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Effect of Binders on EFB Bio-briquettes of Fuel Calorific Value

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Abstract— **The development of biomass has been assumed as an important issue in the past several decades and would remain to be attractive in the future due to its clean, renewable, and carbon–neutral properties. Biomass is one of the most important renewable energy resources in the world. In recent decades, the utilization of biomass has dramatically increased. There were many reasons. First, biomass is a renewable resource, because of the availability of biomass is unlimited, and its regenerative process runs well. Second, the extraction of biomass energy can be carried out more flexible. The biomass can be burned directly without high technology. Biomass bio-briquettes are often used as an energy source for cooking purpose and in some industries. The bio-briquettes are produced by densification of waste biomass using various processes. In this, the study manual densification of bio-briquettes was tested by three different binding agents; cassava flour, sago flour, and starch flour. The objective of this study was to compare different binding materials in the production of Empty Fruit Bunch (EFB) bio-briquettes between binders. The binder is used as a mixture on the EFB fiber. Three types of the binder are cassava flour, sago flour and starch flour are used as comparators to obtain high heating value. The percentage of binder in each sample is 2%. The ratio of the use of water as a diluent between the fiber and the adhesive is 1: 5. Samples of solid cylindrical shape diameter 4 cm and 5 cm high and density sample is 0.8 g/cm3. The pressure is used to generate samples specified in the mold volume. The volume of the cylinder is 62.8 cm3. The adhesive cassava with a percentage of 2% can provide power to the sample mechanically by a drop test at the height of 1.20 m. The result shows that the binder cassava has fuel calorific value average is 3661 cal/g, a binder of starch 3584 cal/g and sago 3537 cal/g. Results indicated that sample binder cassava flour has calorific fuel value higher than sago and starch flour.**

Keywords— **EFB, binder; bio-briquettes; strength; fuel calorific value.**

I. INTRODUCTION

Increasing environmental and energy dependency concerns have been the motivation for the increased use of bioenergy as a substitute for fossil energy in both space heating and electricity generation. The development of biomass has been an important issue for the past several decades and would remain to be attractive in the future due to its clean, renewable, and carbon–neutral properties [1]. Energy and fuels are the critical links in the civilization and human development. The issues associated with the use of the fossil fuel, demand and supply gap, ever increasing prices, global warming and other environmental issues made the world to think for alternate sources of energy like solar, wind, ocean and biomass which are the only indigenous renewable energy sources capable of replacing large amount of solid, liquid and gaseous fossil fuel [2].

Biomass energy has attracted as one of the potential alternatives as it is an ideal renewable energy source with several advantages like lower sulfur, CO neutral emission, and abundant availability generally in the form of waste from agriculture as well as other 2 sources. Bioenergy derived from biomass is a promising, inexhaustible, sustainable source and can help in minimizing the rising environmental, economic, and technological issues related to depleting fossil fuels [3]. Utilization of waste for deriving secondary fuel has received a worldwide acceptance as it can provide fuel and at the same time solution to waste disposal maintaining the environment.

Palm oil is one of the commodities traded agricultural products, both for domestic and export industries. Following the processing of palm oil, eventually leaving palm Empty Fruit Bunch (EFB), which generally are not processed again by the oil industry in the processing of palm oil. Remaining empty bunches, this poses a problem for venues and transportation disposal resulting in additional production costs for the processor. EFB in exile usually burned, it also creates problems for the environmental damage that air pollution and odor [4] – [8].

Another problem is the disposal of palm oil mill and burning EFB. Disposal EFB without control to land in palm groves, resulting in piles of biomass EFB in huge quantities.

Therefore EFB an organic material, it will happen in a big pile of anaerobic decomposition process or a process of decay large scale. Based on the discussion of some issues and see the potential pollution background to the environment then EFB waste must be managed wisely in order to demand the use of biomass renewable energy alternative, biomass utilization technologies and produce heat energy that can be used by the public.

One of the optimistic technologies for alleviating these problems is briquette, which has been revealed by many studies. The technology may be defined as a densification process for improving the handling characteristics of the raw material and enhancing the volumetric calorific value of the biomass. A considerable amount of research on briquette technology has been conducted [5].

