STUDY ON PRODUCTION OF *COCOS NUCIFERA L.* (COCONUT) SHELL AS A BIO-BRIQUETTE

by

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DECLARATION

I declare that this thesis entitled "**Study on production of *Cocos Nucifera.L* (Coconut) Shell as a Bio-Briquette**" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ______________________________

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Date : ______________________________

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Study on production of *Cocos Nucifera. L* (Coconut) Shell as a Bio-Briquette

ABSTRACT

Charcoal is the principle cooking or fuel that widely used as households rural. This study covers the production of briquette from coconut shell as a solid bio fuel. The solid bio-briquette has been produced by coconut shell by adding different binding agents. Investigations was undertaken to produce fuel briquette from coconut shell powder waste with two different binder namely molasses and starch at the ratio 100:0, 80:20, 60:40, 50:50 and 40:60. Physical properties of the bio-briquette is compressive strength, impact testing and durability time to briquette ignite testing showed rapidly improvement with increasing amount of binder. Other parameter of sample that will be determined is the effect of different shape of bio-briquette such as cylinder, circle (ball shape) and square with uniform composition of CS powder: binder, 80:20. This studied was conducted to determine the mechanical properties and durability of the bio-briquette. Analysis and compressive test has been conducted to study the characteristics of produced bio-briquette. Furthermore, the time of briquette to ignite has been determined to estimate the combustion process for biofuel. The mechanical properties and impact resistance of briquette can be improved with the suitable ratio of coconut shell powder and binder was applied. The testing for mechanical properties and impact test was conducted to investigate the suitable binder composition in bio-briquette production. Usage of binder is an common practice with improving quality of pressure apply in production of bio-briquette 2kg loaded into a cylindrical shape diameter 12.5mm, high 8mm was prepared. Mechanical properties was tested by Universal Testing Machine (UTM), 9 sample was prepared and 5 sample can be tested due to another 4 sample not completely dry because unforeseen event. Impact testing was studied the percentage of weight losses of bio-briquette when the sample drop onto the floor at 1.83cm. Shatter resistance index of sample also can calculated, and from this method the maximum strength of bio-briquette was predicted. Final result of experiment testing was showed the more strength bio-briquette is bio-briquette contain 20% of starch binder that showed low weight loss when the sample was dropped from the height and it sample has higher shatter resistance index. In durability testing whereas the sample's time to ignite, it found that bio-briquette with molasses more easily to ignite compared to bio-briquette with starch. Different geometry of bio-briquette was effected the time to bio-briquette ignite. The shorter time take to bio-briquette ignite is ball shape sample due to the surface contact on the flame.

Mengkaji pembuatan Cocos Nucifera.L (Kelapa) Tempurung sebagai Bio-Briket

ABSTRAK

Arang adalah prinsip memasak atau bahan api yang digunakan secara meluas sebagai isi rumah luar bandar. Kajian ini meliputi kajian pengeluaran briket daripada tempurung kelapa sebagai bahan api pepejal. Briket pepejal akan dihasilkan oleh tempurung kelapa dengan menambah ejen pegikat yang berbeza. Siasatan telah dijalankan untuk menghasilkan bahan bakar briket daripada serbuk tempurung kelapa dengan menambahkan dua pengikat berbeza iaitu molas dan kanji yang bernisbah 100:0, 80:20, 60: 40, 50: 50 dan 40:60. Ciri-ciri fizikal briket adalah seperti kekuatan mampatan, kesan ujian briket menyala dan ujian ketahanan briket menunjukkan peningkatan yang cepat dengan peningkatan jumlah pengikat. Lain-lain parameter yang menentukan kesan berbeza terhadap sampel ialah bentuk briket seperti silinder, bulatan (bentuk bola) dan segi empat tepat dengan keseragaman komposisi serbuk CS: pengikat, 80:20. Kajian ini dijalankan untuk menentukan sifat-sifat mekanikal dan ketahanan briket. Analisis dan ujian mampatan telah dijalankan untuk mengkaji ciri-ciri briket yang dihasilkan. Tambahan pula, masa briket untuk menyala apabila dikenakan api telah ditentukan untuk menganggarkan kadar proses pembakaran bahan api briket. Sifat ketahanan dan kesan mekanikal briket boleh diperbaiki dengan mengaplikasikan nisbah serbuk tempurung kelapa dan pengikat yang sesuai. Ujian bagi mengkaji sifat-sifat mekanikal dan kesan ujian telah dijalankan untuk menyiasat komposisi pengikat yang sesuai dalam penghasilan briket. Penggunaan pengikat adalah satu rutin yang biasa untuk peningkatan kualiti, tekanan digunakan dalam penghasilan briket (2kg pemberat) komposisi serbuk tempurung kelapa dan ajen pengikat dimuatkan ke dalam bentuk silinder (diameter 8.5 mm, mm tinggi) telah disediakan. Sifat-sifat mekanikal diuji oleh Universal ujian Mesin (UTM), 9 sampel telah disediakan dan 5 sampel boleh diuji kerana sampel 4 yang lain tidak kering kerana komposisi ajen pengikat yang lebih tinggi. Peratusan kerugian berat briket telah diuji apabila sampel dijatuhkan daripada ketinggian 1.83 cm ke lantai. Indeks berkecai sampel dapat dikira dan melalui kaedah ini briket yang mempunyai kekuatan maximum dapat diramal. Keputusan akhir ujian menunjukkan kekuatan briket yang lebih banyak ialah briket mengandungi 20% dari ajen pengikat kanji yang menunjukkan index berkecai yang rendah apabila sampel ini telah jatuh dari ketinggian dan sampel ini mempunyai rintangan rintangan index berkecai lebih tinggi. Manakala dalam ujian ketahanan masa untuk sampel menyala, ia mendapati bahawa briket dengan molas lebih mudah terbakar berbanding briket dengan kanji. Geometri briket yang berbeza mempengaruhi masa untuk briket terbakar. Briket berbentuk bebola mengambil masa yang lebih pendek untuk terbakar kerana permukaan yang berhubung pada api.

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LIST OF ABBREVIATION

Cs	Coconut shell
CO_2	Carbon Dioxide
O_2	Oxygen
BB	Bio-briquette

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Increasing environmental on coal utilization within the European Community sustain a demand for the manufactured smokeless fuel. This makes the industry of fuel is grows so fast to produce fuel resources for cooking household, construction and others. The conversion of agricultural residue material into alternative fuel is one of the physical technology that could be applied (Thabuot *et al.*, 2015). Result in increasing technologies development and industrialization has been conducted to disrupt and destroy the fragile ecology (Okafor *et al.*, 2012).

Energy resources are classified into two namely renewable and non-renewable resources. Renewable resource is the better option since the lack of non-renewable resources such as gasoline, kerosene and diesel.

Besides that, non-renewable resource causes environmental impact during combustion of non-renewable resource like carbon dioxide (CO_2), sulphur oxide (SO_2), and nitrogen oxide (NO_2) (Jittabut, 2015). Abundant of waste material will cause increasing the number of risk health to environment. Waste utilization helps to reduce the environmental pollution control. Different types of agricultural waste show a big variety in composition and fuel characteristics. Moreover, the briquette form have high percentage of the combustible element in agricultural waste compared to fossil fuels (Jittabut, 2015).

One of the popular agricultural residues is coconut shell or *Cocos Nucifera L.* Coconut shell has the ability to produce the bio-briquette and be an eco–friendly solid fuel. Besides that, the cost of fuel oil, natural gas and electricity supply have increased, coconut shell has been considered as a new sources of fuel (Madakson *et al.*, 2012).

Briquetting technology is already well-known in many developing countries due to the technical constraints involved and the lack of knowledge to adapt the technology to local conditions.

1.2 Problem Statement

The increasing of the number of fuel industries in Malaysia brings increased in the demand of solid fuel. The tendency lack of natural resources will occur, such as decreasing the petroleum energy sources as fuel. Alternative ways should be chosen to tackle this issue. Biomass is the residual from plant or animal that can be renewable and has potential to generate energy for electricity. Agricultural residual can produce bio-briquette. Biomass is an abundant waste materials and need to promising alternative to reduce the wasting of biomass. The production of bio-briquette from waste material such as coconut shell will increase population growth and improved living standard of agricultural waste (Zubairu *et al.*, 2014).

