INCORPORATION OF BANANA PEEL FIBER IN JELLY AS A FUNCTIONAL FOOD PRECURSOR

By

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LIST OF ABBREVIATIONS

Abbreviation	Caption
ANOVA	Analysis of variance
BPP	Banana Peel Powder
^{o}C	Degree Celsius
^{o} Brix	Degree Brix
FAO	Food and Agriculture Organization
g	Gram
h	Hour
min	Minutes
mg	Milligram
µg	Microgram
mL	Millilitre
µL	Microlitre
n	Sample size
s	Second
N	Newton
TDF	Total Dietary Fiber
WHO	World Health Organization

PENAMBAHAN SERAT DARIPADA KULIT PISANG KE DALAM AGAR-AGAR SEBAGAI PREKURSOR MAKANAN BERFUNGSI

ABSTRAK

Kulit pisang telah dinilai mempunyai potensi untuk digunakan sebagai serat kepada makanan berfungsi. Objektif utama dalam kajian ini adalah untuk menghasilkan agar-agar serat kulit pisang dengan memasukkan ekstrak serat daripada kulit pisang dalam formulasi agar-agar, bagi mengkaji jumlah keseluruhan kandungan serat makanan, sifat tekstur dan sineresis agar-agar serat kulit pisang. Serbuk kulit pisang telah diolah dengan kaedah enzimatik-gravimetrik untuk mengekstrak serat daripada kulit pisang sebelum proses pengeringan dan penggilingan. Serbuk serat kulit pisang dimasukkan ke dalam agar-agar dengan dua nisbah yang berbeza (5% dan 10%) bagi menghasilkan agar-agar daripada sisa buah yang mempunyai kandungan serat yang tinggi. Kedua-dua sampel agar-agar telah menjalani analisis untuk keseluruhan kandungan serat, tekstur dan sineresis dalam agar-agar ini. Peningkatan jumlah serat kulit pisang dalam agar-agar telah menyebabkan peningkatan secara signifikasi ($p<0.05$) terhadap keseluruhan kandungan serat dalam sampel agar-agar. Untuk sifat tekstur, kepekatan serat kulit pisang di dalam agar-agar mempengaruhi sifat tekstur agar-agar tersebut. Peningkatan jumlah serat telah menyebabkan perubahan terhadap kekerasan, kelekatan, koheren, keanjalan dan kekenyalan kecuali parameter lain iaitu kelekitan. Seterusnya, agar-agar dibuat dengan 10% ekstrak serat kulit pisang telah menurun secara ketara ($p<0.05$) terhadap nilai sineresis untuk kedua-dua masa penyimpanan. Ringkasan, kulit pisang yang digunakan dalam kajian ini mempunyai potensi untuk digunakan sebagai bahan-bahan berfungsi dengan penambahan serat dalam agar-agar. Kedua-dua agar-agar kulit pisang tersebut selamat untuk dimakan.

INCORPORATION OF BANANA PEEL FIBER IN JELLY AS A FUNCTIONAL FOOD PRECURSOR

ABSTRACT

The peel of banana was evaluated for the potential to be utilized as dietary fiber for functional food. The main objectives of this study were to develop banana peel fiber jelly by incorporating the banana peel fiber extract in the jelly formulation, to determine total dietary fiber content, texture properties and syneresis of produced fiber-added jelly. Banana peel powder was treated with the enzymatic-gravimetric method to extract the fiber powder from banana peel prior to drying and grinding treatments. Obtained banana peel fiber powder was incorporated into the jelly with two different ratios (5 and 10%) to produce jelly from fruit wastes with high fiber content. Both jelly samples including jelly sample with 5% banana peel fiber added and jelly with 10% banana peel fiber added were undergone total dietary fiber (TDF), texture and syneresis analysis. The increasing amount of banana peel incorporated into jelly had significantly increased ($p<0.05$) in TDF of jelly samples. For texture properties, it was found that the concentration of banana peel fiber had a significant effect on the texture properties of the jelly. An increase the fiber content caused a significant difference ($p<0.05$) in hardness, adhesiveness, cohesiveness, springiness and chewiness except for the other parameter which is gumminess was not significantly affected ($p>0.05$). Fiber-added jelly made with 10% banana peel fiber extract had significantly decreased ($p<0.05$) in syneresis values for both of refrigerated storage time. In summary, peel of banana used in this study had a great potential to be used as the functional ingredients for dietary fiber addition in the jelly. Both banana peel jellies were safe for consumption.

CHAPTER 1
INTRODUCTION

1.1 Research Background

Recently years, functional foods (FFs) are the alternative modern medicinal tool that has a growing demand among consumers due to the beneficial effects on human health. It represents a new term to food products with the basic nutritional impact by enrichment of natural substances with a specific physiological preventive to promote specific health effects (Vukasović, 2017). Consumers are interested in FFs which more prone to take these products that contribute directly to their health (Annunziata & Vecchio, 2011). The amount intake of FFs should not be in form of tablet or capsule, only for dietary purposes as part of the daily diet which gives the required amount of nutrients to provide basic nutrition and reduce the risk of chronic disease (Ballali & Lanciai, 2012).

There are three key terms of functional foods which are nutrients, herbals and dietary supplements, dietary fiber (Donato-Capel et al., 2014). Dietary fiber is defined as a non-starch polysaccharide, derived from plants that cannot be absorbed by endoenzymes in the human gastrointestinal tract because mammals are unable to produce enzymes that can hydrolyze them into constituent monomers (Turner & Lupton, 2011). It plays an important role in providing beneficial effects for the regulation of human bodies. Primarily, dietary fiber can delay the gastric emptying and increase small intestinal transit time, conferring in enhanced glucose tolerance and a decreased starch digestion; second, help in large bowel functions due to fermentation by bacterial microbiota (Ferrandis Vila et al., 2018).

Dietary fiber can be obtained from fruit waste such as banana peel (Wachirasiri et al., 2009). Banana peel is a food waste generated by the food industrial area in large quantities in the world due to high usage of edible parts of the banana (Amini et al., 2019). Research has been done in 30% from banana pulp is peels which can cause a tough environmental issue because of the large amount of nitrogen and phosphorus and its high-water content (González-Montelongo, 2010). Therefore, these peels should be reduced by fully utilized in the food industry application. Banana peels contain high amount of dietary fiber which acts as an indicator of a good source of dietary fiber. The high dietary fiber content could help in treating constipation and improving general health (Anhwange et al., 2009).

Various functional food can be produced from dietary fiber such as bakery, beverages, jelly and meat products. Jelly can be produced from agricultural by-products such as banana peel due to high pectin content as well as soluble dietary fiber that has the capability to form gels under specific conditions (Lee et al., 2010). Banana peel can replace any gel additives to make jelly in the production of health-care food (Happi Emaga et al., 2007; Lee et al., 2010). Globally, jelly is one of the most favorite desserts among consumers of all age groups and regions, especially by children. Some consumers are taking the jelly products as a part of their daily basis (Palve et al., 2013). However, the consumers are continuously searching for healthier and tastier jellies that possess health-promoting properties. Therefore, banana peel used as a new base in making a new peel jellies product for its nutritional value (Mohd Rasidek et al., 2016).

1.2 Rationale of study

The food industry produces high amount of wastes mainly, peel of banana due to the production of fruit juices, concentrates, jams and dried fruits. Due to increasing population, the by-product banana generated every day rises largely, resulting in an environmental problem such as the municipal landfills as a result of their high biodegradability and indicating a loss of valuable biomass and nutrients (Padam et al., 2014; Sagar et al., 2018). Besides, Malaysian adults had very low dietary fiber intakes than the recommended intake. Referring to Recommended Nutrients Intakes (RNI) for Malaysia, dietary fiber for daily intake must be between 20-30 g (Lee & Wan Muda, 2019). According to the Department of Agriculture of Malaysia (2018), the total production of banana for the year 2017 reached 350,493 metric ton, with value worth 1 billion Ringgit Malaysia. The pulp of banana is utilized for human consumption, while the other part such as the peels and seeds will be discarded. Therefore, new methods and policies using banana waste are required to overcome the environmental pollution.