Optimization of adhesive levels and waste biomass briquette is one of an essential factor in making briquettes. The addition of adhesive levels in the briquettes will increase the calorific value of briquettes such as the addition of the element carbon. However, when granting an excessive amount of adhesive, it will affect the ease of burning briquettes because the pores filled adhesive briquettes and briquette becomes too dense. The type of waste biomass also influences levels of adhesive on waste biomass briquettes. As the fuel that will be used for the household, the amount of smoke of burning briquettes should also be reduced to a minimum. Therefore, optimization of adhesive levels in the briquette of waste biomass as fuel needs to be done.

Extra adhesive excessive levels will cause the briquettes produced are too sticky to form briquettes becomes less good and quite challenging to remove from the mold briquettes elsewhere [6]-[7].

The purpose of this research is to know the effect of using some adhesive to fuel calorific value resulting from EFB biomass waste. In this study, the effects of 2% binder and operating parameters such as briquette pressure, briquette volume, particle size distribution, and water ratio functional group on briquette strength are systematically studied.

II. MATERIALS AND METHODS

A. Materials

The EFB fiber and briquette were acquired from AMP, Ltd at Pasaman Selatan, West Sumatera - Indonesia. The use of EFB has been the condition of fiber and conditions of EFB is still fresh. Fig. 1 is a step to the processing of data analysis bio-briquette. Waste EFB used in this study as shown in Fig. 2

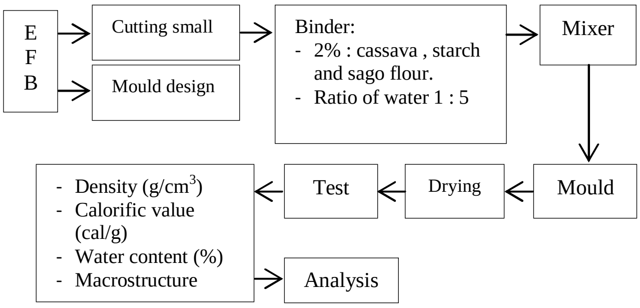

Fig. 1 Briquetting process step

Fig. 2 Empty Fruit Bunch waste

The EFB was dried in open sun drying show in Fig. 3. Enumeration of fibers to be more finely done manually until the size of the fineness of the fiber to be between 1-5 mm. Chopped fiber produce powder and fiber lengths of varying sizes. The powdered EFB and fiber as shown in Fig. 4. Digital scales used to determine the weight of fibers and adhesives on each sample with the specification of the scales is KW 0600378 500 g x 0.01 g. The ratio of the use of water as a diluent adhesive and fiber mixture is 1:5. Intended use is as mixture adhesives and binders so that the fiber has the form.

The binder can be commercial plain flour (maida) starch, rice powder, rice starch, readily available and other cost-effective materials like clay soil mixed in different proportions and shapes with the help of the briquette machine. Flour contains a high proportion of starches. Suitable binders include starch (5 to 10 %) [8]. Adhesives used in this experiment are; cassava flour, starch flour, and sago flour.

Fig. 5 are three types of flour used as adhesive fibers. The heating value of the EFB fiber and briquette was determined using an Oxygen Bomb Calorimeter (OBC) Type Ignition Unit 2901EE.

Fig. 3 EFB of dried in open sun drying

Fig. 4 Empty Fruit Bunch powder and fiber

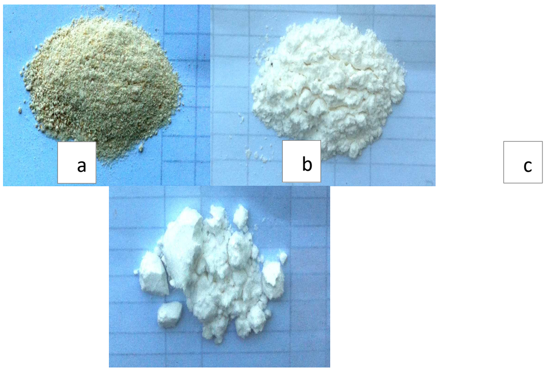

Fig. 5 Powder as the binders: cassava flour (a), starch flour (b), and sago flour (c)