The increasing categories of agricultural waste becoming a rapidly growth problem as rotten waste agricultural biomass emits methane and leachate while open burning are occurred. Preparation of coal briquette is prefer than raw coal due to the briquette has smokeless, strong and low emission fuel that can be used safely on domestic and commercial applications (Habib *et al.*, 2013). Other than that, production of bio fuel from biomass can be pelletized to improve its undesirable characteristic such as poor transportation, storage properties and troublesome to co-fire with coal (Hu *et al.*, 2015). Due to increase of agricultural waste, an alternative was found to replace an expensive energy resource which is coal briquette was made up from indigenous coal reserves. It can provide fuel local residential and commercial market.

Furthermore, usage of agricultural waste is more efficient to decrease abundant of waste agricultural and deforestation problem can be controlled. The lack of capital among household in rural communities make it difficult to move from firewood or charcoal, the bio-briquette from agricultural waste can help to reduce capital for producing fuel. Besides that, agricultural waste such as coconut shell serve a cheaper and affordable alternative fuel energy for domestic application (Tembe *et al.*, 2014).

The studies on bio-briquette show that coal briquette's quality depends on the type of binder used, ratio of binder in composition of briquette, moisture level and briquette particle size.

1.3 Research Scope

Mechanical testing will be conducted to determine the strength of bio-briquette effect by variety of binder's content in briquette. Study will be conducted to coconut shell by adding molasses or starch binder with ratio 100:0, 80:20, 60:40, 50:50 and 40:60 to identify the briquette properties such as tensile strength, durability and high heating value. Selection of natural binder used depends on their properties and availability in briquette. The potential of coconut shell residual as briquette will make it suitable in this study.

1.4 Research Objective

The objectives of this study are:

i. To synthesize bio-briquette from coconut shell

ii. To investigate the compressive strength of bio-briquette with different type of binder and different binder ratio

iii. To determine the effect of different geometry on bio-briquette production

CHAPTER 2

LITERATURE REVIEW

2.1 Biomass

The third largest primary energy resource in the world is biomass. Biomass is the domestic energy resources that are naturally present by plant or animal and could be a promising renewable energy. Due to the depleting of the natural resources or petroleum energy, alternative energy has been in the centre of attention from many researchers.

Biomass fuels are long term potential sources that can be renewable because of it is abundant and have ability to generate CO_2 neutral. Biomass can exist in many forms such as animal or plant. Biomass can generate energy when it converted, during the combustion process the emission of CO_2 from the combustion biomass is equal in value to the amount of CO_2 absorbed during its growing cycle, it causes the net CO_2 is almost zero by mass.

Biomass can be utilized as fuel in form of solid, liquid or gas. Biomass waste is very independent fuel resources which could avoid the reliance on non- renewable energy supply and improving sustainable of economic. However, there are challenges need to be addressed for biomass application such as to their high moisture content, irregular shape and sizes and low bulk density. Biomass constituent is an environmentally friendly sources since it is a carbon neutral sources of energy (Montiano *et al.*, 2015).

Furthermore, biomass is very difficult to handle, transport, store and utilize is in its original form. One of the solutions to these problem is densification of biomass material into pellet, briquette or cubes (Kaliyan *et al.*, 2009). Variety of biomass in this world is from plant and animal. The most common biomass that applied in manufacturing of biomass material is groundnut shell, cotton sticks, bagasse, coffee husk and coconut shell. Each type of biomass material has its own characteristic and properties. For example groundnut shell, which is widely used as biomass material due to their properties that contain low ash about 2-3% and the moisture content less than 10%. Besides that, it also has an excellent material for briquetting production (Grover *et al.*, 1996).

Other material is cotton stick, which is one type of secondary plant. Secondary plant is where the fibers come as by product from some other primary utilization. Cotton stick is the type of material required to be chopped and stored in dry form. It has tendency to degrade when storage and it also have higher content of alkaline mineral (Grover *et al.*, 1996).

Bagasse is also one type of biomass. This residue has high moisture content of 50% after milling and low ash content. Other than that, pith is the small fibrous in the bagasse that should be removed. Bagasse is also suitable in making of briquette.

2.2 Coconut Shell

In tropical countries like Malaysia, Indonesia and Thailand the coconut shell is the one of important natural fillers (Bhaskar *et al.*, 2013). According to Bhaskar *et al*. (2013), coconut shell filler is a potential candidate for the development of new composite due to their high strength and modulus properties. In tropical and subtropical area, coconut known as a great versatility in domestic, commercial and industrial uses of different parts of coconut palm.

The *plantae* order- *Arecales* of the family *Arecaceae* (Palm family), coconut palm *Cocos Nucifera L*. is one of the member of this family. Coconut can be referred to the entire coconut palm, the seed, or the fruits also not a botanical nut but it is drupe. Coconut has the exocarp and mesocarp layer that make up husk of the coconut. The mesocarp composed in fibers that called coir which is many traditional and various commercial uses (Okafor *et al*., 2012).

Bio-composite is the materials consist of biodegradable matrix and biodegradable natural fibers as reinforcement. Coconut shell is the one of the most important natural filler composite in tropical country. According to Sarkia *et al*. (2011), coconut shell mainly consists of carbohydrates compound such as cellulose, hemicellulose and lignin. The functional chemical composition entangled complex structures have a potential for the development of new composite.

Besides that, the potential of coconut shell to replace conventional synthetic fibers like aramid and glass fibers are increasing which can be used as a reinforcement in thermoplastic due to their low density, good in thermal insulation and mechanical properties, reduce tools wear and low price (Bhaskar *et al*., 2013).

The coconut shell also has hard wearing quality and high hardness (not fragile like glass fiber). In application, the coconut shell as a bio-briquette have attracted a lot interest due to the good acoustic resistance, moth-proof, not toxic, resistant to microbial and fungi degradation (Verma *et al*., 2016).

The most important factors that influence the making of briquette from coconut shell is the higher carbon content. Higher content of carbon in coconut shell improved the strength and yield strength of the composite or bio-briquette at all particle size (Agunsoye *et al.*, 2014).

2.3 Bio-Briquetting

Wood fuels such as (firewood, wood chips and wood pellets) are generally has lower in energy content but higher in combustion emission compared with fossil fuels (Guo *et al.*, 2015). High level of CO_2 emission, increasing the use of coke in metallurgical industries and it could be reduced if bio-coke obtained from renewable fuels were employed as feedstock (Montiano *et al.*, 2015). Bio-briquette is one of high densified biomass briquette, due to their manufacturing by high compression at moderate temperature. It has high mechanical strength and it be able with stand the compression strength in melting furnace (Nakahara *et al.*, 2014).

Raw agricultural residue has some disadvantages as an energy feed stock, include relatively low calorific value, difficulty in controlling rate of burning and larger volume or area required for storage (Hongliang *et al.*, 2014). Coconut shell briquette is very suitable for preparing carbon black due to an excellent natural structure and low ash content. Briquette is made from raw material and compacted into mould with different shape.

Bio-briquette has been developed to solve the supplementing the fuel requirement to the sosio-economic and fulfil the need of market. Bio-briquette is the alternative to convert coconut shell from low bulk density biomass into high density and energy concentrated fuel briquette. Bio-briquette can be produce by agricultural residue, such as coconut shell. For obtaining the smokeless fuel, an exploitation of good caking coal resources should be done (Zubkova *et al.*, 2014).

Biomass briquette has higher density that is almost twice compared than common wood. It also can improve its heating value and combustibility. Bio-briquette can be used for heat generation in household and small scale home industries or for power generation in large industries (Saptoadi, 2008). The parameter in coal briquetting process is briquette size on combustion behaviours determine the combustion kinetics. Sometimes small amount of conventional solid fuel, such as coal or char, is added into biomass briquettes to improve its heating value and combustibility (Saptoadi, 2008).

2.4 Advantages of Bio-briquette

Bio-briquette have many advantages compare to commercial coal, one of their advantage is it not contain sulphur and not pollutes the environment. Other than that, briquette will give much higher boiler efficiency due to low moisture and higher density (Sharma *et al.*, 2015). Briquette also have potential over traditional biomass fuels such as lower fuel costs for user and could be tailored to the particular usage.

2.5 Characteristics of Bio-briquette

Many effort have been made from researches for preparing the carbon black from agricultural residue by product such as coconut shell, apricot stones, sugarcane bagasse, nutshell and tobacco stems. In the production of coconut shell ash, coconut shell has a minimum economic value. Other than that, the coconut shell is very suitable in producing carbon black due to their low ash content (Olafadehan *et al.*, 2012).