Dietary fiber is one of the valuable components that can be obtained from such as banana waste. According to Happi Emaga et al. (2007), there are three different genetic of banana peel makeups namely AAA, AAB, ABB, and AAAB were rich in total dietary fiber. The dietary fiber composition in banana peels is influenced by the maturation of banana. Ramli et al. (2010) were agreed that the total dietary fiber (TDF) is slightly increased in banana peel as known as a yellow banana peel. Besides, there is some studies found high amounts of lignin, cellulose and hemicelluloses in banana peels (Eshak, 2016). The clinical recommends the intake of dietary fiber as a routine meal which helps in the reduction of diverticular disease (Aune et al., 2020). Also, the consumption of food that

contains fiber is recommended by the physicians for the reduction of cardiovascular disease, obesity, type 2 diabetes and some cancers (Turner & Lupton, 2011).

1.3 Objectives

The aim of the study was to evaluate the potential of banana peel as a functional fiber source for the formulation of jelly. In order to achieve this aim, the specific objectives of this study were as follow:

I. To analyze dietary fiber from peel of banana (*Musa acuminata* × *Musa balbisiana 'Pisang Awak'*)

II. To determine the textural properties, syneresis and total dietary fiber content of the banana peel dietary fiber jellies.

CHAPTER 2

LITERATURE REVIEW

2.1 Functional Food

Functional food is defined as a food that gives a good effect on the health of human beyond the amount of essential nutrients (Hasler, 2002). It refers to a new term to food products which satisfactorily demonstrated to provide beneficial functions in the body above the basic of nutrition to enhance the stage of health well-being (Vukasović, 2017). As mentioned by Holdt and Kraan (2011), functional food can enhance the quality of life by the lowering risk of chronic illnesses and increasing the ability to control chronic disease. The amount of functional food intake and form is usually for dietary goals (Siro' et al., 2008). Hence, it must be not in the pill or capsule form because it normally is consumed in the daily diet as part of the typical food habit (Diplock et al., 1999; Siro' et al., 2008). Lau et al. (2012) quoted a statement from Poulsen (1999) that stated there are four methods in producing functional food: upgrading by increasing the amount of substance already found in the food; enrichment by adding an ingredient that the food not normally contains; elimination by removing an unhealthful substance from food product; and substitution by replacing an ingredient that has similar functions.

Food with health benefits is declared as one of the rapidly-growing sectors in the food and drink industry (Siro' et al., 2008). According to Agri-Food Trade Service (2018), the global market size for functional food is estimated at USD 161.49 billion. In Malaysia, the market of functional food is still growing owing to the awareness among consumers regarding their good lifestyles and healthy diets (Lau et al., 2012). The growing demand for functional food and beverages is influenced by frequent exposure in

the worldwide market to improve the joint health, weight loss and bone and muscle strength (Lau et al., 2012). Functional food also can provide the optimal health by minimizing the risk of non-communicable disease, improving metabolism, boosting the absorption of nutrient in the body and helping for better digestion (Abuajah et al., 2015).

2.2 Banana (Musa Sapientum)

Banana is a tropical fruit as a general term of crossbreed in the genus Musa of the family Musaceae. It is the world's most vital food yield following by rice, wheat and corn (Mahajan et al., 2010). It is one of the oldest cultivated plants and most fruits intake in the tropical and subtropical regions. All the known banana cultivars are produced from two diploid species, Musa acuminata (AA) with the AA genotype that grow in clumps and Musa balbisiana (BB) with the BB genotype from South East Asia (Manzo-Sánchez et al., 2015). The hybridization of these diploid species have created other two genome groups which are triploid and tetraploid that creating subspecies of M.acuminata, and subspecies between M.acuminata and M. balbisiana (Aurore et al., 2009)

The major genome groups are AA, AB, AAA, ABB and AAB. They are classified into two classes, namely dessert banana and plantain. The dessert bananas belong to the AA, AB, AAA, and AAB genomic groups whereas cooking banana as known as plantain belong to the ABB genomic group (Bakry et al., 2009; Dash & Rai, 2016). Most types of dessert banana in the worldwide are AA or AAA, this last category includes the majority the varieties transferred to market for export (Karamura et al., 2012). Each of these groups has a difference due to their character as a raw material for food production. It can be

characterized based on colour, taste, sweetness and softness of their flesh. Table 2.1 shows the main cultivars of banana and plantains in different countries.

Table 2.1: Main Cultivars of banana and plantain (Cooking banana).

Group	Subgroup	Cultivars	Fruit Usage	Geographic Distribution
AA	Sucrier	Frayssinette	Sweet dessert	All continent
	Pisang Lilin	Figue sucree'	Dessert	Indonesia, Malaysia
	Pisang Berangan		Dessert	
	Lakatan		Dessert	
AAA	Gros Michel	Gros Michel		All continent
	Cavendish	Lacatan		Export countries
		Poyo		
		Grand Naine		
		Williams		
		Petite Naine		
	Figue Rose	Figue Rose	Dessert	
	Lujugira	Intuntu	Cooking, Beer	E. Africa, Highland
		Mujuba	Cooking, Beer	
AAAA	Champa Nasik		Dessert	
AAAB	Goldfinger	Goldfinger	Dessert	America, Australia
AB	Ney Poovan	Safety Velchi,	Dessert acid	India, East Africa
		Sukari	Dessert acid	
AAB	Figue Pomme	Maca, Silk	Dessert acid	All continent
	Pomme	Prata	Dessert acid	Brazil, India
	Mysore			India
	Plantain	French	Cooking	Africa, Caribbean
		Horn Corne	Cooking	
ABB	Bluggoe	Bluggoe	Cooking	Philippines, America
	Poteau		Cooking	
	Pisang Awak	Fougamou	Dessert	
ABBB		Klue Terapod	Cooking	
BBB	Saba	Saba	Cooking	Malaysia, Indonesia

Source: Adapted from Aurore et al (2009)

2.2.1 Nutritional Content of Banana Fruit

Banana cultivars can be classified into two classes; cooking (plantain) banana and dessert (sweet) banana. It has a large nutritious value and contains an abundant mixture of energy value, proteins, tissue-building elements, vitamins, and minerals (Sidhu & Zafar, 2018). Banana is rich in the energy as calorie resource for people in tropical humid regions due to the high carbohydrate content (Padam et al., 2014). Calories that the body needs for warmth, work and play are obtained from sugars and starch in the bananas (Ghag & Ganapathi, 2018). According to Offem and Thomas (1993), cooking bananas are nutritionally high in carbohydrates, vitamins and minerals however, low protein food material. Next, Goswami and Borthakur (1996) had stated that potassium which ranged between 4.10-5.55 mg per 100 g dry weight is one of the minerals that can be found in the banana. Anhwange et al. (2009) also agreed that banana consists of a high value of potassium that retains normal blood pressure and control body fluids.

Bananas are rich in micronutrients such as vitamin A (carotene), vitamin B (thiamine, riboflavin, niacin, B6), vitamin C (ascorbic acid) and phosphorus (Aurore et al., 2009). According to Englberger et al. (2003), Musa spp. are rich in pro-vitamin A (carotenoid) that important in protecting against infection and providing a good vision and eye health. Davey et al. (2009) mentioned that banana consist of high variability in provitamin A of various types however, it has low iron and zinc content due to the type of soil and environmental conditions. Banana consists of high provitamin A and trace minerals able to boost the nutritional health among the banana-consuming populations. The pulp of banana consists of catecholamine at the different ripening level. Bananas also can be categorized as one of antioxidative food due to high amount of strong antioxidant,

dopamine with range of 2.5-10 mg per 100 g (Kanazawa & Sakakibara, 2000). Table 2.2 represents the nutritional value of banana and plantain at different stages of physiological.

Table 2.2 Nutritional value of banana and plantain at different stages of physiological, per 100 g of fresh weight.

