



UNIVERSITI PUTRA MALAYSIA

***DETERMINATION OF PROXIMATE COMPOSITIONS AND
TOTAL SUGAR CONTENT OF SUGARCANE
(*Saccharum Officinarum* L.) PEEL AND BAGASSE***

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TOTAL SUGAR CONTENT OF SUGARCANE (*Saccharum
Officinarum L.*) PEEL AND BAGASSE**

**BY
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**A project submitted as a partial fulfilment of the requirement for the degree of
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Medicine and Health Sciences, Universiti Putra Malaysia**

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ABSTRACT

DETERMINATION OF PROXIMATE COMPOSITIONS AND TOTAL SUGAR CONTENT OF SUGARCANE (*Saccharum Officinarum* L.) PEEL AND BAGASSE

Siti Zulaikha Mazlan

Sugarcane (*Saccharum Officinarum* L.) is known as one of the major sources of sugar and mainly planted in subtropical and tropical area. The sugarcane wastes such as peel and bagasse provide wide range of benefits. Besides, they can be used as a potential supplement in food ingredients for their nutritional value. Although the nutritional composition of sugarcane bagasse can be found in the literature, little is known on the sugarcane peel. Hence, this study was conducted to determine and compare the proximate compositions and total sugar content of these sugarcane wastes. Sugarcane peel and bagasse were acquired from a sugarcane juice vendor in Kajang, Selangor. Then, they were washed, freeze-dried, homogenized and analysed for the nutrient contents. For the moisture content, oven-drying method was used (105°C; 36h) and dry ashing technique with a furnace was used to determine the ash content. Kjeldahl method and Soxhlet extraction method with petroleum ether were used to analyse protein and fat contents, respectively. The total dietary fibre (TDF) was determined based on the AOAC 985.29 method, and carbohydrate was calculated by difference. Lastly, total sugar was determined by using acid hydrolysis method. The protein content was significantly different ($p < 0.001$) between the samples, where its content in the peel ($1.23 \pm 0.00\%$) was significantly higher than in the bagasse ($0.88 \pm 0.00\%$). However, other nutrients and total sugar content were not significantly different ($p > 0.05$) between the peel and bagasse. Although not significant, both samples were found to have relatively high TDF (Peel= $63.22 \pm 2.27\%$) and (Bagasse= $63.10 \pm 0.76\%$). These findings indicated that the sugarcane's nutrient compositions are not much different by its part of the plant. Both sugarcane bagasse and peel are agro-industrial by-products that can be a good source of dietary fibre. Besides, they can be further explored as a potential source of nutraceuticals and functional foods.

ABSTRAK

PROKSIMAT ANALISIS DAN JUMLAH GULA DALAM KULIT DAN HAMPAS TEBU (*Saccharum Officinarum L.*)

Siti Zulaikha Mazlan

Tebu (*Saccharum Officinarum L.*) dikenali sebagai salah satu sumber utama gula dan terutamanya ditanam di kawasan subtropika dan tropika. Sisa tebu seperti kulit dan hampas mengandungi pelbagai manfaat. Selain itu, sisa-sisa ini boleh digunakan sebagai makanan tambahan dalam ramuan makanan untuk menambah nutrien. Walaupun komposisi nutrisi hampas tebu boleh didapati dalam kajian terdahulu, namun tiada kajian dilakukan terhadap kulit tebu. Oleh itu, kajian ini dijalankan untuk menentukan dan membandingkan komposisi-komposisi proksimat dan jumlah kandungan gula dari sisa-sisa tebu ini. Kulit tebu dan hampas diperoleh daripada vendor jus tebu di Kajang, Selangor. Kemudian, mereka dibasuh, dibeku dan dikeringkan, dihomogenkan dan dianalisis untuk kandungan nutrien. Untuk kandungan lembapan, kaedah pengeringan oven digunakan (105°C ; 36j) dan teknik pembakaran kering dengan relau digunakan untuk menentukan kandungan abu. Kaedah Kjeldahl dan kaedah pengekstrakan soxhlet dengan petroleum ether digunakan untuk menganalisis kandungan protein dan lemak. Jumlah serat pemakanan (TDF) ditentukan berdasarkan kaedah AOAC 985.29, dan karbohidrat dikira oleh perbezaan. Terakhir, jumlah gula ditentukan menggunakan kaedah hidrolisis asid. Kandungan protein adalah sangat berbeza ($p < 0.001$) antara sampel, di mana kandungannya dalam kulit ($1.23 \pm 0.00\%$) jauh lebih tinggi daripada hampas ($0.88 \pm 0.00\%$). Walau bagaimanapun, kandungan nutrien dan kandungan gula yang lain tidak banyak berbeza ($p > 0.05$) di antara kulit dan hampas. Walaupun tidak signifikan, kedua-dua sampel didapati mempunyai jumlah serat yang tinggi (Kulit = $63.22 \pm 2.27\%$) dan (Hampas = $63.10 \pm 0.76\%$). Penemuan ini menunjukkan bahawa komposisi nutrien tebu tidak banyak berbeza antara bahagian tumbuhannya. Kedua-dua kulit tebu dan hampasnya adalah produk sampingan agro-perindustrian yang boleh menjadi sumber serat makanan yang baik. Selain itu, mereka juga berpotensi sebagai sumber nutraseutikal dan makanan tambahan yang berkhasiat.

CHAPTER 1

INTRODUCTION

1.1 Background

Sugarcane is a large grass which is a member of genus *Saccharum*. There are a few numbers of species of sugarcane, such as *Saccharum officinarum*, *Saccharum robustum*, *Saccharum sinensis*, *Saccharum barberi* and *Saccharum spontaneum*. It is known as one of the major sources of sugar crops other than sugar beet, sugarcane is a perennial grass that is replanted at intervals using pieces of the cane stalks (Kaffka & Grantz, 2014). *Saccharum officinarum* or “noble cane” or yellow cane is the one that produces juice and is commonly found in Malaysia. The main product of sugarcane that is normally found in the country is its expressed juice from the stalk. In Malaysia, sugarcane juice is usually sold at small stalls as thirst reliever for people, especially during the hot day. After expression of the juice, the remaining peel and bagasse would be thrown away.

The Sugar Association (2015) reported that about 80% sugar production in the world came from sugarcane. Brazil is the country that produces the largest amount of sugarcane for whole world utilization, hence its economic growth is dependent on this crop. Not only for the cane sugar production, sugarcane in Brazil also plays a huge role in the production of ethanol fuel. There were more than 700 million tonnes of sugarcane produced by Brazil in 2010 and it was almost half of the world's sugar production (Hofsetz & Silva, 2012).

Apart from producing sugar for human consumption and ethanol fuel, sugarcane has also said to be a potential source of feed for cattle, especially in the subtropical and tropical areas. Some of the factors to be considered before feeding

the cattle with sugarcane are crop yield, nutritive quality (sugar and fibre contents) and ease of harvesting (Pate, Alvarez, Phillips, & Eiland, 2002). Moreover, the crop can withstand the hot-humid weather, diseases attack and maintain good quality as standing crop despite being grown in poorly fertilized soil.