Physical properties will be identified as the important characteristics in developing and processing the bio-briquette. For example is compressive strength or crushing resistance, impact resistance, abrasion resistance, weathering and density

(Rahul Sen *et al.,* 2015). All of these are related to the effectiveness of the agglomeration process such as strength and durability of the bond that hold the solid bio-briquette.

In fuel briquette production, it needs to be able to withstand the crushing loads they receive. It is a crucial factor in handling, transport, storage and firing the solid fuel. Weather also becomes more important for the long term storage in outdoor, but the briquette should survive the sometimes severe handling treatment.

There are no standardizes of acceptance level for strength and durability from biomass material (Kaliyan *et al.,* 2009). Strength of the bio-briquette tested by compressive and impact resistance strength. The purpose of compressive strength is to investigate the mechanical properties of bio-briquette (Antwi-Boasiako *et al.,* 2016). Compressive strength is the maximum crushing load a briquette can withstand before cracking or breaking. The load at fracture is recorded in stress-strain curve. The strength and the durability of bio-briquette depend on the physical forces that bond the mixture together.

Durability is the main parameter describing the physical quality solid biofuel like bio-briquette (Temmerman *et al.,* 2006). Moreover, fine particle and dust of biomass powder in production of bio-briquette will disturb feeding system of boilers and lead to inhomogeneous combustion process. Durability testing is very important in quality parameter to handle and transportation process of bio-briquette. High durability of sample means the high quality of product (Sakhare *et al.,* 2015).

The moisture content of bio-briquette fuels will decrease with the increasing of the fiber such as rice straw and sugarcane leaves. It is due to the lower amount of moisture where the moisture was removed from biomass due to compression during briquetting process (Jittabut, 2015).

The different in moisture content for material will cause greater variation in energy requirement where bio-briquette should not be too dry to increase energy demand during pressing (Antwi-Boasiako *et al.*, 2016).

The more influence factor in the production of bio-briquette is their moisture content of material. If the material moisture content at the briquette process is a very low or very high, material element are not consistent and it will make the briquette may fall into pieces and broken (Krizan.P *et al.*, 2011).

2.6 Carbonization Process

Carbonization process is a process where raw material firstly partially burning in an environment but a fresh air on environment should be control. This process is very important due to three factors. First factor, fuels are highly complex chemical and physical composition. Second is combustion takes place in an uncontrolled environment and lastly is moisture content and density of fuel material have negative effect on efficiency combustion especially for make testing (V. *et al.*, 2010).

2.7 Effect on Addition of Binder

Type of liquid or solid that forms a bridge, film, matrices or causes a chemical reaction to make strong inter-particle bonding is called binder or additives (Shyamalee *et al.*, 2015). Selection of binder add to mixture of briquette powder depend on cost and environmental friendly of the binder. The addition of additives will increase the briquette quality. It is desire for the binder material to be more combustible, though a non-combustible binder effective at low concentration can be suitable (Zubairu *et al.*, 2014).

There are two additives have two types of additives such as biological binder and chemical binder. For environmental friendly binder, selection of biological binder such as starch or molasses (sugar) could help to improve the quality of densified product. Addition of different binder also brings different effect to the briquette. When the higher amount of molasses binder added, the briquette durability would be higher. Molasses binders have better effect in sticking of particle bio-briquette resulting in stronger bonds of sample (Chirchir *et al.*, 2013). Furthermore, molasses bonding of bio-briquette has higher calorific values which could be due to improve characteristics.

While for the starch binder, it makes the durability and hardness of the briquette better. Bio-briquette with binder give lower compressive energy consumption than briquette that does not have binder (Hu *et al.*, 2015). Starch is one type of bio-based that completely biodegradable, renewable and inexpensive.

It also has strong intra and intermolecular bonding of hydrogen bond. The thermal decomposition temperature of starch is lower than its melting points. Starch will be poor ability to process directly used in plastic and composite (Jian Bing Zeng *et al.*, 2011).

Other factors that influence bio-briquette performance is when fine particle fill the intersection of larger particles and maximum contact surface between briquette and will affect the compressive strength. Another factor that effect the strength of briquette is briquetting temperature (Sun *et al.*, 2014).

2.8 Strength of bio-briquette

The strength of bio-briquette depends on the several factors such as moisture content, briquette particle size, time compaction, binder type and rate of carbonization. The important factor that affected the strength of bio-briquette is type and amount of binder use in production of bio-briquette (Habib *et al.*, 2013).

Other factors that affect the mechanical performance of briquette is the size of coconut shell powder. The strength of briquette will decrease when particle size are increases (Habib *et al.*, 2013). The size and shape of bio-briquette also affect the strength of briquette. The size and shape was studied by the stress on cylinder shape, square shape and ball shape.

CHAPTER 3

MATERIALS & METHOD

3.1 Study Area

Coconut shells were collected at local markets in Jeli, Kelantan. This study was conducted at Material Science Laboratory and Wood Laboratory Universiti Malaysia Kelantan, Jeli Campus.

3.2 Material

The material that have been used in this study is coconut shells as showed in Figure 3.1 which was cut into smaller pieces and followed by burning them. The coconut shells were carbonized in a furnace in the absence of air with temperature 300˚C for 15 minutes. After that, the coconut shell was grinded into powder form and put the prepared sample into zipped bag.

Then, starch and molasses as a binder was added in the mixture of production of bio-briquette. Instruments were used in this study are furnace, oven, grinding machine, sieve shaker, universal testing machine (UTM), hammer, beaker, container and mould with different shape. Figure 3.2 (grinding machine) and Figure 3.3 (oven) was shown the instrument was used in this study.

Figure 3.1 Coconut Shells

Figure 3.2 Grinding Machine

Figure 3.3 Oven

3.3 Method

3.3.1 Preparation of Sample

The coconut shells have collected and cleaned. Next, the coconut shells were dried under sunlight for three days to remove moisture content. The coconut shells were dried in oven at 150 ˚C for 45minutes. Then, coconut shell was crashed into smaller pieces. After that, carbonisation process was implemented to the sample. Carbonisation is one type of incomplete pyrolysis process. When the coconut shell was burnt in the furnace about 15 minutes at 300 ˚C, the coconut shell became more fragile and easy to break down. After that, the coconut shell was grinded to form coconut shell powder as shown in Figure 3.4.

Figure 3.4 Coconut Shell Ash

3.3.2 Preparation of Homogenous Sample

Grinder powder of coconut shell was sieved to the fineness powder. The different fineness size of the coconut shell powder particle have been carried out, where fineness (< 425μm mesh) have used. The sieve was shaken about 2 minutes to achieve a complete classification. Then, the coconut shell powder on each sieve was weighed before making bio-briquette.

3.3.3 Preparation of diluted starch

Powder starch was weighed 10 g and mixed with 10 ml distilled water. 50ml distilled water was heated using hot plate until it reached 100˚c as shown in Figure 3.5. Diluted starch was mixed with boiled water and stir continuously. After that, the mixture should be cooled and wait until diluted starch become coagulated. The prepared starch and molasses was shown in figure 3.5.

Figure 3.5 Prepared starch and molasses

3.3.4 Bio-briquette Production with Addition of Binder

For production bio-briquette, the coconut shell powder was mixed with binder. Binder was added to enhance the compactness of briquette and prevents it from falling apart. For preparation of binding material starch or molasses was added to water in 10:1. Five samples were produced with different ratio of coconut shell powder to binder. The binder was added with different ratio that is 20%, 40%, 50%, 60% in production of briquette sample.

Then mixture was added into cylinder mould that has 8.5 cm height. The weight of five samples is equivalent to get accurate result. The weight of every sample is 150 g. After the mixture was added into the mould, the sample was compressed with 1kg load on the sample and the sample was held about 10 minutes to constant and relaxation. The sample should be dried under sunlight for 3 days. The sample was kept in the oven at 150˚C for 15 minutes. Table 3.1 shows the composition of mixture in the sample.