Component	Unit	Sweet banana pulp				Plantain pulp	
		Ripe	Unripe	Dried	Flour	Unripe	Ripe
Energy	g	89.0	110.0	257.0	340.0	91.0	122.0
Water	g	74.0	69.0	28.0	3.0	63.0	65.0
Protein	g	1.1	1.4	3.0	3.9	0.8	1.3
Total lipid	g	0.3	0.2	1.0	1.8	0.1	0.4
Carbohydrate	g	21.8	28.7	63.0	82.1	24.3	32.0
Dietary fiber	g	2.0	0.5	5.5	7.6	5.4	2.1-3.4
Na	mg	1.2	-	8.0	3.0		4.0
K	mg	385.0	-	1150.0	1491.0		500.0
Ca	mg	8.0	8.0	20.0	22.0	7.0	3.0
Mg	mg	30.0	-	90.0	108.0	33.0	35.0
Protein	mg	22.0	-	75.0	74.0	35.0	30.0
Fe	mg	0.42	0.9	1.3	1.15	0.5	0.6
Cu	mg	0.11	-	0.4	0.39	0.2	-
Zn	mg	0.18	-	0.5	0.61	0.1	-
Mn	mg	0.2	-	-	0.57	15.0	-
Vitamin E	mg	0.29	-	0.6	-	-	-
Vitamin C	mg	11.7	31.0	4.0	-	20.0	20.0
Thiamin	mg	0.04	0.04	0.1	0.18	0.1	0.08
Riboflavin	mg	0.07	0.02	0.18	0.24	0.1	0.04
Niacin	mg	0.61	0.6	2.0	2.8	0.7	0.6
Vitamin B6	mg	0.47	-	-	-	-	-
Dopamine	mg	65.0	-	-	-	-	-

Source: Adapted from Aurore et al., 2009

2.2.2 Banana Peel

Along with the fast-economy growth, Malaysia produced many types of banana that not only consumed directly but also used in some food industrial processing such as the production of fruit juice and the flavoring (Padam et al., 2014). The peels of banana are a food waste generated by the food industrial area in large quantities in the world (Sagar et al., 2018). Research has been done in 30% from banana pulp is peels which can cause a tough environmental issue because of a large amount of nitrogen and phosphorus and its high-water content (González-Montelongo, 2010). The municipal solid waste (MSW), as well as by-product fruit, should be reduced to overcome the environmental hazard problem (Lohchab, 2018). Therefore, the amount of fruit waste especially peels need to be reduced by full usage in the food sector. Some researchers have reported that banana waste (peels) have abundant of active compounds and nutrients that are important in the food industry application for human health. (Happi Emaga et al., 2007a; Padam et al., 2014).

2.2.3 Nutritional of Banana Peel

Banana peel is the outer part of banana that protects its inner flesh. It always been discharged and leftover as a waste product for the banana-based product in the industries (Ibrahim et al., 2017). The peel of banana which known as a waste of banana production is discarded without any purposes and usually be classified as the solid waste at large expense (Padam et al., 2014). Hence, some researchers have conducted food innovation research for years to investigate the useful application for banana peel in order to solve

some diseases (Khoozani et al., 2019). Some studies have been carried out in the purpose of finding the nutrition content in banana skins (Anhwange et al., 2009).

According to Anhwange et al. (2009), the peel of banana is a good source of nutrients due to high value obtained from the determination of lipids, carbohydrates and fiber. Some studies have been done by represents that banana skin had higher total dietary fiber, fat, ash content, but lower starch and protein content (Mosa & Kahlil, 2015; Wachirasiri et al., 2009). The higher dietary fiber content of banana byproduct is also have been researched by Giri et al. (2016). Moreover, Nagarajaiah and Prakash (2011) stated that banana peel consists of antioxidant compounds such as carotenoids, catecholamines, polyphenols and high amounts of micronutrients were established in the peel of genus *Musa*. Table 2.3 shows the nutrient composition content of banana peel and Table 2.4 shows the mineral composition of banana peel.

Table 2.3 Nutrient composition of banana peels.

Nutrient composition	Content (g/100g)
Protein	8.6 ± 0.1
Fat	13.1 ± 0.2
Starch	12.78 ± 0.9
Ash	15.25 ± 0.1
Total dietary fiber	50.25 ± 0.2

Sources: Adapted by Wachirasiri et al. (2009)

Table 2.4 Minerals composition of banana peel.

Mineral composition	Concentration (mg/g)
Potassium	78.1
Calcium	19.2
Sodium	24.3
Iron	0.61
Manganese	76.2
Bromine	0.04
Rubidium	0.21
Strontium	0.03
Zirconium	0.02
Niobium	0.02

Sources: Adapted from Anhwange et al. (2009)

2.2.4 Chemical Composition of fresh banana peels and dried banana peels

González-Montelongo et al. (2010) mentioned that banana skin has high amount of dietary fiber, 50% on a dry matter (DW) basis and high in phytochemical compounds, mainly antioxidant. The banana peel contains phenolic compounds which range 0.90 to 0.30 g/ 100 g DW. Research investigated by Phatcharaporn et al. (2010) claims that banana peel has high fiber content (46.63%). Referring to Table 2.6, it shows the chemical composition of fresh banana peels and dried banana peels for ash, fat, protein, carbohydrates, moistures and total dietary fiber. Mosa & Khalil (2015) stated by had higher fat, ash and total dietary fiber in both fresh and dried of banana peels, but lower starch and protein content due to differences in the factor of cultivars or geographical. In contrast, Marin et al. (2007) reported that banana skins have a lower total dietary fiber content than fiber gained from different types of fruit production by-products (60–78 g/100 g dry matter). Table 2.5 represents the comparison of chemical composition between fresh banana peels and dried banana peels.

Table 2.5 Chemical composition of banana peels.

Chemical composition (g)/100g	Banana peels (mean ± SD)	
	Fresh	Dried
Protein	10.04 ± 0.04	7.25 ± 0.37
Fat	5.32 ± 0.72	4.81 ± 0.94
Carbohydrates	54.01 ± 1.03	79.87 ± 0.26
Moistures	21.96 ± 0.25	6.73 ± 1.05
Ash	8.23 ± 0.04	1.34 ± 1.05
Total dietary fiber	50.25 ± 0.04	44.28 ± 0.04

Sources: Adapted from Mosa & Khalil (2015)

2.2.5 The Effect of Banana Peel Intake in Human Body

Skin of banana can be able to consume as a natural source of antioxidants due to the classification as non-toxic to normal human cells (Lee et al., 2010). It is rich in phenolic compounds which, prevent heart illnesses and cancer (Someya *et al*., 2002). Some studies mentioned that banana peels promote the beneficial health which, treats the cardiac disease, diarrhea, diabetes, dysentery, gout, hypertension, intestinal lesion, ulcerative colitis and nephritis (Emaga et al., 2007; Emaga et al., 2008; Iman and Akter et al., 2011). Peel of banana also have high concentration of manganese with value 54.73 mg/kg which aids in the cartilage and skeletal formation (Eshak, 2016). The deficiency of manganese is very rare in human however, it could affect the formation of cartilage and skeletal, glucose tolerance and normal reproductive (Smith et al., 1996). Banana peels consist of more dopamine than banana pulp which, triggers hormones in glycogen metabolism. Dopamine plays a major role in the prevention of depression (González-Montelongo et al., 2010; Kanazawa & Sakakibara, 2000).

According to Anhwange et al. (2009), the highest amount of mineral content in banana peel contributed by potassium which, aids in order to regulate fluids of body and retain normal blood pressure. It also helps to control the kidney failure, heart oddities and respiratory flaw (Padam et al., 2014). Besides, banana peels also have a high content of manganese that promotes the formation of skeletal and cartilage (Eshak, 2016). The high amount of fiber in banana peel could help in treating constipation and improving general health (Anhwange et al., 2009).

2.3 Dietary Fiber

Dietary fiber is the indigestible carbohydrate polymers that derived from plants that incapable to be hydrolyzed by digestive enzymes of human (Yang et al., 2017). It has many different functions and activities when passing through the gastrointestinal tract (Prosky, 1999). Naturally occurring dietary fiber can be categorized into two groups; insoluble dietary fiber (IDF) such as cellulose, hemicellulose, lignin and soluble dietary fiber (SDF) such as pectin, gums, inulin, mucilage and other non-starch polysaccharides (Papathanasopoulos & Camilleri, 2010; Yang et al., 2017). Dietary fibers are the important components of the plant cells such as beans grains, fruits and vegetables (Dhingra et al., 2012). Differences of different types of dietary fiber generally exist in the branching, degree of polymerization, monosaccharide composition, and glycosidic bond (Esteban et al., 2017). Dietary fiber contains high molecular weight of polysaccharides which, cellulose is consist of more than hundreds of β (1→4) linked d-glucose monomer units (Mudgil, 2017). Soluble dietary fiber (well-fermented fibers) is fermented within the colon and bioactive by-products that able to act as rheology modifiers and prebiotics (Anderson et al., 2009). Insoluble dietary fiber (less fermented fibers) is metabolically

inert which, absorbing water through the digestive system to ease defecation and prevent constipation (Anderson et al., 2009). Besides, dietary fiber of fruits and vegetable can act as a carrier of bioactive compound which carry significant amounts of polyphenols and carotenoids related with the fiber matrix through the gastrointestinal tract in human body (Saura-Calixto et al., 2007).