B. *Tool and Specimen*

One of the support molding in this experiment mold briquette. Mold is used to shape briquettes with a predetermined classification. The working process of this mold is to press one part of suppressant that produces an optimal density. Fig. 6 is mold dimension cylinder shape; total length 10 cm, diameter 4 cm and resulting high-briquettes is 5 cm. The formula determines the briquette volume;

$$\text{Volume} = \pi\, r^2 .\, t \qquad (1)$$

The density of bio-briquette, most technological processes produce are bio-briquettes with densities above 1000 g/cm3, which sink in water as a test for quality. The physical upper-density limit for lignocellulosic materials is about 1500 g/cm3. High-pressure processes (e.g., mechanical piston and pellet presses or some screw extruders) make briquettes compact from the density range of 1200-1400 g/cm3. Hydraulic piston presses briquette which makes less dense bio-briquettes, sometimes below 1000 kg. Making of dense briquettes is not effective, as combustion properties are likely [9]. In these experiments, the density is determined by the equation:

$$D/\rho = \frac{B}{V} \qquad (2)$$

where : D/ρ is density (g/cm^3), B is an initial mass of briquette (g), and V is the volume of briquette (cm3).

The density used in this equation has been set at 0.8 g/cm3, and mass of briquette (B) is 50.24 g. Each sample is given adhesive 2% percentage; then the adhesive weight amounts 1.0048 g. Next, for fiber material, the weighing is 50.24 g – 1.0048 g = 49.235 g. Figure 7 is schematic dimensional molds and briquettes burning process in the mold. The pressure on the piston to urge the fiber with a predetermined volume to solidify and produce briquettes maximum length of 5 cm.

Fig. 6 Mould of briquettes

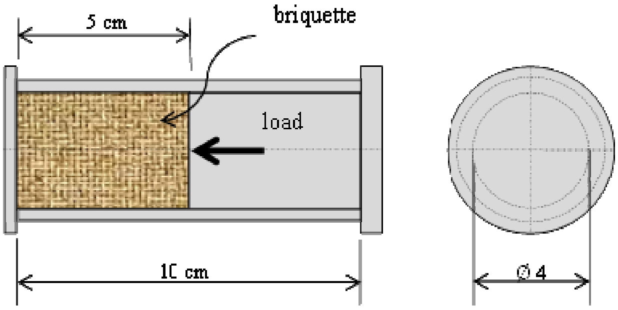

Fig. 7 Schematic dimensional molds and briquettes are burning process.

III. RESULT AND DISCUSSION

A. *Enumeration Fibre*

After the drying process of EFB, then the next enumeration manually fiber to obtain fiber length on average. Enumeration is a critical step in outlining EFB into fibers. This enumeration aims to minimize the size of EFB. This activity is carried out using a knife/machete stainless steel material with optimum sharpness. In addition, to reduce the size, the enumeration will also reduce the water content EFB. Most of the water will evaporate due to the increased surface area EFB.

B. Mould Bio-briquettes

Before the fiber are formed the first, set the volume of bio-briquettes. Bio-briquettes are formed in a cylindrical pipe as directed in Fig. 6. After a mixture of fibers and adhesive volume is determined then the material being mixed and inserted into the cylinder pipe and given the maximum pressure. The optimum pressure is to limit the bio-briquettes into 5 cm long; then briquettes were detained in the cylinder pipe for ± 30 minutes to obtain a solid form of bio-briquettes while reducing the water content of the briquettes in the pipeline. After process mentioned above the sample is removed and dried in the open air until the water content in the bio-briquettes is reduced.

Fig. 8 is a sample of resulted briquette adhesive cassava that had been formed. The length of the initial samples in the mold is 5 cm but when removed samples of briquettes have added a length of 0.5 to 1 cm. When the briquettes are removed from the long mold fiber accreting due to the elasticity of the fiber material. This problem occurs on every sample briquettes. On the other hand, the percentage of 2% adhesive will also affect the structure of briquettes, the bond between the fibers with an adhesive, physical and density of briquettes.

Fig. 8 One of a sample of briquettes cassava

C. High Distance Falls Test.

This test is done manually to see the quality bio-briquette produced, then do some testing of bio-briquette strength. One of the tests were conducted by dropping a sample at a certain height. This testing is done to look at the strength of the sample briquettes. Testing is done by dropping the sample at some height starting from 0.2 m to 1.20 m.