Table 3.1 The composition on mixture of bio-briquette sample

Type of binder	Ratio of coconut shell Powder	Ratio of binder
Starch		
Sample A	100	0
Sample B	80	20
Sample C	60	40
Sample D	50	50
Sample E	40	60
Molasses		
Sample 1	100	0
Sample 2	80	20
Sample 3	60	40
Sample 4	50	50
Sample 5	40	60

3.3.5 Bio-briquette Production with Different Geometry

Three samples were prepared for each combination of coconut shell powder and binders. The mixture of sample was put into mould with different shape namely all shape, square and cylinder. The weight for every sample was constant and it consisted of 80% of coconut shell powder and 20% of binder. Example of different briquette shaped was shown in Figure 3.6. Table 3.2 showed the composition of bio-briquette with various shape.

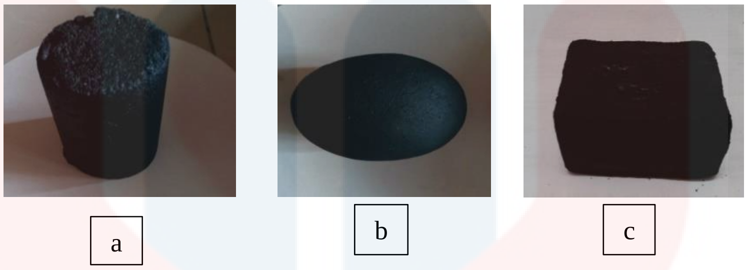


Figure 3.6 Sample of bio-briquette (a) cylinder shape (b) sphere shape (c) square shape

Table 3.2 The various of bio-briquette shape

Sample		Shape of mould
Coconut shell with starch (80:20)	Coconut shell with molasses(80:20)	
A	1	Cylinder
B	2	Square
C	3	Sphere (Ball shape)

3.3.6 Analysis of Ignition Bio-briquette by Durability Test

Six samples with different geometry were tested in this testing. Three geometry of bio-briquette was selected that is ball shape, square and cylindrical with binder molasses and starch. To determine the burning rate of sample bio-briquette, it was dried at 150˚C in oven for 15 minutes. Then it was placed on steel wire mesh on grid resting on the top of Bunsen burner. All the samples with different geometry were tested. The time of sample started to ignite was recorded.

3.3.7 Mechanical Properties Test

The compressive strength which is the maximum stress a material can withstand without failure was determined. For testing purpose, the briquette will be measured by using Universal Testing Machine (UTM). It was tested by compression strength test using compression testing machine.

For the compressive resistance or hardness measurement testing, all samples were prepared with the same diameter and height namely 12.5 mm and 8 mm. The sample with different composition of mixture was tested. The load applied for this testing was 1.000 N with speed 10.00 mm per min. The increasing load was applied at constant rate until the sample collapsed by cracking or braking. The sample was placed between plates of machine, with uniform stress distributed. The forces versus sample fracture time were recorded. Figure 3.7 showed example of compressive strength testing machine.

Figure 3.7 Compressive strength test of Bio-briquette

3.3.8 Impact Resistance Test

ASTM D440-86 method has been used to determine the impact shatter index. The impact resistance used to present the durability values of bio-briquette sample. The test was conducted after two weeks of bio-briquette to ensure the sample completely dried. Sample was placed in the polyethylene plastic bag. Sample was dropped from 1.83 m height onto the sample. The unbroken sample was separated and dropped again maximum three times.

Initial weight was weighed and the average weight of sample after dropping was calculated. The shatter resistance as percentage loss of weight from shattering was calculated by Equation 2 (Kaliyan *et al.*, 2009). The shatter resistance is the percentage of unbreakable sample.

Percentage of weight loss, % = $\frac{\text{Weight of the sample after drop}}{\text{Weight of sample before drop}} \times 100$ **--Eq 1**

Shatter Resistance = 100 – Percentage of weight loss **--Eq 2**

Figure 3.8 was showed the method in production and testing method on bio-briquette sample.

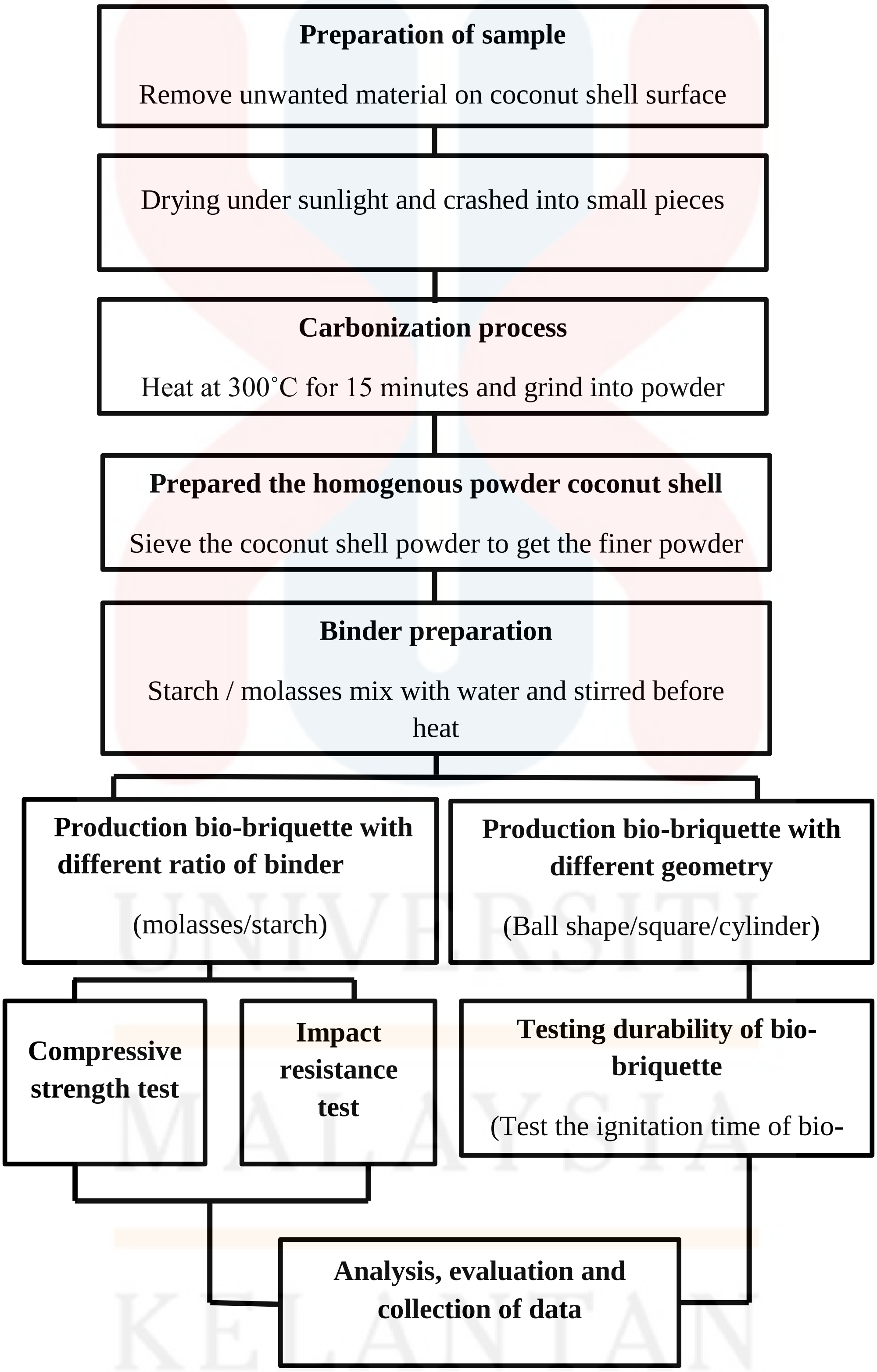


Figure 3.8 Flowchart of production of bio-briquette

CHAPTER 4

RESULT AND DISCUSSION

4.1 Overview

Bio-briquette with different binder was produced. Three testing was conducted to investigate the strength of bio-briquette. The testing of the bio-briquette's testing that is mechanical test, durability and impact resistance test.

Compressive testing method is testing the maximum crushing load of bio-briquette can withstand before cracking or breaking. The compressive strength is necessary to manufacturing industry, and storage.

Durability testing was conducted to analyse the bio-briquette's time to ignite. The sample was exposed to the flame and the time sample ignite was taken.

The falling strength of briquette was measured through weighing the weight after the sample dropped. The briquettes were dropped on the floor from 1.83 cm repeatedly about three times. Drop test of impact tested can be used to determine the safe height of briquette production during mass production. ASTM D440-86 method has been used to determine the impact shatter index.

