied using texture analyser and the result was tabulated in Table 4.3.1. The dough composition of 1:1.25 was used to determine the stickiness value.

Table 4.3.1: Stickiness behaviour of the cookie dough on different material surfaces

	Teflon (PTFE)	Silicone	Stainless steel	Parchment paper
Dough stickiness (N)	1150.94	1227.31	1525.20	1862.45

The stickiness behaviour on different material surfaces is recorded in Figure 4.3.1. As could be seen above, teflon (PTFE) has the lowest stickiness value which is 1150.94N while parchment paper has the highest stickiness value which is 1862.45N. This result shows that the materials have lowest stickiness value as compared to the result in Table 4.3.1. The used of these materials allow the decreasing of contact area which produced in lower stickiness value. There are many authors found a correlation between adhesion force and contact area from other applications such as adhesion between polymer balls and silicone surfaces or rubber or stainless steel (Kim et al., 2008; Meine et al., 2004, Pastewka and Robbins, 2014).

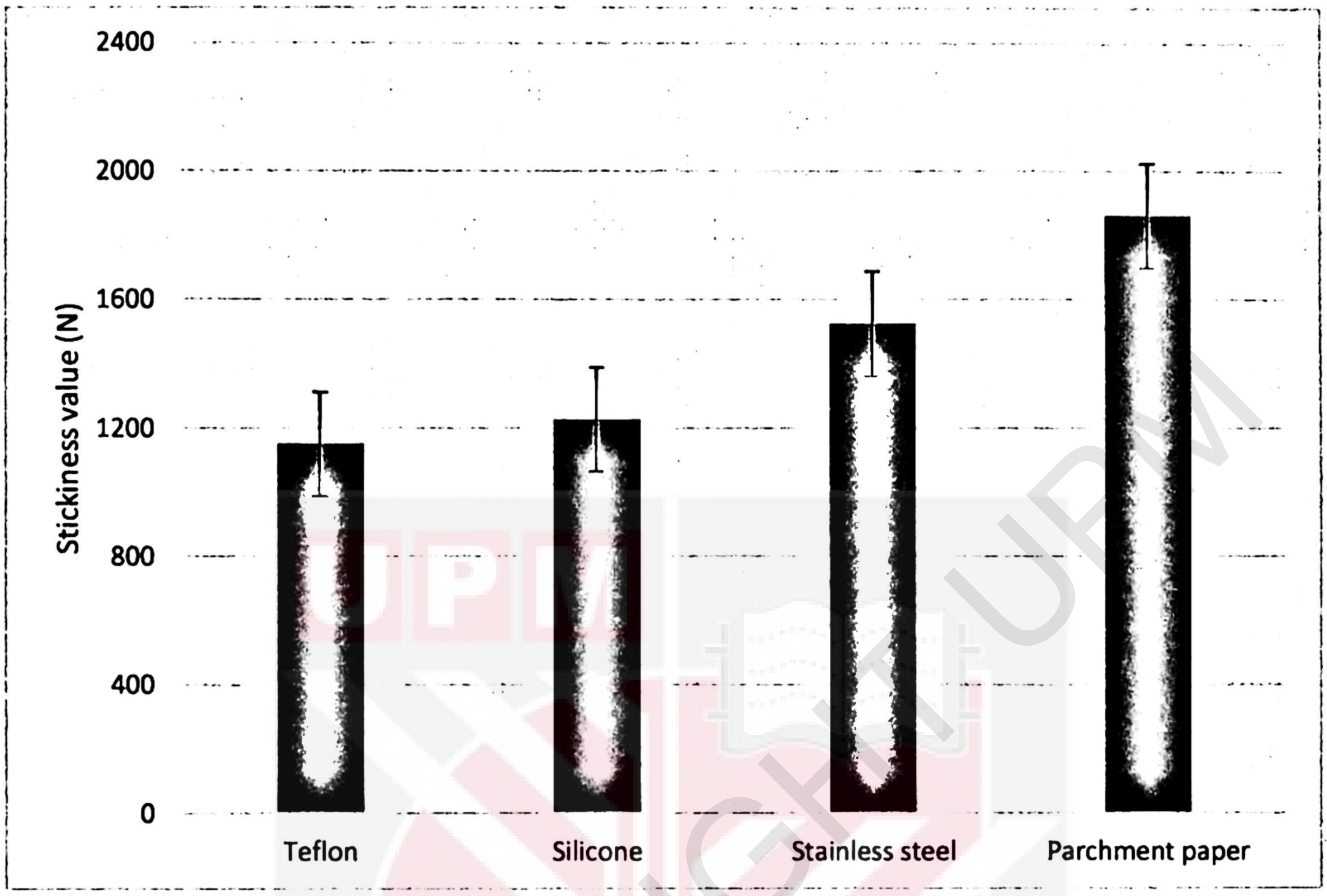

Figure 4.3.1: Stickiness value for different type of materials

As shown in figure above, Teflon (PTFE) has the lowest stickiness compared to other materials. This is because it has a lower surface energy which make it is easier for cleaning as well as a non-stick surface to food (Saranaya et al., 2010; Balasubramanian and Puri, 2009; Zhang et al. 2009).