The contents of sugarcane can be determined by conducting food analysis. The proximate analysis encompasses of determination of moisture, ash, protein, fat, fibre and carbohydrate content in the sample. Sugarcane peel and bagasse are the focus of analysis in this research. Sugarcane stalk is peeled off before it is expressed for the juice while the bagasse is obtained after the juice extraction. Appropriate analysis were conducted to determine the nutrient compositions of these two samples.

1.2 Problem statement

According to Agamuthu (2009), agricultural wastes include animal waste, food processing waste, crop waste and hazardous waste. Sugarcane peel and bagasse fall into the category of crop waste other than cornstalks, rice husks and fruits and vegetables culls. Agamuthu (2009) also reported that almost one billion tonnes of agricultural waste are produced globally in a year. In Malaysia, about 1.2 million tonnes of agricultural waste being disposed into landfills annually and it is estimated in the year 2025, an individual in Malaysia will produce 0.21 kg of agricultural waste daily (Agamuthu, 2009). In addition, the economic census conducted by the Department of Statistics Malaysia in the year 2015 reported that 29.6% (RM0.78 billion) of the environmental protection expenditure were spent on the waste management (DOSM, 2017). The statistics clearly shows that proper

management of waste must be taken into action to control the impact on environmental pollution.

Nevertheless, agricultural wastes provide wide range of benefits. They can be utilized to make paper pulp (Agamuthu, 2009), producing bioethanol (Sarkar, Ghosh, Bannerjee, & Aikat, 2012) and removing heavy metal (Foo, Tee, Raimy, Hassell, & Lee, 2012). Moreover, sugarcane bagasse has been reported to reduce the fertilizer's cost, improve soil properties and enhance productivity of sugarcane crop itself (Dotaniya et al., 2016). Even though there are many studies reported about the utilization of agricultural waste, there are limited studies found on the usage of sugarcane peel and bagasse as ingredient in the food production. While it potentially can sustain food sources for world population in the future, the utilization of sugarcane peel and bagasse can also reduce the amount of disposed waste on the landfill. Therefore, research on their nutritional value is required to accomplish the missions.

Sugarcane might not become the main interest for researchers because there are no data available on literature for the past five years on its nutrient composition. There was a local study conducted by Leang and Saw (2011) on proximate compositions of sugarcane bagasse. Based on the study, sugarcane nutritional value differ by the origin of the sugarcane itself, the weather and species. Since the study was conducted in 2011, there are no latest and current information on the Malaysian's sugarcane in this past few years. More comparable study is preferred to occupy demand on the latest data of sugarcane's proximate composition. Moreover, literature search has been done on research on sugarcane peel but there is none of it. Most of the studies on sugarcane focused on either its juice or bagasse.

In this study, interest is put on sugarcane peel and bagasse. The different parts of this crop might compose of different values of nutrient content which can be utilized in food production. So, it strengthens more the need to conduct nutrient analysis of this part of sugarcane. There are a few studies on the benefits of the peel of fruits such as pomegranate and citrus fruits. According to Ismail, Sestili, & Akhtar (2012), pomegranate peel and its extract are widely used in various cultures across the world. In the Egyptian culture, the pomegranate peel extracts are used to heal inflammation, intestinal worms, cough and infertility. Meanwhile, the use of pomegranate peel in Indian culture are commonly known to treat diarrhoea, nose bleeding, ulcers, sore throat and bleeding gums. All the benefits are mainly due to its antioxidant properties of the pomegranate peel. Nevertheless, it shows that the waste from fruits can also be used to bring beneficial impacts for the health. Other than that, a study conducted by Chao, Chang, & Nieva (2014) on the biosorption of heavy metals found out that the orange peel, passion fruit shell and sugarcane bagasse can be used to adsorb heavy metals from wastewater. They are the cheaper option to help with the treatment of wastewater. The studies proved that the wastes from the crops are reusable and more research should be done to discover further potential of the wastes. Hence, the aim of this study is to determine the proximate compositions and total reducing sugar content of sugarcane peel and bagasse.

1.3 Significance of the study

Malaysian food composition data contain a lot of common foods and beverages that we have in the country. Be it from raw to the cooked foods, the data on nutritional value is always available for the nutritionist, dietitian or food manufacturer to refer to. However, it is uncommon to see the nutrient compositions data on inedible parts of plant such as the seeds, peel and the waste. Sugarcane peel and bagasse are among of the examples of plant that may benefit consumer for their nutrient content. Therefore, further research on nutrient content of sugarcane peel and bagasse will add more information for the nutritionist, dietitian and also food manufacturer. Besides, there is not much study conducted on sugarcane especially sugarcane peel in Malaysia or overseas. Hence, more research using standardized analytic method is needed to add to the latest data about sugarcane waste compositions. This can help more future similar studies to get baseline data to be compared with.

While people are becoming more concern on consuming nutrient-dense foods, nutritious foods are receiving high demand from the consumers. Sugarcane which has relatively high content of fibre (Leang & Saw, 2011) might benefit the consumers, provided they are not having any gastrointestinal disorder. The reasons are dietary fibre provides satiety effect, helps to slow gastric emptying and prevent constipation (Anderson et al., 2009).

Moreover, new findings on the compositions of sugarcane peel and bagasse might add value to foods which brings a positive effect on health. For example, they can be the potential carbon source for probiotic in food and also providing food with higher content of dietary fibre (Sah, Vasiljevic, McKechnie, & Donkor, 2016). Today's community is becoming more health-conscious where the food

choices are more likely to be among of nutrient-dense food compared to energy-dense food. This study may provide additional knowledge on nutrition for them such as getting to know about the different types of dietary fibre and their benefits. Besides, consumers can also learn how to differentiate refined and complex carbohydrate and make a better choice while purchasing food. Hence, this study can help in the improvement and understanding of nutrition knowledge of the consumers.



1.4 Objectives

1.4.1 General objective

To determine and compare the proximate compositions and total sugar content of sugarcane peel and bagasse.

1.4.2 Specific objectives

1. To determine the proximate compositions (moisture, ash, protein, fat, total dietary fibre, carbohydrate) of sugarcane peel and bagasse.
2. To determine the total sugar content of sugarcane peel and bagasse.
3. To compare the proximate compositions and total sugar content between sugarcane peel and bagasse.

1.5 Null hypothesis

There is no significant difference in the proximate compositions (moisture, ash, fat, protein, total dietary fibre, carbohydrate) and total sugar content between sugarcane peel and bagasse.

CHAPTER 2

LITERATURE REVIEW

2.1 Sugarcane

2.1.1 Botany of sugarcane

Sugarcane plant has three main parts which are the stalk, leaf and the root. The stalk of the plant is segmented by joints. At the joints, there are node and internode. Node is the place where leaf and stalk are connected while internode is the space between the nodes. The length and diameter of the joints are dependent with the variety of sugarcanes. Meanwhile, the leaf of sugarcane are divided into two, namely sheath and blade. The sheath are wrapping the stalk which extended until one complete internode normally. The blade plays role in the protection of the plant tissues, gas exchange and photosynthesis. Lastly, the root system of sugarcane plant function to nourish the plant with water and nutrients and also helps to keep the plant stand still. The germination of sugarcane are usually done by the cutting of the stalk containing more than two nodes with buds. Some minerals that are important for the growth of sugarcane include carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, boron, chlorine, copper, iron, manganese, molybdenum, sulphur, and zinc (Sandhu, Singh, Gilbert, & Odero, 2016). However, the rate of growth of sugarcane also depends on its internal factor such as the species (Sandhu, Singh, Gilbert, & Odero, 2016).