4.2 Analysis of Bio-briquette by durability test

Different geometry of bio-briquette has different surface area and volume. Surface area is a one parameter that was affected the combustion fuel due to the surface contact with flame. Before the sample dry each sample has same amount of coconut shell (120 g) and each binder (30 g). The table 4.1 showed the sample of bio-briquette with different geometry have been influenced the ignition of bio-briquette. Figure 4.1 showed the relation of rate of combustion of briquette with geometry of bio-briquette. Table 4.2 showed the volume and surface area of each shape of sample.

Table 4.1 Time for bio-briquette ignite

Sample	Weight sample before dry	Weight of sample after dry	Time for bio-briquette ignite
Coconut shell powder : Starch A (cylinder)	150g	133.78g	9m 19s
B (square)	150g	87.08g	7m 25s
C (ball shape)	150g	147.53g	5m 07s
Coconut shell powder : Molasses 1 (cylinder)	150g	128.07g	2m 21 s
2 (square)	150g	89.09g	1m 04 s
3 (ball shape)	150g	137.00g	51 s

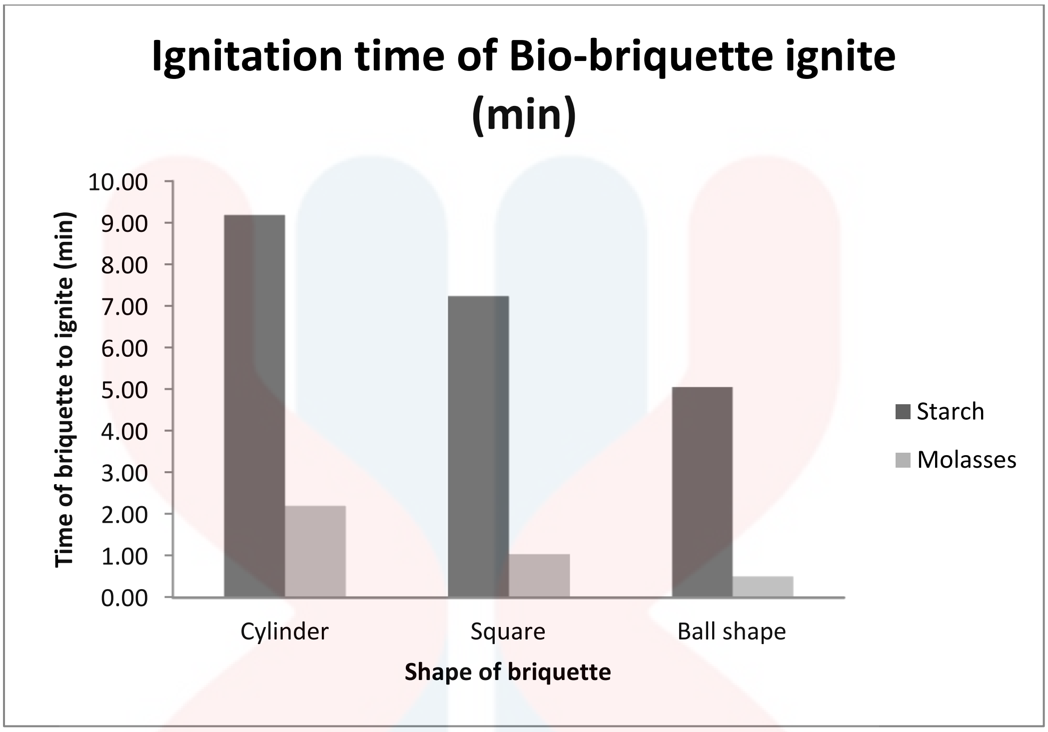
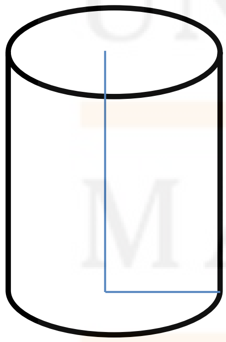
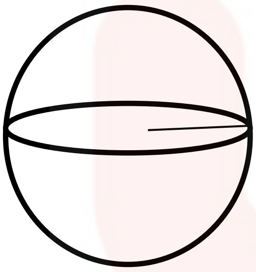
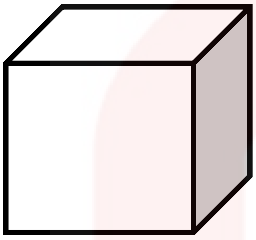


Figure 4.1 Ignition time for different geometry briquette

Table 4.2 Surface area, volume and base area of bio-briquette

Shape	Volume	Surface Area	Base Area	Time for bio-briquette ignite	
				CS with Molasses	CS with Starch
h= 8.50cm **r= 2.75cm** 	**V** = $\pi r^2 h$ = 201.95cm^3	**S$_a$** = $2\pi rh + 2\pi r^2$ = 194.39cm^2	**Ba** = πr^2 = 23.76cm	**2m21s**	**9m19s**

r = 2.75cm 	**V =** $\frac{4}{3}\pi r^3$ = 87.11cm^3	**S$_{a}$ =** $4\pi r^2$ = 95.03cm^2	**Ba =** πr^2 = 23.76cm	**51s**	**5m07s**
A =5.5cm 	**V = α^3** = 166.38cm^3	**Sa = 6α^2** = 181.5cm^2	**Ba = α^2** = 30.25cm	**1m04s**	**7m25s**

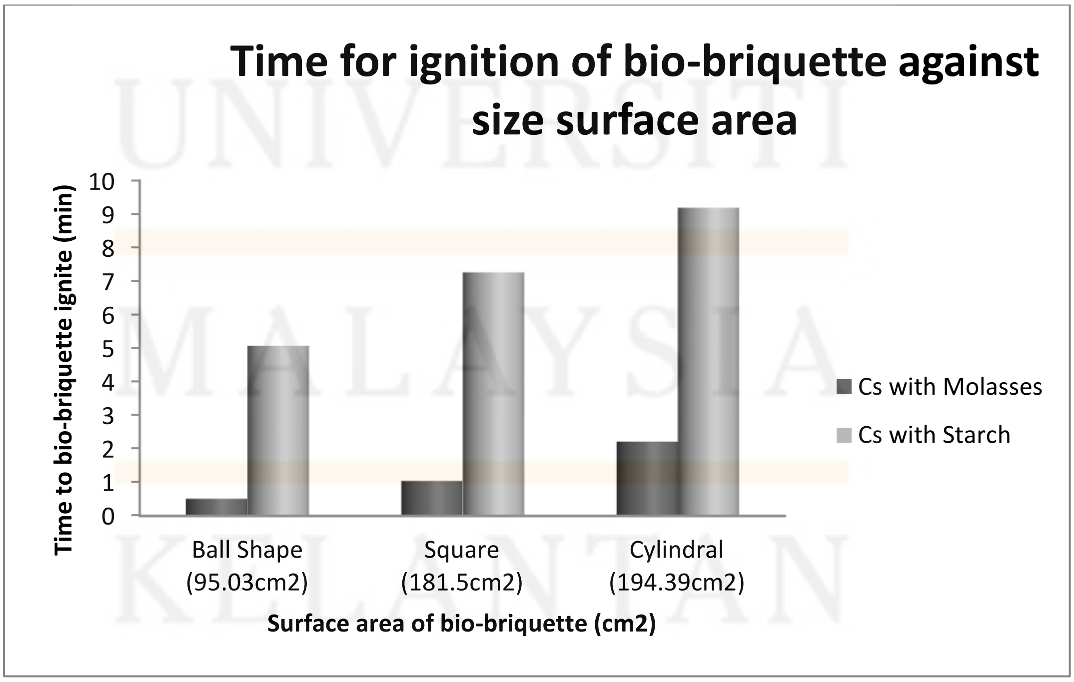


Figure 4.2 Geometry of bio-briquette with different surface area against the time for ignition

Effect of different geometry of briquette

In order to investigate the effectiveness of bio-briquette for ignited, geometry of bio fuel influenced the time of bio-briquette ignited. It is due to the variety geometry of sample has different surface area that contact with flame during testing. Table 4.1 and figure 4.1 showed the relationship between geometry of bio-briquette with time for briquette ignited. Durability test was conducted for looked into characteristics of burning from combustion kinetic point of view.