Stainless steel is very important for food industries. It is a material which used widely for designing food process equipment (Benezech et al. 2010; Lewan, 2003; Saikhwan et al. 2006; Verran et al. 2008; Yoon and Lund, 1994). This is because the advantages when used as a food contact surface such are good corrosion resistance (Verran et al. 2008) and good hygienic properties (Boulané-Petermann, 1996).

Lower (2017) studied on the differences between silicone mat and parchment paper for food purpose and she found that both have the same function such as provide non-stick surface and reduce time for cleaning but they have a lot of differences. Silicone can make an excellent surface for kneading sticky dough because of their washable properties which means that it can be used repeatedly. Thus, it can reduce the operation time for your cooking or baking process. However, it cannot provide a good surface for browning, so for making cookies with crisp and browned bottoms, parchment paper is the better choice. This make both are very important for food industry especially for cookies production.

Based on this result, it was proven that the materials are suitable to be used in the cookies shaping machine as the dough have lower surface contact to the teflon (PTFE), silicon, stainless steel and parchment paper. Only low energy This can avoid the dough from stick to the surface. Thus, it can improve production capacity and efficiency for the cookies.

4.4. Performance evaluation on the cookies shaping machine

4.4.1. Machine design

Figure 4.4.1 shows the finalized design of the cookies shaping machine. The are three main station of the machine which are extruding, cutting and moulding which including pressing process. The operation of the machine is carried semi manually with the use of a single manpower.