2.1.2 Sugarcane peel and bagasse

Sugarcane waste consist of two major parts. They are the peel or rind and the bagasse. Peel is the outer part of the stem and bagasse is the white-creamy inner

part of sugarcane (Wirawan, Sapuan, Robiah, & Khalina, 2010). There are many uses of sugarcane waste such as producing bioethanol fuel, electric energy and power generation. In Brazil, by the year 2030, the increasing amount of sugarcane waste is up to 25.9×10^6 tonnes can be used to produce second-generation ethanol (Hofsetz & Silva, 2012).

According to Agamuthu (2009), sugarcane waste is known as crop waste among the agricultural wastes which include cornstalks, drops and culls from fruits and vegetable and pruning. In Malaysia, about 1.2 million tonnes of agricultural waste are disposed into landfills every year (Agamuthu, 2009). Therefore, reduction of agricultural waste on landfills can be done by utilization of the waste such as making pulp and cultivating mushrooms by using sugarcane bagasse.

2.2 Proximate compositions

2.2.1 Moisture

According to Nielsen (2017), moisture content of food has been the main concern in assuring the quality of food and its resistance towards deterioration. It is also used to perform other analysis of nutrients which require dry sample. The measurement of moisture content is very significant for the food manufacturer such as for preservation and advantage in packaging (Bradley, 2003). For example, foods that are preserved by eliminating their moisture content include powdered eggs, dehydrated fruits and spices and herbs whereas the advantage in food packaging includes concentrated milk and liquid sweetener.

Moisture content can be determined by using a few methods such as oven drying method, vacuum oven, microwave drying oven, Karl Fischer method and Near-Infrared Analyzer (Nielsen, 2017). Even though there are other methods can be used to determine moisture content, oven drying method is often be used by heating the sample until constant weight is achieved (Hart & Fisher, 1971). The advantage of this method is that it is easy to be measured through weight difference because the moisture content of the food has been fully evaporated (O'Kelly, 2004).

A study in Malaysia, conducted by Leang & Saw (2011) on the proximate properties of sugarcane bagasse shows results of 63% of moisture content, 1.01% of ash content, 1.7% of protein content, 2.0% of fat content and 79.5% of total dietary fibre content. However, there is no data on available carbohydrate and total sugar content.

2.2.2 Ash

According to Popping & Diaz-Amigo (2014), ash is defined as non-organic waste left after all organic element in food is completely combusted. Ash determination is useful to provide measure of mineral content in foods. Specific analyses of food sample are commonly begin with ashing. There are two types of ashing; dry ashing and wet ashing method. The sample preparation prior to ashing such as milling and grinding might not change the ash content significantly. However, precaution may be taken into consideration if the analysis is done for specific mineral because the labware usage can also contaminate the sample.

There was a study conducted on six energy crops which are Cynara, giant reed, sweet Sorghum, fibre Sorghum, switchgrass and miscanthus to determine their mineral and ash content (Monti, Di Virgilio, & Venturi, 2008). The ash content was determined by using furnace at 550°C. The study reported that crops with the highest content of ash, which are Cynara and giant reed have the highest amount of most of the minerals thus resulting in slagging, fouling and corrosion tendencies. This is due to the amount of ashes and minerals released during combustion for biofuel production.

2.2.3 Protein

Protein consists of amino acids connected by peptide bonds and it is a complex molecule. It can be categorized according to its structure, composition, biological function and solubility properties (Chang, 2010). Protein is an important nutrient for tissue repair and growth as well as functions as basic unit for enzymes and hormones. Malaysian recommended intake of protein for normal adults is 20% from total energy intake daily. Lack of protein in dietary intake can cause muscle wasting, anaemia and slow healing process (RNI, 2017).

Kjeldahl method and nitrogen combustion in the Dumas method are the common methods used to determine protein by nitrogen value in the food (S. Nielsen, 2009). Kjeldahl method provides the nitrogen value which acts as the measure of protein content in foods. There are three major steps to analyse protein content, namely digestion, distillation and titration processes. The final volume of hydrochloric acid used during titration is used to calculate nitrogen content.

Meanwhile, combustion of samples applies in the Dumas method will release nitrogen gas which is then quantified by using gas chromatography.

The conversion of nitrogen to protein is normally fixed at 6.25 (Mariotti, Tomé, & Mirand, 2008). However, not all foods have the same amount of nitrogen in their protein fractions. The nitrogen content in food also does not only due to its protein content, but may be caused by many other elements such as urea, ammonia and nucleic acids. Even though the conversion factor might be specific for certain foods, but if the study being conducted with the aims to determine the average amount of protein, there is no issue regarding the conversion factor. Some of the proposed conversion factors for different types of foods include 5.85 to 6.15 for milk products, 5.6 for meat, fish and eggs and 5.5 for soybean. Meanwhile, a conversion factor of 5.4 for other legumes and also most cereal products is used to calculate protein content (Mariotti, Tomé, & Mirand, 2008).

2.2.4 Fat

According to Khatri (2017) there are a few types of fat such as saturated fat, *trans* fat and unsaturated fat. The general functions of fat in the body include to preserve heat, warm the body, transport fat-soluble vitamins, produce certain hormones and also to protect the organs. Unsaturated fats are commonly known as good fat while saturated fat and *trans* fat may bring adverse effect on health. *Trans* fats and some of saturated fats are unhealthy because they can increase the level of LDL cholesterol in the body. Meanwhile, unsaturated fats are grouped into two which are monounsaturated and polyunsaturated fats and they mostly come from vegetables, nuts and fish. Therefore, they are considered as good

sources of fat because they can lower the risk of getting high blood cholesterol. The American Heart Association recommends intake of saturated fat daily not more than 5% to 6% from total energy intake daily.

Some of the common methods used to determine fat content in foods include Soxhlet and Goldfish method (Carpenter, 2010). These methods involve extraction of fat by using solvents such as petroleum ether, hexane and ethyl ether. In the Soxhlet extraction method, the condensed solvent from its heating soak the sample in the Soxhlet extractor. The fat in the sample is then extracted and measured by weight of fat accumulated in the flask. Goldfish method uses a quite similar method as the Soxhlet extraction apart from the usage of Goldfish condenser bracket. Moreover, all materials are similar for both extractions.

A study conducted by Sánchez Pardo, Ramos Cassellis, Escobedo, & García (2014) on the proximate compositions of pulp and residues of pineapple found that the highest amount of crude fat was found on the pulp. Meanwhile, the lowest amount of crude fat was found in the leaf. This study gives the idea that the waste from sugarcane also may have low concentration of crude fat.