Before testing, briquette required to undergoes heated process for make sure the briquette dried completely. Six samples have been prepared that is three samples bio-briquette with molasses (1, 2, 3) and bio-briquette with starch (A, B, C). Each briquette was ignited by placing a Bunsen burner on a platform 4 cm directly beneath. Bunsen burner was used to ensure that the whole of the bottom surface of the briquette was ignited simultaneously after adjusting it to blue flame. Several cautions were taken to avoid flame spread in the transverse directions. The burner was left in until the briquette was well ignited and time was recorded when briquette start to ignite.

Firstly, the bio-briquettes ignition efficiency and the effectiveness of combustion depend on type of binder used. It also depends on the amount of binder use and water addition in the mixing of bio-briquette. Molasses and starch binding agent apply in the production of bio-briquette with different geometry. From figure 4.1 it can see the bio-briquette with molasses take shorter time to ignite compared to bio-briquette with starch. Heating value is the most important combustion properties in determining the suitability of the material used in the production of fuel. The effect of type of binder and compactness of briquettes was reported. Chirchir et.al 2013 showed that the clay binder has longer ignition time compared to molasses binder.

Due to the presence of incombustible matter form of ash in clay bonding briquette might slow down the flame propagation because clay and starch has low thermal conductivity. The effect of binder and amount present on briquettes is very important factor in combustion and burnt. Surface area of is another factor that effect the durability of briquette and performance of briquette for ignite. It has been observed the size of briquette has a large influence on the combustion and stability on the final briquette formed.

Refer to figure 4.2 the recorded highest ignition time (9 minutes 19 second) recorded for cylinder shape briquette with starch (sample A) could attribute to high surface area of briquette compared to other sample. While cylinder of briquette with molasses (sample 1) it took 2minutes 21 second to ignite. The surface area of cylinder bio-briquette is 194.39 cm^2. For sample square shape of briquette with molasses (sample 2) it took 1minute 04second to ignite while for sample square with starch (sample B) it took 7minutes 25second. The sample surface area of square is 181.5 cm^2. It can conclude that ball shape briquette with molasses (sample 3) easily to burn compared to ball shape briquette with starch (sample C). Sample 3 only take 51 second to ignite compared to sample c 5 minutes and 7 second. It was observed that ball shape has smaller surface area (95.03cm2). It was found that the lower surface area of briquette, the shorter the ignition time of briquette.

This study is quick related to the research from (Onnuegbu *et al.*, 2011), overcame that the factor that control the burning rate of material are chemical and geometry that is the bulk, packing and orientation of the material. Other than that, the increasing the proportion of the biomass is expected to increasing burning rate of the bio-briquette. In term of the quality of bio-briquette, this can concluded that an excellent bio-briquette can be product with ball shape with molasses due to the sample easily to ignite.

4.3 Mechanical properties test

Compressive strength of briquette is a one type of mechanical strength testing. Figure 4.3.1 and figure 4.3.2 showed the sample of bio-briquette before testing. Each sample has similar height and diameter that 8mm and 12.5mm.

Figure 4.3 Sample for compression testing

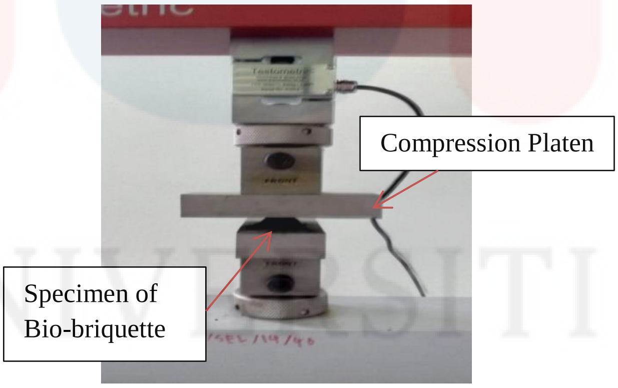


Figure 4.4 Compressive Machine testing

Table 4.3 and 4.4 present the result from compression testing. These result clearly indicate that binder contain apply onto the sample has a major impact on the bio-briquette compressive strength.

Table 4.3 Force (N) for breaking sample

No	Composition	Force @ Peak (N)	Def. @ Break (mm)	Youngs Modulus (N/mm²)	Def. @ Break (mm)
1	100% Coconut Shell	13.100	2.925	0.001	2.925
2	80% Coconut Shell : 20% Molasses	15.600	2.530	0.001	2.520
3	80% Coconut Shell : 20% Starch	33.500	3.988	0.003	3.988
4	50% Coconut Shell : 50% Molasses	7.400	3.949	0.002	3.949
5	50% Coconut Shell : 50% Starch	75.700	3.999	0.017	3.999
Min		7.400	2.520	0.001	2.520
Mean		29.060	3.476	0.005	3.476
Max		75.700	3.999	0.017	3.999
S.D.		27.839	0.703	0.007	0.703
C. of V.		95.799	20.228	144.296	20.228
L.C.L.		-5.506	2.603	-0.004	2.603
		63.626	4.349	0.013	4.349

Table 4.4 Data of Compression Testing

Test No	Composition	Def. @ L.O.P. (mm)	Force @ Yield (N)	Force @ L.O.P. (N)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)
1	100% Coconut Shell	1.733	5.400	14.500	0.000	0.000
2	80% Coconut Shell : 20% Molasses	2.915	3.500	12.800	0.000	0.000
3	80% Coconut Shell : 20% Starch	2.922	7.100	23.600	0.001	0.001
4	50% Coconut Shell : 50% Molasses	3.534	3.200	5.400	0.000	0.000
5	50% Coconut Shell : 50% Starch	1.290	22.100	21.800	0.001	0.001