2.3.1 Importance of Dietary Fiber in Human Body

Dietary fiber has a vital role in the prevention of a few diseases, mainly in the gastrointestinal tract from ingestion to excretion in the human gut (Palafox-Carlos et al., 2011). It is primarily important for bulking fecal matter, increasing viscosity, increasing transit time and producing short-chain fatty acids (Lattimer & Haub, 2010). These compounds cannot be hydrolyzed by the enzymes in the large intestines, is fermented by microbiota in the large bowel (Williams et al., 2017). It gives the different positive effects on health, for example, improved intestinal function, increased microbial biomass and cholesterol reduction (Dikeman et al., 2006) .

Next, dietary fiber involved in the lowering of the risk of obesity and type-2 diabetes. It plays an important role in glycemic control. Higher fiber intake has a lower glycemic index (Fujii et al., 2013). They release glucose slowly into the blood due to its ability to decrease the intestinal transport of glucose, therefore helping to reduce the risk of type 2 diabetes associated with increased insulin sensitivity (Krawecka et al., 2019) . Also, the high viscosity of soluble fiber solution in the gastrointestinal tract can trap nutrients and delay gastric emptying and therefore subsequently decreased energy intake (Capuano, 2017). While, insoluble fiber can control weight and satiety because of increased

hormone secretion (Dikeman et al., 2006). Parillo & Riccardi (2004) found that the short-chain fatty acids during fermentation of dietary fiber in the gastrointestinal tract may able to slow a hunger response and promote satiety. Thus, dietary fiber can lower the risk of diabetes and obesity by improving insulin sensitivity and glucose regulation (Krawęcka et al., 2019).

Besides, obesity and diabetes are two of the most risk contributors to heart disease (Goran et al., 2003). Slavin (2008) mentioned that an adequate amount of fiber can consistently lower the risk of coronary heart disease (CHD) and cardiovascular heart disease (CVD). It is caused by a reduction in low-density lipoprotein (LDL) levels. Soluble fiber, for example, beta-glucan, psyllium, pectin and guar gum were most effective in lowering serum LDL cholesterol concentration, without influencing high-density lipoprotein (HDL) concentrations (Chawla & Patil, 2010). Moreover, Wirstrom et al. (2013) also stated that fiber intake also can reduce the risk of other risk factors for CHD, like insulin resistance, inflammation, dyslipidemia and oxidative stress.

2.3.2 Banana Peel Fiber

Banana peels are one of the important sources for soluble and insoluble fiber which are lignin, pectin, cellulose, hemicellulose and galacturonic acid (Emaga et al., 2008). The amount of dietary fiber in banana peels is influenced by the stage of ripeness (Ramli et al., 2010). According to Happi Emaga et al. (2007), the maturation of banana was reported to affect the composition of dietary fiber in banana peels. Based on their studies, the banana peel contains higher total dietary fiber and insoluble dietary fiber compared with the plantain peel. For the maturation for all stages, the pectin content of banana skins

is higher than plantain skins (Emaga et al., 2008). Additionally, the galacturonic acid and methoxy group content of plantains peels are lower compared to banana peels. However, plantain peels consist of a higher amount of lignin while had less hemicellulose content than banana peels (Emaga et al., 2008).

2.3.3 Extraction of Dietary Fiber

Extraction of dietary fiber is a separation process into their constituents for isolation of desired and elimination of unwanted compounds (Maphosa & Jideani, 2016). According to Daou and Zhang (2012), fiber can be extracted either as a whole, referred to total fiber, or soluble or insoluble fiber or as its components. The common methods in the extraction of fiber from plant sources are drying process, wet process, chemical, gravimetric, enzymatic, microbial, physical or a mixture of these methods (Yang et al., 2017). There is continuing research on developing methods to extract total, soluble, insoluble and individual fiber constituents. Soluble fiber can be extracted using hot water coupled with EDTA for solubilization of pectin and binding of a cation. The gravimetric method was applied to isolate dietary fiber such as pectin, hemicelluloses and cellulose using water, 80% of ethanol and sodium chloride (NaCl) (Wen et al., 2006). Besides, the chemical-enzymatic and water extractions also were utilized to extract lignin, cellulose and hemicelluloses (Bangoura *et al.*, 2011; Elleuch et al., 2011). Research by Rodriguez at al. (2006) who mentioned that the enzymatic-gravimetric method is closely related to dietary fiber analytical methods. According to Prosky et al. (1985) who developed the enzymatic-gravimetric method, the enzymes are used to eliminate starch and protein, followed by use of ethanol to precipitate the soluble fiber concentrate.

2.4 Jelly

Jelly is a form of gels which is in the middle between a solid and liquid. The gel formation is caused by the transition of sol (liquid) to gel (solid) that require gelling agents in order to reach the desired jellies (Saha & Bhattacharya, 2010). The formation of gels defined as a spontaneous process of a simple polymer dispersion under controllable condition, depending on the temperature or solution composition (Banerjee & Bhattacharya, 2012). It comprised of the aggregation of particles or macromolecules that generate a network holding the whole container volume. The gelling agents are required to provide the texture during the formation of gels (Banerjee & Bhattacharya, 2012). Pectin is one of the gelling agents derived from plants, utilized to thicken and stabilize the various food such as jellies, candies and desserts (Saha & Bhattacharya, 2010). The pectin characteristics for gelling process strongly rely on the degree of esterification (Banerjee & Bhattacharya, 2012). According to Kastner et al. (2017), high methoxyl pectin can form a gel only in the addition of sugar or other co-solutes.

2.4.1 Jelly from fruit waste/ banana waste

Pectin is a soluble dietary fiber that has the capability to form gels under specific conditions (Vanitha & Khan, 2019). It can replace any gel additives in the jelly for production of health-care food (Happi Emaga et al., 2007; Lee et al., 2010). Mohd Rasidek et al. (2016) showed that the formulation of peel jelly was produced from banana peel with the presence of sugar and citric acid. They mentioned that banana peel can act as a new base in making a new peel jellies product for its nutritional value. This peel jelly has great potential to act as a functional food due to higher phenolic content and

scavenging activities (Lee et al., 2010). The antioxidant activities of the banana peel are maintained after the heating process during the production of jelly (Amini Khoozani et al., 2019). Besides, produced jellies have high levels of chewiness and springiness after incorporation of supplementary banana peel powder (Lee et al., 2010).

CHAPTER 3

MATERIALS AND METHODS

3.1 Sample Collection and Preparation

Musa acuminata × *Musa balbisiana* cv 'awak' peels at the colour index of 3 (yellowish) were purchased from local supermarkets in Gelugor, Penang, Malaysia during late February and early March 2020. The samples were chosen based on the physical appearance to ensure the minimal bruises and scars on the peel. They were kept at ambient temperature before peeling. Other ingredients and materials such as sugar (MSM Sdn. Bhd.) and jelly powder were purchased from Tesco Extra hypermarket (Penang, Malaysia).

Figure 3.1: 'Pisang Awak' at stages 3 of ripening

3.1.1 Enzymes and Chemical Reagents

All reagents and chemicals used were of analytical grade as shown in Table 3.1. The chemical and reagents used in this project were kept according to the right conditions and utilized by following the instructions stated on the container. The enzymes used were shown in Table 3.2 and kept under the right conditions and used by according to the instructions stated on the container.

Table 3.1: List of chemical and reagent used.

Reagent	Manufacturer
Acetone	Fisher Scientific (U.K)
Boric acid	R & M Chemicals (U.K)
di-sodium hydrogen phosphate	ChemAR
Sodium dihydrogen phosphate anhydrous	QRec (Germany)
Ethanol (95% and 78%)	HmbG Chemical
Hexane	Merck (Germany)
Hydrochloric acid (37%)	Qrec (Germany)
Micro-Kjeldahl tablet	Merck (Germany)
Sodium hydroxide pellets	QRec (Selangor)

Table 3.2: List of enzymes used.