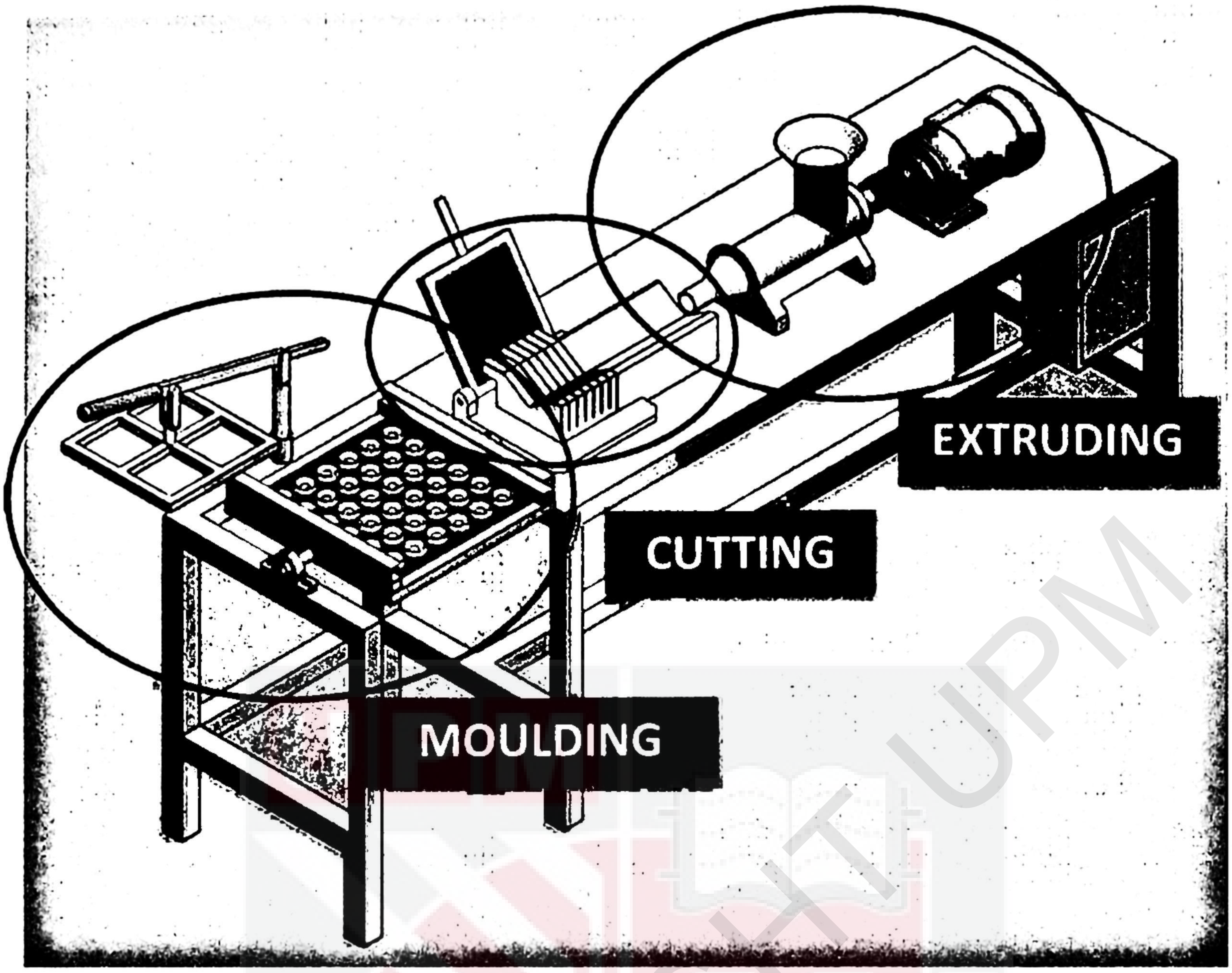

Figure 4.4.1: Cookies shaping machine

The machine is focused on the type of materials used for each part which is important to reduce the stickiness of the dough. The type of materials used for each part is listed in Table 4.4.1.

Table 4.4.1: Type of materials used for different parts of the cookies shaping machine

Part of the machine	Type of materials used
Extruding	Stainless steel
Cutting	Teflon (PTFE)
Moulding	Silicone and parchment paper

4.4.2. Production capacity

The production capacity of cookies between the using of cookies shaping machine and conventional method is shown is Table 4.4.2.

Table 4.4.2: Production capacity of oat-based cookies

	Number of cookies on tray (g)	Time required (s)	Rate (g/s)	Rate (kg/hr)
Conventional method	360	385	0.93	3.35
Cookies shaping machine	360	263	1.37	4.93

From the data obtained and calculated using equation (1), the production capacity of the cookies shaping machine and conventional method are 4.93 kg/hr and 3.35 kg/hr, respectively. This means that there is increasing of 1.47 times in production capacity by using cookies shaping machine. This shows that cookies shaping machine helps in increasing the productivity.

4.4.3. Performance efficiency

The performance efficiency of different oat to flour ratio on the cookies shaping machine is evaluated and tabulated in Table 4.4.3.