2.2.5 Dietary fibre

Dietary fibre consists of two types which are soluble and insoluble dietary fibre. Both of them bring different benefits to the body. Soluble fibre which also known as fermentable fibre forms gel in the gut and soften the stools. It also prevents constipation by making the stools easier to pass. Some examples of soluble dietary include grains, fruits, beans and root vegetables such as carrot. Insoluble fibre is a partially fermented fibre because it can be fermented in the gut

to some extent only. Insoluble fibre gives bulk to the stools make it easier to go through the colon (British Nutrition Foundation, 2017).

Based on the RNI (2017), the recommended intake of dietary fibre per day ranges from 20 to 30g for all age groups. However, the amount of fibre in the body cannot be measured directly using blood because fibre is not absorbed into it. Hence, one must ensure enough consumption of dietary fibre from the diet.

The amount of dietary fibre in food can be assessed by using total dietary fibre assay kit. This method involves enzymatic and gravimetric method where three types of enzymes are used. The enzymes used in this kit are *α-amylase*, *protease* and *amyloglucosidase*. The sample is incubated at pH 6.0 at 95°C for gelatinization with *α-amylase*. *Protease* and *amyloglucosidase* require temperature at 60°C and pH 7.5 and 4.5 respectively to work on the sample. Ethanol is used to precipitate soluble dietary fibre so that the amount of total dietary fibre can be measured from the residue (AOAC 985.29).

There was a study conducted by Sangnark and Noomhorm (2004) to investigate the effect of dietary fibre in sugarcane bagasse on bread. The variables in concern were the bread size, texture and consumer acceptance. They reported that bread enriched with 10% alkaline hydrogen peroxide (AHP)-treated sugarcane bagasse with sucrose ester receive favourable rating from the consumer. This explains the use of bagasse in food is feasible to bring health benefits for the consumer.

2.2.6 Carbohydrate

Carbohydrate is the main source of energy for human body. There are four main types of carbohydrate which are monosaccharide, disaccharide,

oligosaccharide and polysaccharide. They differ by the number of monomeric units (Niinikoski & Ruottinen, 2012). There are two types of carbohydrate normally assessed in food analysis, they are total carbohydrate and available carbohydrate. Total carbohydrate content of foods can be calculated by difference rather than analysed directly. It is done by determining the moisture, ash, protein, fat and alcohol of the food individually and summed them up to be subtracted from the weight of food. Total carbohydrate estimated by using this method includes fibre and other organic compounds. Meanwhile, available carbohydrate is the fraction of carbohydrate that can be absorbed and digested by human enzymes. Therefore, it does not include dietary fibre because they are transferred into large intestine to provide food for the intestinal bacteria. It can be determined by using difference method or direct analysis (FAO, 1998).

According to a study conducted by Leang & Saw (2011) on the proximate compositions of sugarcane bagasse, the amount of available carbohydrate is quite high at 55.4% which makes the bagasse suitable to be incorporated into baked products. In Malaysia, the main source of carbohydrate comes from grains and vegetables such as rice, wheat, cassava and potatoes. The recommended intake for carbohydrate is 50 to 65% of total energy intake per day. The value is reduced by 5% from the RNI 2005 because evidence has found that high sugar intake is associated with obesity, low quality diet and risk of NCDs (RNI, 2017).

2.3 Total reducing sugar

Total reducing sugar or total sugar content can be determined directly by using few different methods such as titration methods, gravimetric methods,

colorimetric methods and enzymatic methods. One of the most common method used is colorimetric method, which is phenol-sulphuric acid method as it is simpler and easy to conduct. A clear solution of sample is put in a test and added with phenol and sulphuric acid. The interaction between the phenol and carbohydrate produce yellow-gold colour to the solution which later the absorbance is read at 490nm. Concentrated sulphuric acid is used to break down all polysaccharides, oligosaccharides and disaccharides to monosaccharides. Therefore, total carbohydrate can be analysed by using this method (S. S. Nielsen, 2010).

Meanwhile, a study conducted by Laopaiboon, Thani, Leelavatcharamas, & Laopaiboon (2010) discovers about the optimum condition for acid hydrolysis of sugarcane bagasse for total sugar determination. The purpose of the study was to identify the best condition of sugarcane bagasse which can yield the highest content of total sugar. They found out that the optimum condition for lignin extraction which was performed first before the acid hydrolysis were by using 10% ammonium hydroxide, 25°C, 24 hours. This is because the removal of lignin can increase the accessibility of the sample's cellulose to the acid during hydrolysis. Therefore, higher yield of sugar can be obtained. The solid fraction from the lignin extraction was used for acid hydrolysis by using 0.5% hydrochloric acid at 100°C for 5 hours. The hydrolysate was then analysed for total sugar content.

CHAPTER 3

METHODOLOGY

3.1 Sample selection and sampling method

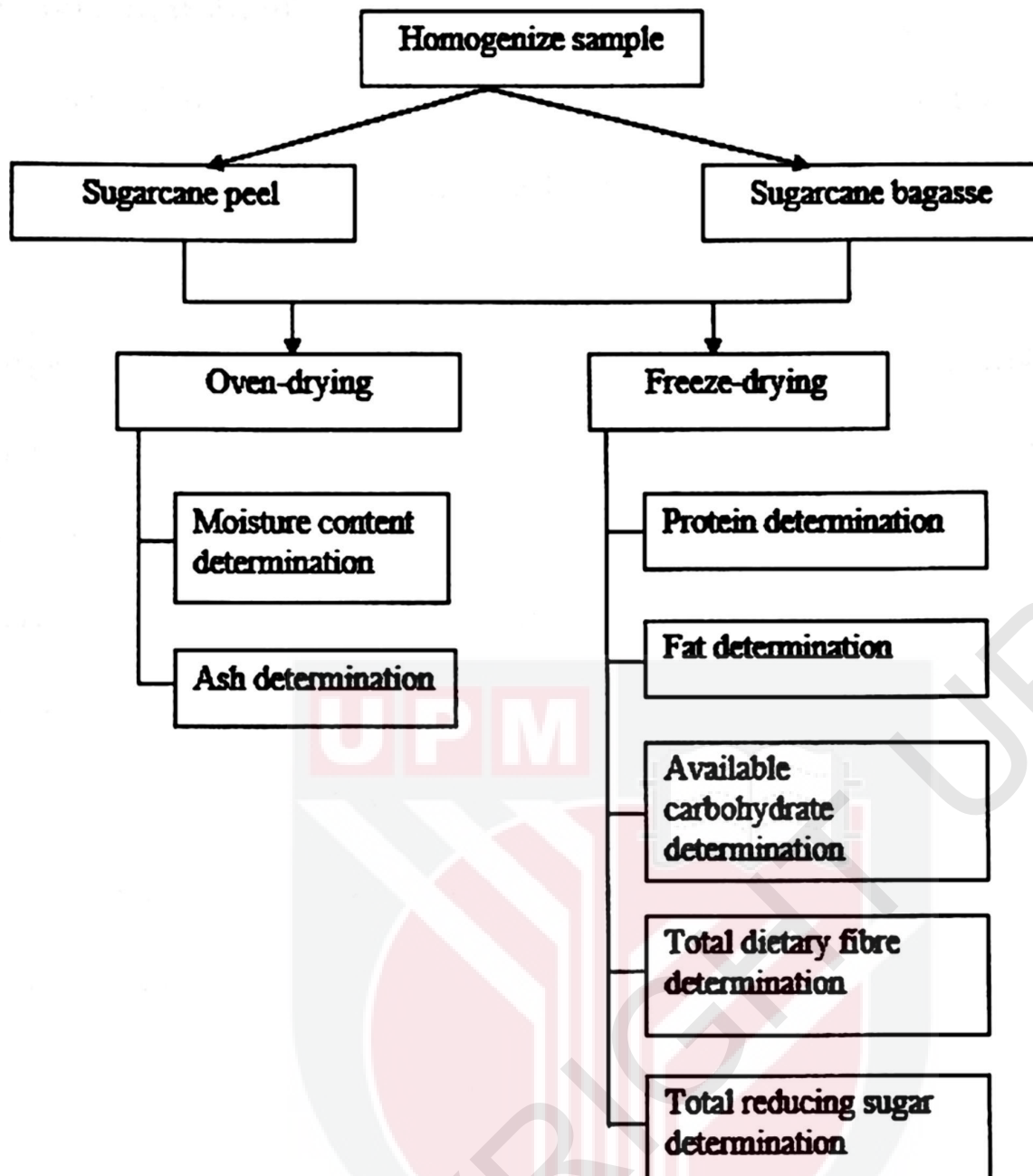
Sugarcane peel and bagasse were analysed in this study. The peel and bagasse were collected through a purposive sampling by purchasing at a stall in Sungai Ramal, Kajang, Selangor. Before the juice expression, sugarcane peel was removed from its stalk while the bagasse was collected after the juice expression.