Enzyme	Manufacturer
Alpha-amylase from Bacillus licheniformis	Sigma Aldrich
Amyloglucosidase from Aspergillus niger	Sigma Aldrich
Protease from Bacillus licheniformis	Sigma Aldrich

3.1.2 Instruments

The instruments used in this final year project as represented in Table 3.3 were conducted by following the instructions stated on the machine. The proper procedure was applied in order to ensure the accuracy of the result.

Table 3.3: List of instruments used.

Instrument	Manufacturer
Freeze Dry Machine	Millrock (New York)
Heating Digester	VELP Scientific (Italy)
Tabletop Centrifuge	Kubota (Japan)
Texture analyzer	Stable Micro Systems, Surrey (UK)
UDK 127 Kjeldahl Distillation unit	Gerhardt (UK)
Ultra-Centrifugal Mill ZM 200	Retsch GmbH (Germany)
Water Bath	Memmert (Germany)

3.2 Samples Extraction

3.2.1 Banana Peel Powder

Banana peels were cleaned and washed using running water, then dried in the freeze dryer for 48 hours. The fully dried peels were grounded by using a hammer mill in 1.5 mm mesh size.

Figure 3.2: Banana peel powder after drying in the freeze dryer.

3.2.2 Extraction of Dietary Fiber from Banana Peel Powder

Dietary extraction was done by using the enzymatic-gravimetric method by Yoshimoto *et al.* (2005) with slight modification from Wachirasiri *et al*. (2009). The powdered banana peels were deffated using hexane as a solvent with 1:3 ratio. The residue was dried overnight under a fume hood to completely remove the solvent. The deffated banana peel powder was mixed with water (1: 20 w/v ratio). Next, the pH of solution was adjusted to 5.8 by addition of 1 N HCl solution. An alpha amylase was added (0.1 ml/ g sample) and incubated at 95°C for 30 mins. The solution was cooled down to 60°C and continued adjusting the pH to 7.5 by adding 1 N NaOH. Protease was then added (10 mg/ g sample) and incubated for 30 min at 60°C. After that, the pH was

adjusted to 4.5 by using 1 NHCI solution before addition of an amyloglucosidase solution (0.1 mg/g sample) and incubated at 60°C for 30 min. Then, the mixture was filtered through Whatman No.4 filter paper and dried in the hot air oven at 50°C for 12 hrs. The dried samples were turned into powder.

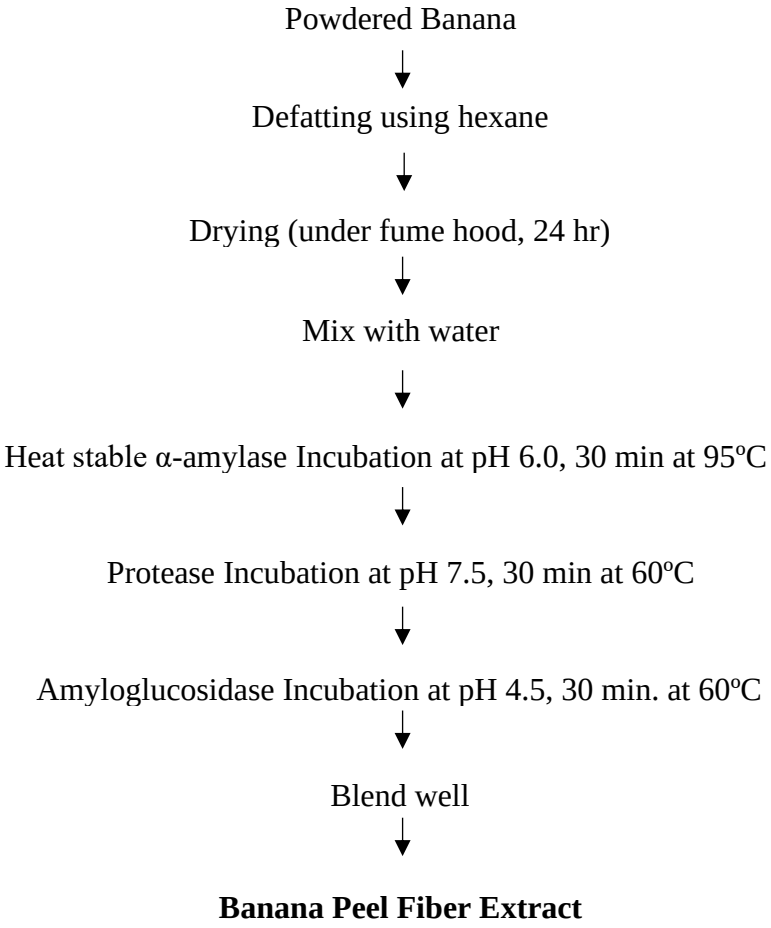

Figure 3.3: Flow chart for the banana peel fiber extraction.

3.3 Banana Peel Jelly Processing

The formulation of jelly at the concentration of 5% and 10% were prepared based on the formulation and method adapted from Mohd Rasidek et al. (2016) with slight modification. Prepared banana peel fiber powder was boiled for 5 min. Then, accurately 20 g of sugar was added and the mixture was stirred completely and cooked for 5 min until reaching the gelling temperature (80 °C). After the cooking process within 5 min, 0.5% of jelly powder was added to the mixture and continued stirring. The mixture was heated again at temperature 80ºC until achieving the desired consistency. The jelly consistency for 60 ºBrix value was measured by using a digital handled refractometer. After that, the dispersion mixture was poured into a cup to cool down at room temperature. Figure 3.4 showed the fiber-added jelly with different percentages of banana peel fiber extract.

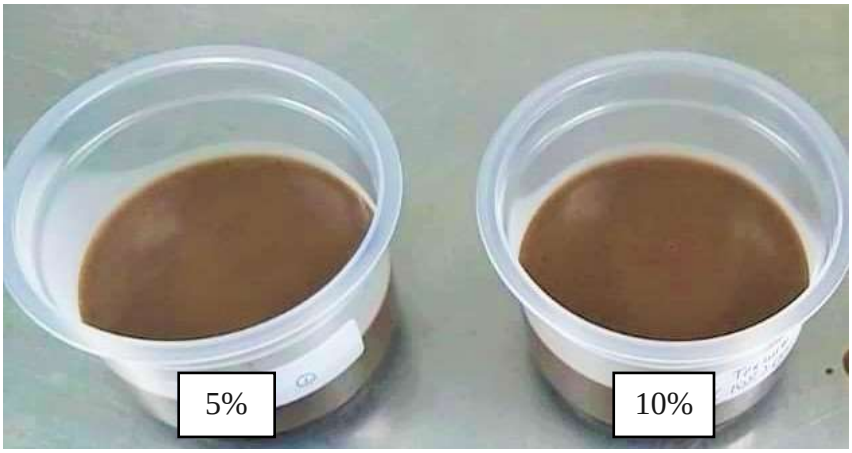

Figure 3.4: The formulation of jelly with 5% and 10% of banana peel fiber extract.

3.4 Analysis of Banana Peel Fiber Jelly

3.4.1 Determination of Total Dietary Fiber of Fiber-added Jelly

The determination of total dietary fiber in banana peel fiber jelly was conducted using Enzymatic-Gravimetric method as described by Prosky et al. (1985) with slight modification as shown in Figure 3.5. The ground sample (1 g) was suspended in 50 ml of pH 6.0 phosphate buffer with 0.1 ml alpha-amylase. Then, the sample was left at 100 °C for 30 min in a shaking bath. A thermometer was used to maintain the temperature of the water bath at 95-100 °C. The solution was cooled at room temperature and pH was adjusted to 7.5 with 0.275 M sodium hydroxide. Protease with 0.1 ml was added and the beaker was covered with Aluminium foil (Al foil) and incubated at 60 °C for 30 min with continuous agitation. Before the addition of amyloglucosidase (0.3 ml), pH of the solution was adjusted to 4.5 with 0.325 M hydrochloric acid. The beaker was covered with Al foil and incubated at 60 °C in the shaking water bath for another 30 min. Next, 280 ml of 95% ethanol as preheated to 60 °C was added. The precipitate was formed at room temperature for 60 min. The crucible containing Celite was weighed and then it was wetted and redistributed bed of Celite in the crucible by using stream of 78% ethyl alcohol from a wash bottle. Suction was applied to draw Celite onto the fritted glass as even mat. Suction was maintained and the precipitate was transferred from enzymes digest to the crucible. The residue was washed successively with three 20 ml portions of 78% ethanol, two 10 ml portions of 95% ethanol and followed by two 10 ml of acetone. Time of filtration and washing will different from 0.1 to 6 h averaging ½ h per sample. The crucible containing residue was dried overnight at 105 °C in an air oven. The crucible was cooled in a desiccator and weighed to obtain the residue weight. The residue from one of the

duplicates was analyzed for ash and the other for protein. Ash was determined by incineration at 525 °C in a muffle furnace while protein (N x 6.25) was determined by the Kjeldahl method. The total dietary fiber (TDF) was determined as the weight of residue less the weight of residual protein and ash.