Table 4.4.3: Efficiency of cookies shaping machine based on different oat to flour ratio

Ratio	Sample weight (g)	Weight (g)		Efficiency (%)
		Fall into tray	Stay on the silicon mould	
1:1	360	150	210	42.67
1:1.25	360	180	180	50.00
1:1.5	360	110	270	30.56
1:1.75	360	190	170	52.78
1:2	360	290	70	80.56

Five samples of different oat to flour ratio are being used to test the performance efficiency of the cookies shaping machine. From the result obtained above, the cookie dough of ratio 1:2 has the highest performance efficiency while the cookie dough of ratio 1:1.5 has the lowest performance efficiency. This can be related with the result in Figure 13 where the cookie dough with ratio 1:1.5 has the highest stickiness value while the cookie dough with ratio 1:2 has the lowest stickiness value. This shows that the dough with high stickiness value has a high surface contact and vice versa. Thus, it is difficult for the dough with high stickiness value to achieve higher performance efficiency on the cookies shaping machine. As a result, dough with ratio 1:2 is the most suitable with the cookies shaping machine.

4.4.4. Advantages and disadvantages

There are some advantages and disadvantages of using cookies shaping machine compared to manual method of shaping the cookie dough by the labour. The common advantage is the using of cookies shaping machine gives higher production rate compared to manual method. Moreover, more time can be saved by using of this machine. However, the fabrication and maintenance cost for this machine is higher compared to manual method. But, with the higher production rate, the SME can gain more profit over time by using cookies shaping machine.

Table 4.4.4: Comparison between cookies shaping machine and manual method

Cookies shaping machine	**Manual method**
Higher production rate	Lower production rate
Save time	Consume more time
Less labour needed	More labour needed
Higher fabrication and maintenance cost	Lower cost

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

There are many parameters that influence the determination of stickiness value of the cookie dough with different composition. In food industry, one of the major issues in finding out the dough stickiness is that there is no standardized standard for measurement of the stickiness value. This research enabled an assessment of the parameters influence to dough stickiness. The aim of this research has been accomplished with the fabrication of the cookies shaping machine.

The current study indicated a high potential in developing fibre-rich cookies with less inclusion with composition of 1:2 of oats and flour respectively. The increasing of oat and flour content in the formulation show a significant effect on dough stickiness. This research also proves that the stickiness value increases as the resting time increases.

In terms of microstructure characteristics, the starch granules were partially embedded in the protein matrix due to the surface adhesion induced by the protein with the highest stickiness value for the cookie dough with highest stickiness value while the starch granules were mostly covered with thin protein film which was responsible for network formation for the cookie dough with les stickiness value. Thus, the cookie dough with 1:2 ratio has a smoother surfaces compared to the dough with 1:1.5 ratio.

As for the stickiness behaviour of stainless steel, Teflon (PTFE), silicon and parchment paper, it shows that the dough has low stickiness value. This makes the materials are been chosen for the fabrication of the cookies shaping machine. The lowest stickiness value has the highest performance efficiency with 80.56% on the cookies shaping machine. Thus, the cookies shaping machine helps to increase the production capacity by 1.47 times more than conventional method. Thus, it is highly recommended to replace the conventional method which is manually produced by the labour and higher time consumption with this cookies shaping machine. This research provides additional information on the technological quality and performance in moulding the oat-based cookie dough with different dough composition and resting time.

5.2. Recommendation for future research

Several potential improvement were identified during the research that may improve on the stickiness behaviour of the cookie dough. The followings are recommended for future research:

- Other test can be performed including cohesivenss, hardness, baking test, physical characteristics of the cookies and sensory evaluation to possibly improes its properties and widen its applications.

Some modifications are essential to optimize the performance of the cookies shaping machine. The recommendations of modifications that probably can be done to the machine are listed as below:

- The current 36 moulds can be increased in amounts. This definitely will improve the performance capacity of the cookies shaping machine.
- Use a bigger size of cookie dough holder, which can fill more cookie dough. This will reduce time cunsumtion of fill in the dough into the holder.

- Increase length of the dough cutter, so that more cookie dough can be cut in one time. So, the operator can transferred the dough into the silicon mould in short time.

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