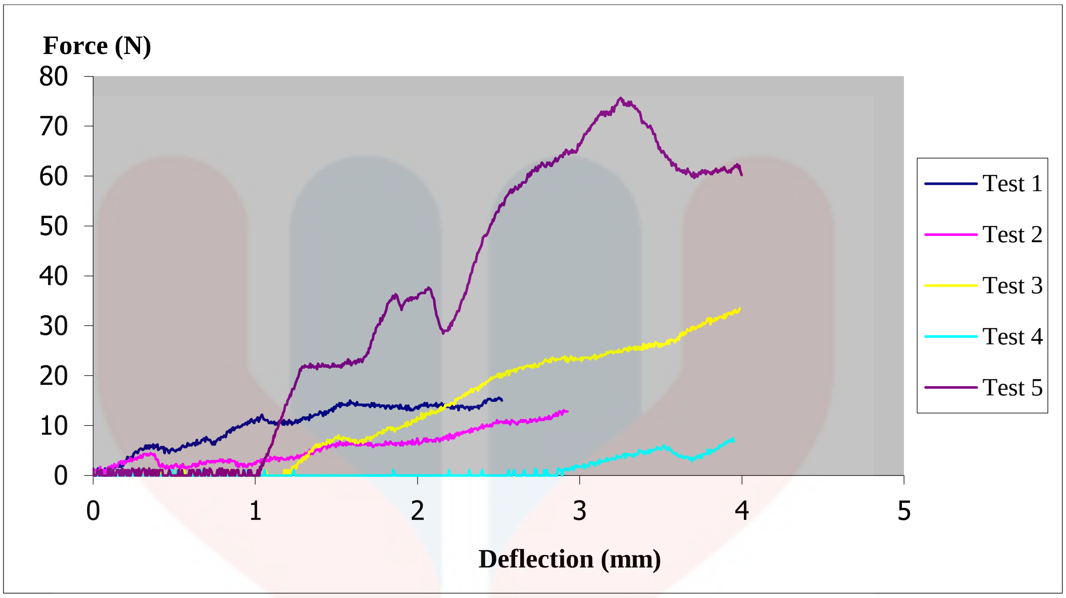


Figure 4.6 Force against deflection of bio-briquette

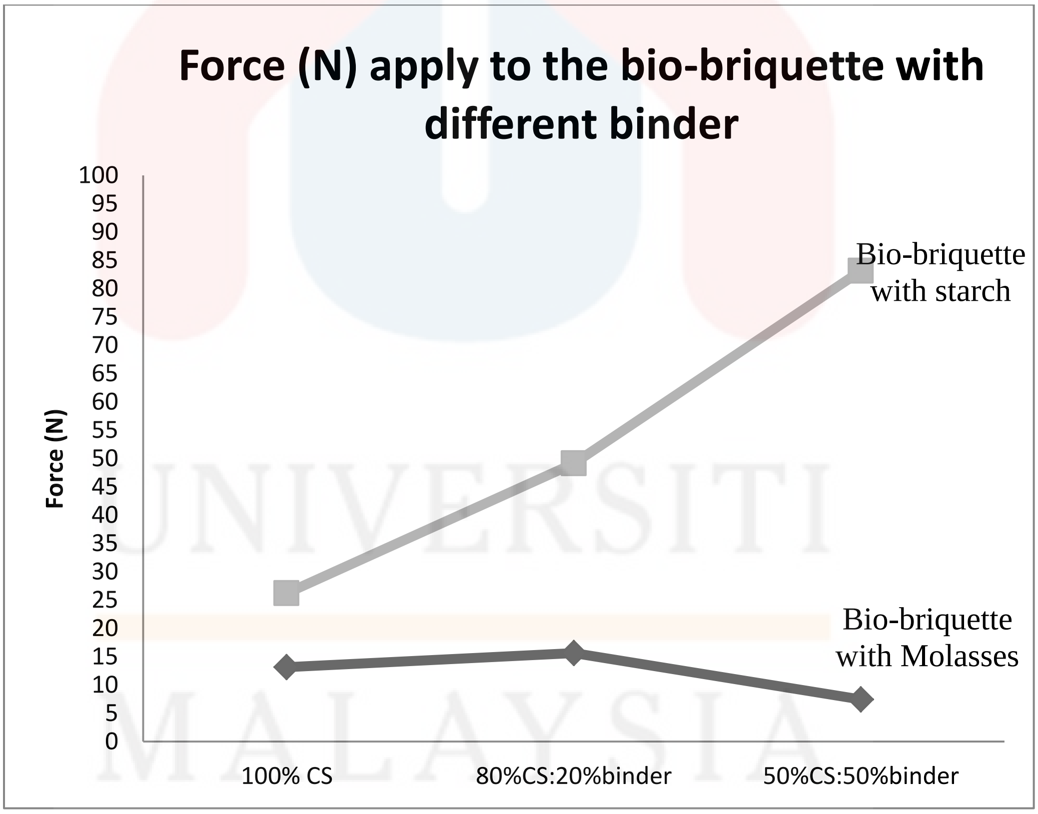


Figure 4.7 Compressive strength of bio-briquette as a function of the binder

Mechanical strength of briquette depend on the amount of binder

Compressive strength is the maximum crushing load of bio-briquette can withstand before breaking. The test was conducted using a Universal Tensile Machine (UTM). An increasing load is applied at a constant rate, until the briquette fails by breaking or cracking. In this testing, the load applied are constant it to investigate the force needed to break or crack the sample. 5 samples with different binder and ratio of binder were tested. The samples have been tested is sample 100% coconut shell, 80% CS 20% molasses and 80% CS 20% starch, 50% CS 50% molasses and 50% CS 50% starch. For this testing, actually 9 samples were prepared but another 4 samples do not completely dried after 7 days due to high composition of binder.

The compression testing was discussed in this section completely with load rate applied 1.0 N of load on the surface of sample with speed 10.00 mm per minute. All samples has 8 mm height and 12.5 mm diameter. From this testing, it was observed the effect of the binder content different for the various types of binders and binder ratio. The force needed to break the no binder bio-briquette is 13.100 N. The compressive strength of bio-briquette with molasses is not too much different with no-binder bio-briquette. The compressive strength of sample briquette with adding molasses are decreasing with increasing the binder content from (20% to 40%). While force compressive strength of bio-briquette with molasses binder will decreasing when increasing the binder content that is from 15.60 N when 20% binder to 7.40 N when 40% binder. While for bio-briquette with adding molasses are increasing with increasing the binder content from (20%- 40%). The force compressive strength of bio-briquette with starch binder will increase when increasing the binder content that is from 5.50 N when 20% binder to 33.00 N when

40% binder. The mechanical strength of the bio-briquette related to the bonding and transformation process with bio-briquette mixture. The bonding forces involving in the production of bio-briquette was related to the hydrogen bonding, van der waals forces and mechanical properties as reported by (Hu *et al.*, 2015). High breakage level during handling, transportation and storage affected when the mechanical hardness of bio-briquette is weak. Several reports from (Hu *et al.*, 2015) have shown that starch can be prevent as potential binder from point view of energy saving and hardness strength. The mechanical strength of binder starch and molasses was related to the bonding and transformation process with bio-briquette mixture. The bonding forces in the binding agent include the van der waals, hydrogen bonding and mechanical interlock.

4.4 Impact test

This test was stimulated the forces detected during empty of densified products from the height 1.83m onto the ground. Table 4.5 showed the sample of bio-briquette with molasses before and after impact testing. Table 4.6 showed the sample of bio-briquette with starch before and after impact testing.

Table 4.5 Result for impact testing of bio-briquette with molasses binder

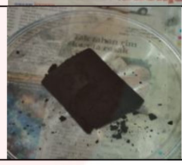
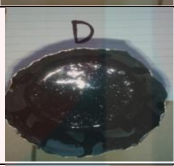
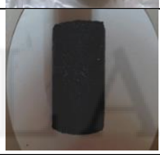
Sample (Molasses)	Before apply impact	After apply impact
A		
B		
C		Not Available
D		Not Available
E		Not Available

Table 4.6 Result for impact testing of bio-briquette with starch binder

Sample (Starch)	Before apply impact	After apply impact
A		
B		
C		
D		
E		

Shatter resistance index by impact testing

Sample weight before testing is 150.00g. Table 4.7 showed the average weight of bio-briquette after tested. The shatter test was aimed to investigate the percentage of weight loss of briquette after dropped the sample. A sample was placed into the zipped bag before falling to ground from height 1.83m. The result of the impact test was preview on the figure 4.8 and 4.9.

Table 4.7 Calculation of percentage weight loss and shatter index

Sample	**Weight after dropped, 1 (g)**	**Weight after dropped, 2 (g)**	**Weight after dropped, 3 (g)**	**Average weight (g)**	**Percentage weight loss ,%**	**Shatter Resistance Index, %**
Sample Molasses A	137.40	68.60	32.32	79.44	47.04	52.96
B	139.15	138.80	133.22	137.06	8.63	91.37
C	NA	-	-	-	-	-
D	NA	-	-	-	-	-
E	NA	-	-	-	-	-
Sample Starch 1	137.40	68.60	32.32	79.44	47.04	52.96
2	147.35	140.07	137.80	141.74	5.50	94.50
3	120.00	117.23	111.44	116.22	22.30	77.70
4	117.00	115.77	90.60	107.79	28.14	71.86
5	112.00	109.16	77.01	99.39	33.74	66.26