Calculation:

%TDF= [(weight residue-P-A-B)/ average weight sample] × 100

Where,

P= average weight of protein

A= average weight of ash

B= blank

Equation 3.1

3.4.1a Protein and Ash Determination of Fiber-added Jelly

The residue from samples was analyzed for protein by Kjeldahl nitrogen analysis as stated in the (AOAC, 2000) method. First, 0.5 g of the sample was weighed onto the pre weigh filter paper and inserted inside the micro-Kjeldahl tube. Before the addition of 10 ml concentrated sulphuric acids, 1 tablet of catalyst was added into each of the digestion tubes. The samples were digested using a digestion block until light blue solution produced. The mixture was cooled down by the addition of a few drops of water into the tubes and left for the cooling process. Next, the digestion mixture was diluted with 20 ml distilled water and transferred to distillation unit with minimum water. The collecting Erlenmeyer flask containing 25 ml of 4% boric acid solution and addition of 5 drops of methyl red-methyl blue indicator were placed in the steam distillation unit. The distillation process was started by slowly adding 35 ml of 35% sodium hydroxide (NaOH)

by using the automatic dispensing device and the time for distillation was set at 3 min 30 sec. Next, the distillate with yellowish-green color was titrated by using 0.02 M hydrochloric acid. The pink or purple color appearance was used as an indicator to reach the endpoint. The volume of HCl used was recorded which was equivalent to the amount of ammonium ions present in the sample. The percentage of nitrogen was calculated using the formula:

$$\text{Percentage of nitrogen (\%)} = \frac{(\text{mL HCl sample} - \text{mL of HCl blank}) \times \text{molarities} \times 14 \times 100}{\text{mg of sample}}$$

Equation 3.2

Protein content = % nitrogen × conversion factor (6.25)

Equation 3.3

For ash determination, the residue in crucibles was placed in a muffle furnace. Temperature was adjusted to 525 °C and the samples were kept burning for 5 hours. The furnace was turned off and cooled to 100 °C. The crucibles were transferred into a desiccator and cooled down to room temperature. The dry weight of crucible with ash was weighed to the nearest 0.1 mg and recorded this weight as "Ash + celite + crucible weight". The ash content was calculated by using the formula below:

Ash content (g) = $W_f - W_b$

Where,

W_f = Weight of "Ash + Celite + Crucible" (g)

W_b = Weight of "Celite + Crucible" (g)

Equation 3.4

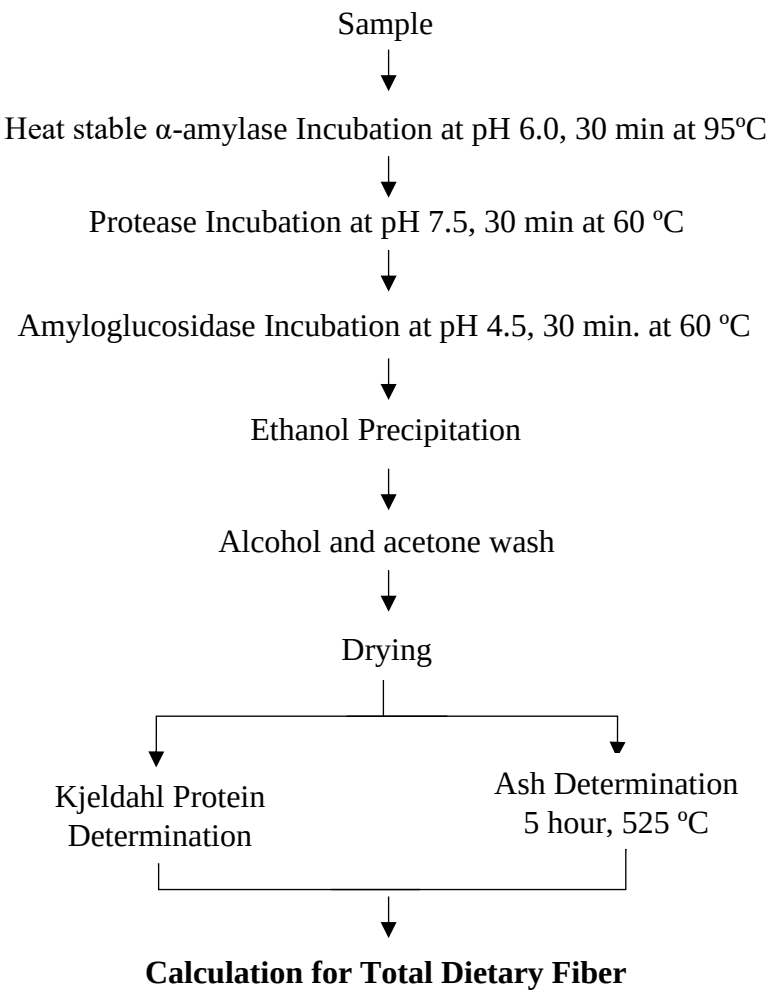

Figure 3.5: Analytical scheme of total dietary fiber.

3.4.2 Texture Determination of Fiber-added Jelly

Texture Profile Analysis (TPA) was an instrumental method used to evaluate the textural properties of the jelly as described by Yusof et al. (2019). Texture analyzer (TA-XT plus, Stable Micro Systems, Surrey, UK) was attached to a 5 kg load cell. The parameter of texture for jelly was measured using a cylindrical probe (P/1 DIA cylinder aluminium) with diameter 12 mm and 5 kg load cell. This test was conducted at room temperature. The hardness, adhesiveness, cohesiveness, gumminess and springiness of jelly were measured from reading on the force-time graph. Readings were done in triplicate. The TA setting for measuring the texture of jelly was according to Table 3.4.

Table 3.4: Texture analyzer setting

Pre-test speed	: 1.0 mm/s
Test speed	: 1.0 mm/s
Post-test speed	: 1.0 mm/s
Strain	: 50%
Trigger mode	: Auto
Tare mode	: Auto

3.4.3 Syneresis of Fiber-added Jelly

Syneresis, which occurred during gel storage was determined by keeping the banana peel fiber jelly at refrigerated temperature (4℃) for 24 hours, and 48 hours. The banana peel fiber jelly was placed in the sample cup to retain water, which was released from jelly during storage. Measurement was conducted by calculating the water loss of banana peel jelly weight (W_t) during storage divide by the initial weight (W_0) (Chan et al., 2013)

$$Syneresis = [(W_0 - W_t)/W_0] \times 100$$

Where,

W_0 = initial weight of jelly before storage (g),

W_t = weight of jelly after storage (g)

Equation 3.5

3.5 Statistical Analysis

The findings in this study were reported in the form of mean value ± standard deviation for duplicate determinations. The mean and standard deviation of parameters in this study for all analyses were expressed by analyzing variance (ANOVA) at 5% significance level ($p<0.05$), which means the statistical analysis conducted was 95% confident to be correct. The statistical analysis was performed using IBM SPSS version 24.0 for Windows statistical software.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Total Dietary Fiber of Fiber-added Jelly

The statistical results of total dietary fiber contents for the jelly with difference formulations containing different concentration of banana peel fiber (5% and 10%) were showed in Table 4.1. TDF values of jelly with the amount of dietary fiber extract (5%) was significantly ($p<0.05$) different from a sample at concentration of dietary fiber extract (10%). It can be observed that the value of TDF increased significantly ($p<0.05$) with the increase concentration of banana peel fiber added. The contents of TDF in jelly with 10% banana peel fiber extract (7.98 g/100 g) was approximately two-fold to the TDF value obtained in jelly containing 5% banana peel fiber extract.