3.2 Reagents and chemicals

The reagents used in this experiment were concentrated sulphuric acid (H_2SO_4), Kjeltab, sodium hydroxide (NaOH), 4.0% boric acid (H_3BO_3), methyl red indicator, petroleum ether, dietary fibre assay kit (α -amylase, protease, amyloglucosidase and celite), ethyl alcohol, sodium phosphate, hydrochloric acid (HCl), 10% ammonium hydroxide (NH_4OH), and 2% phenol.

3.3 Experimental Design

The samples were kept in a plastic bag in the -20°C refrigerator to avoid degradation of the nutrients. For the sample preparation, both sugarcane peel and bagasse were cut into small pieces. They were weighed and separated into two portions. One portion was freshly used to determine moisture and ash, and the other portion was freeze dried for further analysis of nutrient content.



3.4 Determination of Moisture Content

The moisture content of sugarcane peel and bagasse was determined by using oven-drying method as conducted by Leang & Saw (2011). Determination of moisture content for each sample was done in triplicate. Firstly, the peel and bagasse were cut into small pieces. The aluminium dishes were washed and dried in the oven for 4 hours. Then, the weight of the dish was recorded before adding the samples. Ten grams (10g) of sample was added in the dish and weighed. They were then placed in the oven at 105°C overnight. After that, they were cooled to room temperature in the desiccator. The weight of aluminium dish with samples was recorded after 24 hours and the processes were repeated until a constant weight was obtained. Moisture content of the peel and bagasse was calculated by using formula:

$$\% \text{ moisture} = \frac{\text{weight of wet sample} - \text{weight of dry sample}}{\text{weight of wet sample}} \times 100$$

3.5 Determination of Ash Content

The ash content of sugarcane peel and bagasse was determined using furnace. The determination of ash content for each sample was done in triplicate. Four grams (4g) of sample was put in the crucible and dried in furnace at 550°C overnight. The dried samples from the moisture content experiment was used to determine the ash content. Samples were cooled at room temperature in the desiccator before weighed to calculate the content of ash. The ash content was calculated by using formula (Marshall, 2010) :

$$\% \text{ ash} = \frac{\text{weight after ashing} - \text{weight of crucible}}{\text{dry sample weight} - \text{weight of crucible}} \times 100$$

3.6 Determination of Protein Content

The protein content of sugarcane peel and bagasse was determined by using Kjeldahl method. Kjeldahl analysis measures the crude protein content in the food because the sources of nitrogen can also come from non-protein components. The three steps involve in the analysis include digestion, neutralization and distillation and lastly titration. During digestion, 1g sample was put in the Kjeldahl flask added with acid and catalyst. The purpose of digestion is to completely breakdown all organic matter in the sample to produce ammonium sulphate. After that, during neutralization and distillation, the product from digestion was diluted with water and sulphuric acid was neutralized by adding sodium hydroxide. The ammonia gas produced was distilled into a boric acid solution. Then, few drops of methyl red was added into the flask containing the boric acid as an indicator. The content in the flask was then titrated with hydrochloric acid. Crude protein content was calculated by using formula (Chang, 2010):

$$\% N = N \text{ HCl} \times \frac{\text{corrected acid volume}}{\text{weight of sample}} \times \frac{14 \text{ g N}}{\text{mol}} \times 100/1000$$

Where:

$N \text{ HCl}$ = normality of HCl, in mol/1000ml

Corrected acid volume = (ml std. acid for sample) – (ml std. acid for blank)

14 = atomic weight of nitrogen

Most protein contains 16% N, so the conversion factor is 6.25 (100/16=6.25)

% protein = % N × 6.25

3.7 Determination of Fat Content

The fat content of sugarcane peel and bagasse was determined by using Soxhlet method. Soxhlet method is a semi-continuous solvent extraction method where the solvent builds up in the extraction chamber and surrounds the sample completely before it siphons back into the boiling flask. Firstly, the weight of round-bottomed flask was recorded and petroleum ether was added. The flask and its content was heated for the extraction. 2g of sample was put in the thimble with dry cotton wool as a cover. The samples were then put in the Soxhlet extractor. The extraction took about 8 hours. After the extraction has completed, flask was removed and the petroleum ether left was evaporated by using rotary evaporator. After that, the flask was dried in the oven for 30 minutes. The flask was then cooled to room temperature and the weight was recorded. The percentage of fat in the sample was calculated by using formula (Carpenter, 2010):

$$\% \text{ fat} = \text{weight of fat in sample} / \text{weight of dried sample} \times 100$$

Where:

Weight of fat in sample = weight of (flask + fat) – weight of flask

3.8 Determination of Total Dietary Fibre Content

Total dietary fibre content in sugarcane peel and bagasse was determined by using total dietary fibre assay kit. The procedure involved enzymatic and gravimetric methods. Dried and defatted sugarcane peel and bagasse were gelatinized with α -amylase and enzymatically digested with protease and amyloglucosidase at pH 7.5 and pH 4.5 respectively. This is to remove the protein and starch in the sample. After that, soluble dietary fibre was precipitated by using ethanol. Then, the solution was washed with ethanol and acetone. The weight of the residue was recorded after drying. Total dietary fibre (TDF) content was determined by using formula:

$$\% \text{ TDF} = [(R_{\text{SAMPLE}} - P_{\text{SAMPLE}} - A_{\text{SAMPLE}} - B)/SW] \times 100$$

Where:

R = Average residue weight (mg)

P = Average protein weight (mg)

A = Average ash weight (mg)

B = $R_{\text{BLANK}} - P_{\text{BLANK}} - A_{\text{BLANK}}$

SW = Average sample weight (mg)

3.9 Determination of Available Carbohydrate Content

The available carbohydrate content of sugarcane peel and bagasse was calculated by difference, where:

$$\% \text{ Carbohydrate} = 100 - (\% \text{ moisture} + \% \text{ protein} + \% \text{ fat} + \% \text{ dietary fibre} + \% \text{ ash})$$

The samples used in the moisture and ash content determination were fresh samples while the other experiments used freeze-dried samples.