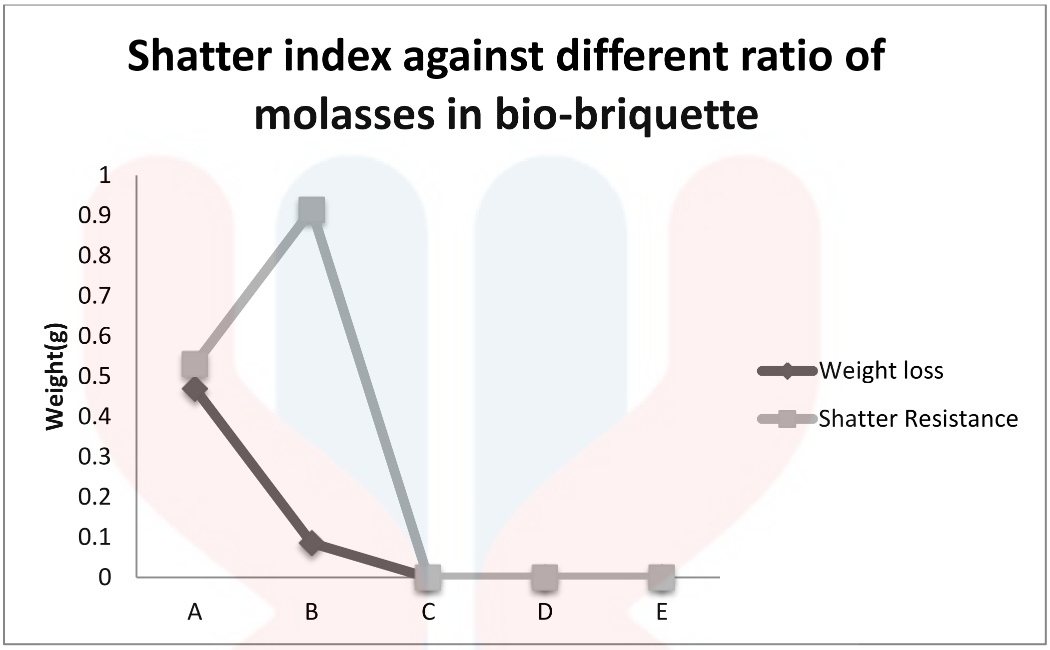


Figure 4.8 Effect of different ratio of molasses binder in bio-briquette

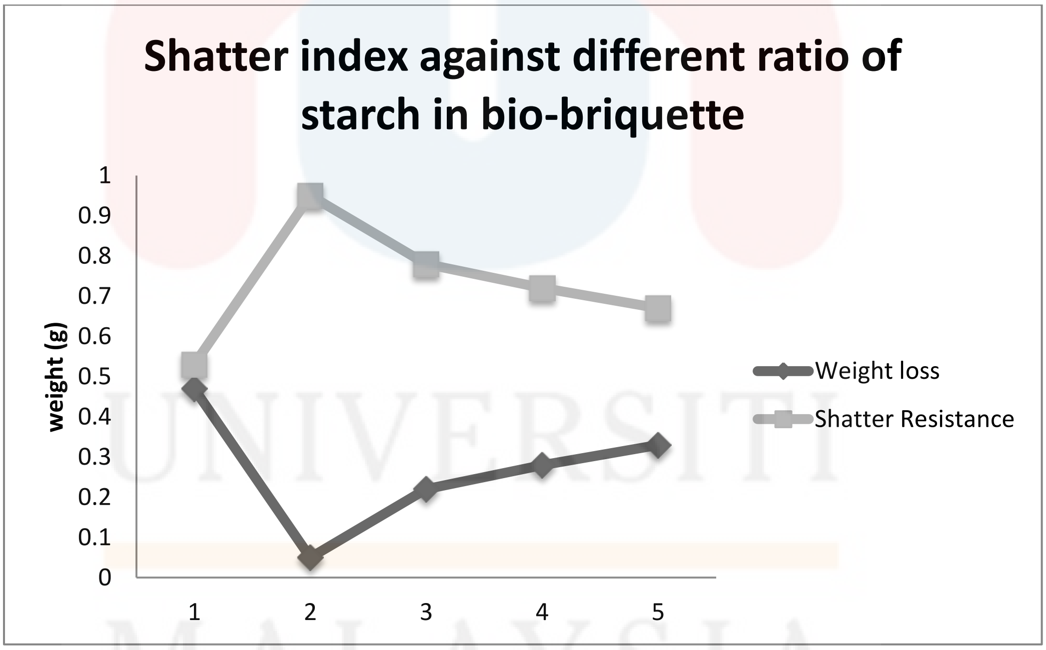


Figure 4.9 Effect of different ratio of molasses binder in bio-briquette

Percentage of weight loss and shatter resistance of bio-briquette

Five samples of briquette with starch have been labelled with 1,2,3,4 and 5 while briquette molasses are labelled with A, B, C, D and E. The briquette was obtained carbonization process before testing that is all sample should dried in oven at 150˚c about 30 minutes. Impact testing was conducted to investigate the effect of binder selection for bio-briquette's strength. This testing was defined the optimum amount of binder (molasses and starch) required for briquette prepared. 10 briquette samples have been tested and the percentage of weight losses was recorded. Percentage weight losses mean the break of sample. The weight of unbreakable sample was measured known as shatter resistance index and the sample dropped onto the ground about 3 times. The average of sample weight was recorded.

The usage parameter in this testing is different type of binder and their ratio in the composition if bio-briquette. The result obtained was shown in figure 4.8 and 4.9 effect of different percentages of starch and molasses on the dropping weight loss on the bio-briquette produced by apply 2kg load as pressure with constant amount of water that is (20%). In this testing, 10 samples were conducted to investigate strongest bio-briquette when the sample was dropped from 1.83m height.

The current study found as shown in figure 4.8 the result of different ratio of molasses as an addition on bio-briquette. As can be seen from the graph, the briquette contain 100% coconut shell is the highest percentage of weight loss that is 47.02% while the shatter resistance is 52.98% compared to briquette contain of binder. The higher percentage of weight losses mean the sample has low strength compare to others. Sample B has smaller weight loss that is 8.63% but it has higher shatter resistance 91.37%. Sample C, D and E briquette made up from molasses as binder but all sample not completely dried due to the higher amount of molasses. From the graph shown the best stronger bio-briquette is sample B consist of 80% coconut shell and 20% molasses.

Figure 4.9 showed the result of different ratio of binder as an addition on bio-briquette. Sample 2 has 5.5% of weight loss that is the lower weight loss but stronger shatter resistance 94.5%. Sample 3 brought 22.30% weight loss and 76.70% shatter resistance. While sample 4 has 28.24% weight loss and 71.66% shatter resistance. Sample 5 loss 33.74% from the sample weight and 63.26% shatter resistance. From this experiment the stronger bio-briquette is sample 2 that contain 80% coconut shell and 20% starch.

When the shatter index rating was carried out, it was discovered that the binder used gave a relatively stable briquette. Shatter index of ratio 80%: 20% bio-briquette with starch obtained in 94.50% bonded briquettes was significant higher than bio-briquette with molasses in 91.37% bonded briquette. It can be predicted that starch bonded can withstand a good mechanical handling better that molasses bonded and it match those observed in earlier studies by (Sotannde *et al.*, 2010).

Furthermore, sample 2 has less weight loss compared to sample B due to the type of binder used. Properties of starch is more plasticity compare to molasses. From this figure it clearly show the amount of starch was increased the dropping damage impact. This is due to the plasticity of bio-briquette because starch is a colloidal material having a higher surface area.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As a conclusion, the palletization of bio-briquette has been synthesized from coconut shell powder with addition of binder. Production of biomass materials into briquette can help to overcome the problem and reduce problem with handling, transportation and usage to industry and household. In production of good strength and durability of bio-briquette the selection of binder, ratio of binder used and geometry of bio-briquette are important factor that affect the good briquette. In this studies, the durability testing was conducted by recorded the time of bio-briquette ignite.

The strength durability bio-briquette was determined that is the ball shape bio-briquette has shorter time to ignite compared to square and cylinder bio-briquette. The strength of the bio-briquette with different ratio of binder was investigated. During impact testing, the strong bio-briquette is briquette made up from coconut shell powder and starch as a binder. The maximum starch composition is 80% CS: 20% starch. The compressive strength of bio-briquette with different type of binder was determined. The bio-briquette consist starch brought maximum value of forces to break the sample.

Binder use is the most important factor that was affected the bio-briquette performance. The selection of binder should be eco-friendly, give a better performance to the rate of combustion. As an alternative to binders, stable briquettes can be formed by blending residues that would needed a binder with residues or processing wastes that naturally bind well, for example blending decomposed banana skins with coconut shell powder. Bio-briquette without binder, the strength of the briquette is very low, so it necessary for adding the binder in the briquette production. There is a need to develop standard on the minimum acceptance level for the strength such as compressive strength, impact resistance and durability testing of the production of bio-briquette are discussed.

5.2 RECOMMANDATION

Further investigation and experimentation into bio-briquette is strongly recommended. The studied suggested this future research such as the technique of production bio-briquette. In form of producing a strength bio-briquette the process making the product is very important. The pressure apply is necessary technique cannot be skip. Pressure should be applied to mixing of waste material and binder by using compaction machine.

Bio-briquette are made up for agricultural waste, the higher carbon content in plant is a factor that enhanced the production of bio-briquette. In future studied, other agricultural waste can be used in producing bio-briquette such as sawdust, coir, groundnut shell, bagasse, bamboo, barks or husks. The selection of waste agricultural was effected the performance of bio-briquette. Low moisture contents and high calorific value is better waste used on production of bio-briquette.

In future experiment, the effect of briquette moisture content should be test due to determine the normalized burn rate. The production of bio-briquette with different binder was carried the different moisture content and effect the rate of combustion.

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