In Table 4.1, the formulation using 10% fiber extract from banana peel was indicated the higher value of TDF compared with other formulation. The result for formulations with 5% and 10% of banana peel fiber extract was 4.15% ± 0.56 and 7.98% ± 1.07 respectively. It was shown that the higher amount of dietary fiber extracted from the banana peel, the higher the TDF values in jelly as determined by using enzymatic gravimetric method. Dietary fiber from the banana peel that incorporated in jelly can increase the dietary fiber content of food production due to DF content inside the banana peel. This result was in line with findings of Figueroa and Genovese (2018) whereby the total dietary fiber in food product will increase after addition of dietary fiber and Giri et al (2016) also mentioned that the by-product of banana consists of high amount of dietary fiber content. Additional, Wachiransiri et al. (2009) stated that the extraction of TDF

using the enzymatic gravimetric method can extract a higher amount of dietary fiber compared to the other methods such as the enzymatic-chemical method. It also may enhance the removal of a fraction of fat, starch and protein from the banana peel powder.

Table 4.1. Percentage of total dietary fiber (TDF) of jelly samples with different formulations by incorporation of different concentration of banana peel fiber.

Analyses	Concentration of banana peel fiber added in jelly (%)	Value (%)
TDF	5	4.15 ± 0.56^{a}
	10	7.98 ± 1.07^{b}

Each value is expressed as mean value ± standard deviation (n=2). For each row, values followed by different superscripts letter, are significantly difference at ($p<0.05$)

*TDF, Total dietary fiber.

It was reported that fruit jelly usually has dietary fiber contents of about 3% with could be claimed as "source of fiber" (Figueroa & Genovese, 2018). While in this study, the incorporation of banana peel fiber in the jelly can increase the amount of dietary fiber content up to 8%. Therefore, the jelly with 10% of banana peel fiber could be considered as "high dietary fiber" when this jelly contains 8 g of fiber per 100 g which exceeds the value mentioned in Fifth A Schedule (Regulation 18c), Food Regulation 1985. It showed that the incorporation of banana peel fiber in jelly helps to produce jelly with a high amount of dietary fiber for daily consumption to prevent a few diseases, mainly in the gastrointestinal tract. This may due to higher dietary fiber content in the banana peel compared to the other fruit wastes. Wachiransiri et al. (2009) quoted a statement by Figuerola et al. (2005) that the banana peel fiber concentrate consists of 83-89% of TDF as higher than fiber produced from other sources of fruit industrial by-products such as

the dietary fiber content in the lemon peel fiber is about 66-70.4% as researched by Ubando-Rivera et al (2005).

As shown in Table 4.1, the TDF of banana peel fiber jellies were successfully obtained via the mentioned method previously. These results were approximately similar with the TDF value of banana peel jelly which is reported by Lee et al. (2010) whereby they directly incorporated banana peel powder in the jelly without any fiber extraction process. Hence, it needs a higher amount of banana peel powder compared to the banana peel fiber powder utilized in this research. Besides, the health organizations advise for incorporating abundant dietary fiber in the formulation of food product as reported by Fleming (2002) in an article written by Lee at al. (2010). Therefore, banana peel fiber powder may be regarded as an alternative source of dietary fiber in the development of functional food products, simultaneously reduce the amount of banana waste from food industrial.

By simple investigation of results, there may be few factors that influenced the TDF content in the jelly and interfere with the result showed. For example, the heating treatments used during the preparation of banana peel fiber and preparation of fiber-added jelly such as grinding and boiling. It was supported by Guillon and Champ (2000) in an article written by Dhingra et al. (2012), different treatments of processing such as enzymatic, mechanical (grinding) and thermal (boiling) will influence the physio-chemical properties of dietary fiber. It leads to a decrease of few components of the fiber-like diminishes the amount of fiber in the sample (Staffolo, Bevilacqua, Rodríguez, & Albertengo, 2012). The change in the structure of dietary fiber is due to the combination of mechanical and thermal energy as fibers may hydrates more rapidly during grinding

while the total dietary fiber value can increase when undergoes thermal treatment (Dhingra et al., 2012).

Overall, the addition of dietary fiber to the food product must involve in an adequate manner as food ingredients to achieve the acceptable level. Banana peel can play an essential role in enhancing the fiber content in the food product. Dietary fiber from banana peel that incorporated in food systems can give a multitude of functional properties to modify the nutrition of food product (Padam et al., 2014; Wachirasiri et al., 2019). Research by Ramli et al. (2009) stated that the banana peel which contains a high content of dietary fiber is added as partial substitution of wheat flour to produce yellow noodles. Similar with Sodchit et al. (2014), Eshak (2016) and Turker et al. (2016) also utilizes the peel of a banana to develop the nutritious and functional baked goods. It is because of good sources of dietary fiber from banana skin. In the other study, the high-fiber biscuit is being produced by using banana peel flour which derived from the *Musa acuminata Colla x balbisiana cv.Saba.* The development of this product is performed by the knowledge on the importance and benefits of fiber content inside the banana peel. (Yasin et al., 2017)

4.2 Texture Analysis of Fiber-added Jelly

Table 4.2 shows the mechanical parameters observed from the force-time curves. Based on statistical analysis in this study, it was found that the concentration of banana peel fiber had a significant effect on the texture properties of the jelly. An increase the fiber content caused a significant difference ($p<0.05$) in hardness, adhesiveness, cohesiveness, springiness and chewiness except for the other parameter which is gumminess was not significantly affected ($p>0.05$). The textural parameters are represented in Table 4.2.

In this study, the hardness of the jelly prepared with 5% and 10% of banana peel fiber extract was 11.62 N ± 0.58 and 12.78 N ± 0.18 respectively. Results showed that the formulation of jelly using a high concentration of banana peel fiber extract caused a higher force value compared to the jelly produced from 5% banana peel fiber extract. This indicated that the maximum force of the jelly was influenced by the concentration of banana peel fiber extract. It has similarities with the research done by Lee et al. (2010) which stated that the hardness of jelly increased significantly with the increasing amount of banana peel fiber added to the jelly. Mehta et al. (2015) also illustrated that the increase in the incorporation of dietary fiber is directly proportional to the increased hardness of the finished product. In contrast, the addition of fiber did not have a significant effect on the hardness of jelly (Figueroa & Genovese, 2018) . Based on the research conducted by Delgado & Banon (2015), the hardness of the jelly is influenced by the moisture content as the texture of jelly changes from soft to hard when the moisture content decline. It is because of the water-binding capacity of dietary fiber. However, the amount of water in

both formulations is constant therefore, the hardness of jelly highly depends on the percentage of banana peel fiber used.

Based on the texture profile obtained from texture analyzer, adhesiveness indicated the work necessary to pull the probe away from the sample after the first compression (Garrido et al., 2015; Yusof et al., 2019). The adhesiveness of the 5% banana peel fiber jelly was 3.09 Ns^{-1} ± 1.13 while a value of 6.70 Ns^{-1} ± 0.10 was recorded for the jelly with 10% of banana peel fiber extract. It showed that adhesiveness of the jelly increased with increases in the concentration of banana peel fiber extract in the jelly. These values influenced by the surface properties related to the molecular structure of the jelly. The jellies with high value of hardness also have a high-scale adhesiveness (Mutlu et al., 2018).

Besides, the value of cohesiveness for the jelly sample with 5% and 10% fiber-added were 0.42 ± 0.01 and 0.34 ± 0.01 respectively. Opposite with hardness of jelly, the cohesiveness decreases with the increasing concentration of fiber added in the jelly. Means, even though the jelly has high hardness value, it can be chewed easily. This result similar to the statement stated by Garrido et al. (2015) that the value of cohesiveness in jelly was inversely proportional to the addition of fiber in jelly. Also, the higher cohesiveness value, the less brittle jelly will be. Besides, other studies have shown that the decrease cohesiveness of gels was due to the increasing hardness of gels (Figueroa & Genovese, 2018; Hurler et al., 2012).