3.10 Determination of Total Sugar Content

Total sugar content of sugarcane peel and bagasse was determined by using phenol-sulphuric acid method. However, lignin extraction and acid hydrolysis were conducted prior the total sugar content analysis (Laopaiboon et al., 2010). Firstly, 10% ammonium hydroxide was used for the extraction of lignin at 25°C for 24 hours with liquor/solid ratio (LSR) of 100ml liquor/g dry weight of sample. After that, the solid fraction was washed twice with distilled water and dried at 90°C for 18 hours until the weight was constant.

After the lignin extraction, the remaining solid fraction was hydrolysed by 0.5% hydrochloric acid at 100°C for 5 hours. The hydrolysis was done by using a LSR of 15ml liquor/g dry weight of sample. The mixtures were then centrifuged and the supernatant was used for total sugar analysis with phenol-sulphuric acid method.

Seven different concentration of glucose solution (0.015, 0.03125, 0.0625, 0.125, 0.25, 0.5 and 1mg glucose/mL) were prepared for generation of standard curve. One millilitre (1ml) of each glucose solution were put into separated test tubes, then 1ml of 2% phenol were added to each tubes. After that, 5 ml of concentrated sulphuric acid was added rapidly into each tube and let stand for 10 minutes before mixed by using vortex. Then, the mixed solutions were left at room temperature for another 20 minutes before the absorbance was read by using uv-vis spectrophotometer at 490nm by using the standard containing 0.5% hydrochloric acid. The steps were repeated by using sample solution obtained from the acid hydrolysis earlier. The total sugar concentration was calculated by

comparison with the standard curve of glucose (S. S. Nielsen, 2010; Wichienchot, Jatupornpipat, & Rastall, 2010).

3.11 Statistical Analysis

Data entry and analysis of all the nutrient content were carried out by using Statistical Package for the Social Sciences (SPSS) Version 24.0. The purpose of the analysis was to identify the difference in proximate compositions and total reducing sugar content between sugarcane peel and bagasse. Independent *t*-test was used to compare the nutrient content and total sugar between the peel and bagasse. Significance level was set at $p < 0.05$.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Moisture Content

The moisture content was assessed by measuring the mass of the sample before and after the water is removed by evaporation. Fresh samples were used for the assessment. The moisture content was higher in bagasse (36.90%) than in peel (32.33%). An independent t-test was conducted and the mean difference of moisture contents was not significantly different ($p>0.05$) between both samples (Table 1).

Table 1: Results of independent samples t-test on the moisture content

Sample	Mean (%) (n=3)	SD	t-value	p-value
Sugarcane peel	32.33	3.02	-2.015	0.114
Sugarcane bagasse	36.90	3.32		

Based on the results, a slightly higher moisture content of sugarcane bagasse was due to its thickness of flesh which is greater compared to the peel. Sugarcane peel is the outer part of the sugarcane stalk whereas bagasse is the inner part of sugarcane, which has been compressed to get the juice (Leal et al., 2013). Figure 1 shows the difference in thickness of the sugarcane peel and the inner part of sugarcane. The inner part is thicker than the peel, hence it stores higher amount of water. That explains the higher moisture content in bagasse. However, the moisture content in both peel and bagasse are considered low to enable them to be one of the additional ingredients in foods and increase the storage life.



Photo credit: www.eccocane.org

Figure 1: The thickness of flesh of sugarcane peel and inner part of sugarcane

There are some studies done on the moisture content of the bagasse and the results are compiled in Table 2. The other study in Malaysia showed a higher percentage of moisture content of fresh samples compared to this study, where the moisture content of the sugarcane bagasse sugarcane is the highest at 63.0% compared to others.

Table 2: Moisture content of sugarcane bagasse from this study and few other studies

Origin	This study (n=3)		References (Leang & Saw, 2011) (n=3)		
	Sg. Ramal, Kajang	Malaysia	Thailand	Costa Rica	US
Moisture content (%)	36.90±3.32	63.0	45.0	45.0-50.0	50.0

The significance of having lower moisture content of sugarcane waste products is they can prolong the shelf life of the foods when they are included as part of the ingredients.

A lower amount of water in the food can help in retaining the quality of food because it is not suitable for the growth of bacteria. Moreover, availability of water is one of

the optimum conditions for bacteria’s growth. Therefore, a lower moisture content is beneficial for the improvement of foods’ quality incorporated with sugarcane peel and bagasse.

4.2 Ash Content

The ash content was determined by using the dry ashing method which involves heating the sample in the furnace at temperature ranged 500-550°C for about 8 hours. Fresh samples were used in the experiment. The weight of ash in the crucible was measured after the heating was completed to calculate the ash content. The ash content in food is important to determine the level of minerals. The ash content is positively correlated with the mineral content (Marshall, 2010). The ash content of sugarcane bagasse is higher (4.17%) compared to the peel (1.15%). However, the mean difference of ash contents was not significantly different ($p>0.05$) between both samples based on the output of independent t-test (Table 3).

Table 3: Results of independent sample t-test on the ash content

Sample	Mean (%) (n=3)	SD	t-value	p-value
Sugarcane peel	1.15	1.99	-1.268	0.274
Sugarcane bagasse	4.17	3.61		

Based on the results, sugarcane bagasse that contained a higher ash content compared to the peel which indicates a greater mineral content. A study on the

proximate compositions of sugarcane bagasse by Leang & Saw (2011) showed a comparable percentage of ash (1.01%) with the sugarcane peel in this study. The ash content of sugarcane bagasse in this study was found to be higher than the previous study. This condition may be due to the heterogeneity of the samples being used. Heterogeneity may occur during the grinding and mixing process of the samples (Raynie & Bruce, 2017). However, there is no data found on the literature on the ash content of sugarcane peel.

Some of the minerals that can be found in sugarcane are phosphorus, calcium, potassium, magnesium, iron, zinc, copper, aluminium and manganese (de Souza, de Menezes, de Souza, Dutra, & de Moraes, 2015). The varieties of minerals in the sugarcane were assessed from its juice and it is assumed that both peel and bagasse have similar composition of minerals as the juice. It was found that potassium and magnesium content are among of the highest minerals in sugarcane at 794mgL^{-1} and 957mgL^{-1} respectively in the previous study. Potassium is known to regulate blood pressure as well as the sodium concentration in the body and the recommended intake of potassium for normal adult is 4.7g/day. However, an excessive intake of potassium does not bring adverse effect for healthy people because it can be easily excreted by urination. Meanwhile, magnesium functions to help with the enzymatic reactions in the body. It acts as the cofactor which can work with either the substrates or the enzymes. It is also found that food with dietary fibre is a good source of magnesium. There is no negative impact of consuming excessive magnesium from natural sources (RNI, 2017).

4.3 Protein Content

The protein content was determined by using Kjeldahl method which consists of three crucial steps; digestion, distillation and titration. The amount of acid used during titration to change the colour of the solution indicated the percentage of protein content in the sample. The protein was higher in the sugarcane peel (1.23%) than the bagasse (0.88%). Furthermore, the mean difference of protein contents was significantly different ($p<0.01$) between both samples.

Table 4: Results of independent sample t-test on the protein content

Sample	Mean (%) (n=3)	SD	t-value	p-value
Sugarcane peel	1.23	0.00	148.492	0.000
Sugarcane bagasse	0.88	0.00		

Based on the results, protein content in sugarcane peel and bagasse are comparable to the previous study conducted in Malaysia on sugarcane bagasse by Leang & Saw (2011) as the authors reported 1.7% of protein content. The reason of the higher protein content of the peel is yet to be known because there are no studies on sugarcane are focusing on the peel. Furthermore, the peel has higher content of protein may be due to the common properties of the plants' peel that offer comparable amount of benefits compared to the flesh. As an example, a study on the nutrient compositions of three species of pumpkin by their different parts (peel, flesh and seed) found that the protein content was higher in peel compared to the flesh for all three species of pumpkin (Kim, Kim, Kim, Choi, &

Lee, 2012). Moreover, the differences of nutrient content in plant may be due to the soil condition (fertilization, moisture, pH), weather, plant spacing and postharvest handling of the crop (He et al., 2015; Hornick, 1992). The decrease in the crop absorption of nitrogen is due to the hot weather, dry soil, low content of nitrogen in the soil and unstable pH. The nutrient composition in different parts of plants also indicate its ability to absorb, deliver and keep the nutrients (He et al., 2015). Therefore, sugarcane peel can be postulated to have higher capacity of absorbing nitrogen from the soil compared to the bagasse due to its higher protein content.



4.4 Fat Content

The fat content was determined by using Soxhlet extraction method with petroleum ether as a solvent. The weight of volumetric flask was measured before and after the extraction in order to calculate the amount of fat accumulated in the flask. The fat content in sugarcane peel was higher (1.72%) than the bagasse (0.67%). In addition, the mean difference of fat contents was not significantly different ($p>0.05$) between both samples (Table 5).

Table 5: Results of independent sample t-test on the fat content

Sample	Mean (%) (n=3)	SD	t-value	p-value
Sugarcane peel	1.72	0.88	2.038	0.172
Sugarcane bagasse	0.67	0.14		

Based on the results of this study, sugarcane peel contains slightly higher content of fat may be due to the contribution of the weight of the peel's colour that was bleached away along with the fat during the extraction. The sugarcane peel has darker greenish yellow colour compared to the bagasse which is whiter. Therefore, bleaching of the dark colour might be the reason of the difference between the fat content of sugarcane peel and bagasse. This is supported by a study conducted by Barbosa et al., (2017) who found that the solvent used in the extraction of fat (petroleum ether) is possible to extract non-lipid components of the samples as well. The non-lipid components include chlorophyll, waxes and essential oil. The low content of fat indicates that the wastes from sugarcane are

suitable to be included as ingredient in low fat food. However, it may also give less satisfaction feeling due to its low fat property.

There are some studies done on the fat content of the bagasse and the results are compiled in Table 6. The other studies show a comparable percentage of fat content of sugarcane bagasse compared to this study where the fat content of the Malaysian sugarcane bagasse is the highest compared to others (Leang & Saw, 2011).

Table 6: Fat content of sugarcane bagasse from this study and few other studies

	This study (n=3)	References (Leang & Saw, 2011) (n=3)				
Origin	Sg. Ramal, Kajang	Malaysia	India	Thailand	Costa Rica	Brazil
Moisture content (%)	0.67±0.14	2.0	1.0	0.35	1.0	0.3

4.5 Total Dietary Fibre Content

The total dietary fibre (TDF) content was determined by using gravimetric and enzymatic method from the TDF assay kit. Three different enzymes were used during the analysis; α -amylase, protease and amyloglucosidase. The weight of the residue, protein and ash were measured in the experiment to obtain the percentage of TDF content. The TDF content in sugarcane peel was almost similar (63.22%) with the bagasse (63.10%). The mean difference of TDF contents were not significantly different ($p>0.05$) between both samples.

Table 7: Results of independent sample t-test on the total dietary fibre (TDF) content

Sample	Mean (%) (n=3)	SD	t-value	p-value
Sugarcane peel	63.22	2.27	0.089	0.933
Sugarcane bagasse	63.10	0.76		

Based on the results, both sugarcane peel and bagasse contain almost similar content of TDF which is slightly lower than reported of 79.5% content of TDF in the bagasse in the previous study (Leang & Saw, 2011). It is may be due to the different properties of the sugarcanes since both studies do not use the same source of sugarcane. The TDF content includes soluble (SDF) and insoluble dietary fibre (IDF) where most of dietary fibre in the bagasse is IDF (75.7%) followed by small percentage of SDF (3.8%) according to the study by Leang and Saw (2011). However, further classification of soluble and insoluble dietary fibre is not conducted in this study due to limitation of resources. The high content of dietary fibre in sugarcane peel and bagasse shows that they are capable of developing

fibre-rich food which is widely known to help in fecal passage and reducing the risk of getting colorectal cancer (Dhingra, Michael, Rajput, & Patil, 2012).

There are also the other components of dietary fibre in the sugarcane which are cellulose, hemicellulose, lignin and pectin. Cellulose makes up the most of the dietary fibre composition followed by hemicellulose and lignin (Leang & Saw, 2011). Cellulose and hemicellulose are polysaccharides that can be further broken down into monosaccharides such as xylose, glucose and arabinose by acid hydrolysis. This contributed to the total sugar content of the bagasse (Laopaiboon et al., 2010).

Agricultural wastes of sugarcane such as the peel and the bagasse can be incorporated into foods to develop high-fibre foods. For example, sugarcane bagasse was used as additional ingredient in chapatti, chutney powder, vermicelli and biscuits (Wahlang, 2011). Sensory evaluation was conducted in the study to determine the acceptance of consumer towards the fibre-fortified foods. All four types of the foods were accepted by the consumers with different percentage of bagasse incorporated into them. The chapatti, chutney powder, vermicelli and biscuits obtained the highest score with the fortification of bagasse at 10, 12.5, 12.5 and 15 percentage respectively. Therefore, it is concluded that these wastes can be a potential ingredient in foods to enhance their nutritional value.

4.6 Available Carbohydrate Content

Available carbohydrate content was determined by difference method. Available carbohydrate indicates the percentage of carbohydrate that can be digested by human enzymes and does not include dietary fibre (Cummings & Stephen, 2007). The carbohydrate content was similar (1.33%) in both sugarcane peel and bagasse. Therefore, the mean difference of total available carbohydrate was not significantly different ($p>0.05$) between both samples.