From Table 4.2, the springiness of jelly was inversely proportional to the firmness of jelly which showed that the elasticity of jelly decreases with the increase of hardness value as stated by Kreungngern and Chaikham (2016). According to Khouryieh et al. (2005), the springiness of jelly candy was a range between 0.90 to 1.50. The result for the jelly with 5% of banana peel fiber was within the range (0.91 mm ± 0.03). However, the springiness value of jelly from 10% fiber-added was 0.72 mm ± 0.05 because it was firmer compared to the 5% fiber-added jelly. Due to the different concentration of fiber used in this study, both jellies showed different springiness results. This textural parameter is important to measure the amount of mastication energy needed to break down the gel structure in the mouth (Chandra & Shamasundar, 2015).

Next parameter, chewiness of the jelly was defined to determine the energy required for mastication of solid food until its ready to be swallowed. Previous studies from Mutlu et al. (2018) and Delgado and Bañón (2015) stated that the chewiness of a product directly proportional to the hardness. Table 4.2 illustrated that the chewiness of jelly with 5% banana peel fiber added was 3.14 N mm ± 0.35, which means 1.5 N mm lower than the chewiness of jelly with 10% fiber added. These studies were acceptable because 10% of fiber-added jelly had higher hardness and higher amount of dietary fiber added. It was supported by Lee et al. (2010) mentioned that the incorporation of banana peel powder will produce jelly with high level of chewiness. Also, Delgado and Bañón (2015) mentioned in their research regarding the value of chewiness can distinguish the elasticity of both jellies.

Table 4.2: Texture parameters of fiber-added jelly from different concentration of banana peel fiber.

Properties	Jelly with 5% fiber added	Jelly with 10% fiber added
Hardness (N)	11.62 ± 0.58^{a}	12.78 ± 0.18^{b}
Adhesiveness (Ns^{-1})	3.09 ± 1.13^{a}	6.70 ± 0.10^{b}
Cohesiveness	0.42 ± 0.01^{a}	0.34 ± 0.01^{b}
Springiness (mm)	0.91 ± 0.03^{a}	0.72 ± 0.05^{b}
Chewiness (N mm)	3.14 ± 0.35^{a}	4.61 ± 0.33^{b}
Gumminess (N)	4.38 ± 0.18^{a}	4.83 ± 0.22^{a}

Each value is expressed as mean value ± standard deviation (n=2). For each row, values followed by different superscripts letter, are significantly difference at ($p<0.05$)

In general, there are other factors will influence the texture of jellies such as the water content, concentration of sugar, other ingredients (Burey et al., 2009), cooking temperature and time (Royer at al., 2006). In this study, these conditions were fixed to avoid affecting the jelly formulation. Therefore, the texture of jelly influenced by the quantities of banana peel fiber added except the gumminess. According to Sila et al. (2009), the high dietary fiber content leads to high cross-linking of the polymer and increase the rigidity of jelly due to the presence of pectin as gelling agent. Pectin is one of groups under the dietary fiber that can be found in the banana peel to set the jellies (Happi Emaga et al., 2008). Therefore, the presence of banana peel fiber extract had a significant effect on the textural characteristics of jelly except for gumminess. Overall, the hardness, adhesiveness, gumminess and chewiness of jelly have been recognized as the attributes which best describes the quality of banana peel fiber jelly.

4.3 Syneresis of Fiber-added Jelly

Based on this study, the statistical results of syneresis values for banana peel fiber jelly from different formulations and different storage duration were presented in Table 4.3. Fiber-added jelly made with either 5% or 10% banana peel fiber extract had significant differences ($p<0.05$) in syneresis values for both of refrigerated storage time. Increasing the amount of banana peel fiber produced and extending storage time had a significant difference in the syneresis of the jelly. It represented that the amount of water loss from jelly depends on the concentration of banana peel fiber added and time of storage.

From Table 4.3, it was found that syneresis in jelly with 5% and 10% of banana peel fiber extract after 24 hours were 9.01% ± 0.27 and 4.47% ± 0.59 respectively, while increased to 13.31% ± 0.60 and 6.46% ± 0.30 respectively, after refrigerated storage of 48 hours. It showed that the longer time of storage, the higher amount of water loss from jelly. By comparing the different concentration of fiber-added in the jelly, it indicated that high concentration of banana peel fiber added can reduce the amount of water loss from the jelly. It was because of the addition of banana peel fiber in jelly helps to increase the gel strength and improve the texture of jelly. Besides, the incorporation of dietary fiber caused a decrease in syneresis of jelly may be related to the interference effect of fiber in the gel due to high water holding capacity of the fiber (García-Pérez et al., 2006). The result of syneresis of jelly by using fiber extract in this study was matched the statement by Figueroa & Genovese (2018) which stated that fiber-added can reduce the gel syneresis due to its high water holding capacity (WHC).

Table 4.3: Syneresis of banana peel fiber jelly with different concentration of banana peel fiber added and refrigerated storage of time.

Analysis	Concentration of banana peel fiber	Time	
		24 hours	48 hours
Syneresis (%)	5%	9.01 ± 0.27^{aA}	13.31 ± 0.60^{bB}
	10%	4.47 ± 0.59^{bA}	6.46 ± 0.30^{aB}

Each value is expressed as mean value ± standard deviation (n=2). Means with different superscripts letter case (a-b) in same column, are significantly difference at ($p<0.05$). Means within the same row, with different superscripts letter case (A-B), are significantly difference at ($p<0.05$)

Syneresis or water loss is generally undesirable in the jelly product however, there are no references values for syneresis of gels nor legal limits for fruit jelly. Based on the results obtained in this study, a syneresis value as showed in Table 4.3 seems a very acceptable limit for fiber-added jelly except syneresis of jelly with 5% banana peel fiber added after keeping 48 hours. According to Figueroa and Genovese (2018), the limit of unacceptability for syneresis value in fiber-enriched pectin gels was greater than 10/100g or 10%. Theoretically, the incorporation of fiber extract in the jelly helps in the creation of desired texture due to pectin content (Bates et al., 2001). It produced only a small amount of syneresis after use of pectin from banana peel fiber extract in jelly. It can be concluded that the incorporation of fiber extract in jelly could either reduce or delay the degree of syneresis.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

The results illustrated that the incorporation of banana peel fiber extracts in the formulation of banana peel fiber jelly had significantly shown an impact on the total dietary fiber content, texture properties and syneresis of jelly. Based on the results of total dietary fiber analysis, it can be concluded that the concentration of banana peel fiber extracts added in the jelly from banana peel had significantly increased the total dietary fiber content of jelly. It was found that the addition of fiber from banana peel had influenced the total dietary fiber content in the jelly.

In texture analysis, the results showed the addition of banana peel fiber extract had a significant effect on the textural parameters of jelly which were hardness, cohesiveness, springiness and chewiness except for gumminess. In this study, the hardness, adhesiveness and chewiness of the jelly prepared with 10% banana peel fiber extract were higher compared to the jelly with 5% of banana peel fiber added due to their gel strength property. In contrast, springiness and cohesiveness of jelly were inversely proportional to the amount of fiber-added in the jelly. It can be concluded that jelly with 10% banana peel fiber added was preferable because the texture of jelly is more rigid. Based on the results of syneresis, both formulations of jelly lead to the loss of water after keeping at the refrigerated storage. Syneresis decreased with the increase of fiber extract in jelly, however, increased when extending the duration of storage. It can be concluded that jelly with 5% fiber extract showed a significantly higher amount of water loss compared with 10% fiber-added jelly for both times of refrigerated storage.

This study represented strong evidence to indicate that banana peels have high dietary fiber that can act as a functional food, simultaneously reduce the amount of banana waste from food industrial. However, further tests should be conducted such as human trials to prove the beneficial effects for the consumption of fiber-added jelly on human health. Moreover, the storage stability of banana peel fiber extract from banana peels needs to be tested in order to determine the shelf life of use for the functional food production at a big scale and commercial level. It should have an acceptable shelf life for safe consumption by the consumer. This research is an incomplete due to the Movement Control Order caused by **COVID-19** pandemic.

For further research, the process of banana peel fiber jelly also needs to be standardized in term of temperature of cooking, amount of ingredients used, type and ripening stages of banana peel extract and preparation ambient for reduction of the product variability and improvement of the consistency in both jellies. Besides, the total dietary fiber analysis on banana peel powder should be carried out in order to determine TDF content, specifically in 'Pisang Awak' peel. Moreover, a more efficient method such as Enzymatic-Gravimetric-Liquid Chromatography Method for the determination of total dietary fiber shall be conducted to obtain a highly accurate result.

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