Table 8: Results of independent samples t-test on the available carbohydrate content

Sample	Mean (%) (n=3)	SD	t-value	p-value
Sugarcane peel	1.33	0.58	0.000	1.000
Sugarcane bagasse	1.33	0.58		

The low amount of carbohydrate calculated by difference in this study is due to the great loss of moisture from the fresh samples. Other experiments where their results were used for the calculation of carbohydrate were obtained from freeze-dried samples. Therefore, the moisture loss from freeze-drying should also be used in the calculation. However, there was no record on the moisture loss after the samples being freeze-dried. Hence, the carbohydrate content calculated by difference in this study is not reliable.

4.7 Total Sugar Content

The total sugar content was determined by firstly extracting lignin extraction, followed by acid hydrolysis and phenol-sulphuric acid method. The lignin extraction was completed by using ammonium hydroxide to remove the lignin from the samples. After that, hydrolysis was done by using hydrochloric acid at optimum concentration, temperature and time; 0.5%, 100°C, 5hours (Laopaiboon et al., 2010). After that, the supernatant was used to analyse the total sugar content by phenol-sulphuric acid method. The total sugar concentration was calculated by using the standard curve from glucose. The standard curve was obtained by repeating the same procedure of phenol-sulphuric acid method with glucose with known concentration. The total sugar content in sugarcane peel was higher (25.33mg/g) than the bagasse (24.83mg/g). The mean difference of total sugar contents were not significantly different ($p>0.05$) between both samples.

Table 9: Results of independent sample t-test on the total sugar content

Sample	Mean (mg/g) (n=3)	SD	t-value	p-value
Sugarcane peel	25.33	2.89	0.256	0.81
Sugarcane bagasse	24.83	1.76		

Based on the previous study by Laopaiboon et al., (2010) the types of monosaccharides that are present in sugarcane bagasse include glucose, xylose and arabinose. Xylose content (22.59g/l) was found to be the highest followed by glucose (1.50g/l) and arabinose (1.29g/l). Therefore, they might also present in

the sugarcane peel as both bagasse and peel came from the same plant. The hydrolysis of lignocellulosic materials is responsible for the sugar yield from the sugarcane. The sugar composition in sugarcane bagasse was previously investigated and are listed in **Table 9** (Laopaiboon et al., 2010). However, there is no data available on the literature on the sugar compositions of sugarcane peel.

Based on the results, there is not much difference of total sugar content in both peel and bagasse where the peel has slightly higher sugar content. It is may be due to the portion of the bagasse that was not separated properly from the peel. Therefore, it contributes to the total sugar content analysed on the peel.

Table 10: The sugar compositions in sugarcane from this study and past study

Sample	This study (n=3) Total sugar (mg/g ± SD)	Reference (Laopaiboon et al., 2010) (n=3)			
		Glucose	Arabinose	Xylose	Total sugar
		(g/L)			
Sugarcane peel	25.33 ± 2.89	-	-	-	-
Sugarcane bagasse	24.83 ± 1.76	1.50	1.29	22.59	25.38

Table 11: The summary of results from this study

Sample	% ± SD (n=3)				
	Moisture	Ash	Protein	Fat	TDF
Sugarcane peel	32.33 ± 2.10 ^a	1.15 ± 1.99 ^a	1.23 ± 0.00 ^a	1.72 ± 0.88 ^a	63.22 ± 2.27 ^a
Sugarcane bagasse	36.90 ± 3.32 ^a	4.17 ± 3.61 ^a	0.88 ± 0.00 ^b	0.67 ± 0.14 ^a	63.10 ± 0.76 ^a
Total sugar (mg/g)					25.33 ± 2.89 ^a
					24.83 ± 1.76 ^a

Different superscript letters within a column indicate significant differences by independent samples *t*-test (*p*<0.05).

The protein content was significantly difference (*p*<0.001) between the samples, where its content in the peel (1.23±0.00%) was significantly higher than in the bagasse (0.88±0.00%). Meanwhile, other nutrients and total sugar content were not significantly different (*p*>0.05) between the peel and bagasse. All nutrients and total sugar content were found to be higher in the peel compared to bagasse, with the exception of moisture and ash content.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

It can be concluded that the moisture and ash content of sugarcane bagasse are higher compared to the peel. Meanwhile, the protein, fat, total dietary fibre and total sugar content are higher in the peel compared to the bagasse. However, the only significant difference between these two samples is on the protein content. The moisture, ash, fat, total dietary fibre and total sugar content were not significantly different between the sugarcane peel and bagasse. The available carbohydrate content of sugarcane wastes in this study was found to be low due to great loss of moisture from the fresh samples.

The moisture content is higher in bagasse may be due to the greater thickness of the flesh which stores more water compared to the peel. The ash content differences may be due to the mineral content that is higher in bagasse, which indicated by its higher ash content compared to the peel. For the protein content that is significantly higher in the peel compared to the bagasse, the potential explanation is yet to be known because there is no literature found on the protein composition of sugarcane peel. However, there is study on pumpkin that found higher protein content in the peel than its flesh. Hence, the findings on the protein compositions of sugarcane wastes may be reasonable to be compared with the study. The higher fat content in the peel might be contributed by the colour pigments that was bleached away together with the fat during extraction. Therefore, it increases the weight of residue accumulated in the flask. Lastly, the

TDF and total sugar content that were found to be almost similar between the peel and bagasse.

The results show that there were no differences on the proximate compositions and total sugar content between the sugarcane peel and bagasse. However, the nutrients compositions in plants can be varied because they are greatly influenced by the place they are planted, the weather and also their species (Leang & Saw, 2011). That explains different findings in the literature on the proximate compositions of sugarcane bagasse. As a conclusion, both sugarcane peel and bagasse can be processed together to make them into additional ingredients in food for the enhancement of nutritional value especially for the dietary fibre. However, other factors such as consumer acceptance towards the food texture, taste and appearance need to be considered to ensure successful application of these agricultural wastes as food ingredient.

5.2 Recommendations

One of the limitations of this study is the state of samples used for assessing moisture and ash were different from the other experiments. Fresh samples were used in moisture and ash content experiments while the other experiments (protein, fat and TDF) freeze-dried samples were used. Therefore, carbohydrate content was not possible to be calculated by difference because the state of samples used in the experiments were not standardized. The carbohydrate content can be determined if all the experiments used same condition of samples either freeze-dried or fresh samples. Hence, future study should ensure the standardized state of the samples being used so that further analysis of carbohydrate content can be calculated by difference.

Other than that, this study does not have enough standard to evaluate the total sugar content. The only standard used in this study was glucose standard. Therefore, the compositions of other types of sugar such as xylose, arabinose, and others that may contain in sugarcane wastes were not assessed. The results of total sugar content was solely dependent on the standard curve of glucose. Hence, the uses of more standards such as the standard of xylose and arabinose in future study can improve the determination of total sugar content in sugarcane wastes.

Lastly, future studies should use more variety of sugarcane collected from a few different places to ensure the results are representable and can be generalized for all sugarcane compositions across the country. Therefore, the data can be used widely without being bias to a type of sugarcane that was collected from one place only.

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