TABLE I
DROP TESTING SAMPLES IN SEVERAL HEIGHTS

High Distance Falls (m)	**Conditions**	**Information**
0.2	Good	-
0.4	Good	-
0.6	Good	-
0.8	Good	-
1 m	Fractured	In the drop height of 1 m, the sample began fractured *(Fig. 9a)*
1.20 m	Damaged /broken	In this condition, the sample partially damaged/broken *(Fig. 9b)*

Table 1, the results showed that when dropped at the height of 0.2 m to 0.8 m sample is still good and has not experienced signs of damage and rupture. Meanwhile, at the height of 1 m samples began developing cracks but does not break (Fig. 9a). However, at the height of 1.20 m to start experiencing the symptoms of damage in the majority of samples such as crack and break (Fig. 9b). The test data as shown in Table 1.

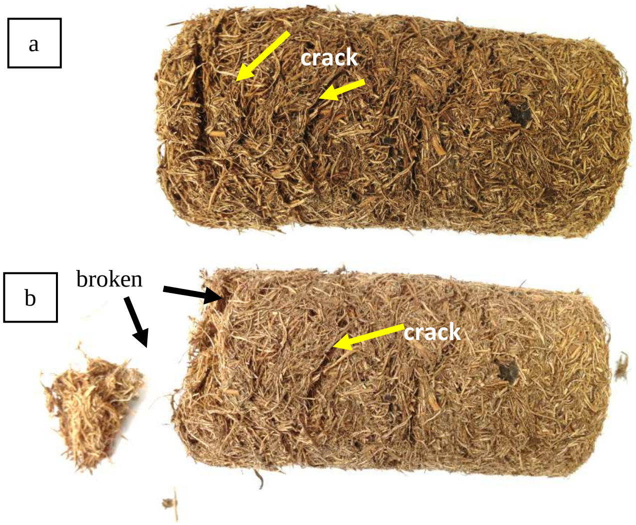

Fig. 9 One of the sample (binder of cassava flour) drop test at the height of 1 m (a) and the physical samples at the height of 1.20 m (b)

Table 2 shows that the use of 2% adhesive on the material cassava flour, sago and starch each of the three samples. The water content obtained in each sample bio-briquettes average for cassava flour was 9.08 %, 8.47 % and sago starch 8.82 %. The level of water in the sample adhesives cassava slightly larger than the sago and starch ingredients. If according to the quality standard of charcoal bio-briquettes (SNI 1/6235/2000), [10] moisture content (%) obtained at $\leqslant$ 8 and under charcoal EFB the moisture content of 9.77 %, so in this study showed no significant differences in values.

TABLE II
ANALYSIS OF THE TEST DATA CALORIFIC VALUE
BIO - BRIQUETTE EFB

	Binder (2%)	**Sample**	**Water Content (%)**	**Calorific Value (cal/g)**	**Average of Calorific Value (cal/g)**
EFB	Cassava	1	9.93	3539	3661
		2	9.15	3581	
		3	8.17	3864	
	Sago	1	8.08	3700	3537
		2	9.13	3372	
		3	8.21	3539	
	Starch	1	9.11	3511	3584
		2	8.20	3673	
		3	9.16	3567	

The calorific value obtained from three types of adhesives are used to show the difference value is not a significant average increase. In Fig. 10 the graph shows the difference and increase the calorific value in each sample bio-briquettes. The results showed that the adhesive material for cassava flour obtained the value (3661 cals/g) is higher than the material sago and starch. While the use of adhesive 2% in the three samples of bio-briquettes in this study generally had produced almost close relative calorific value.

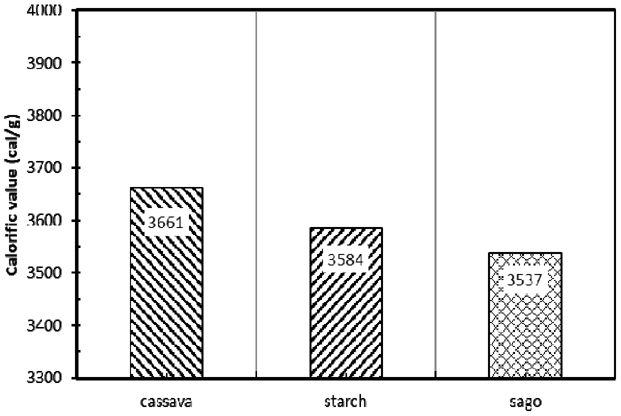

Fig. 10 Graph 2% use a binder to increase the calorific value

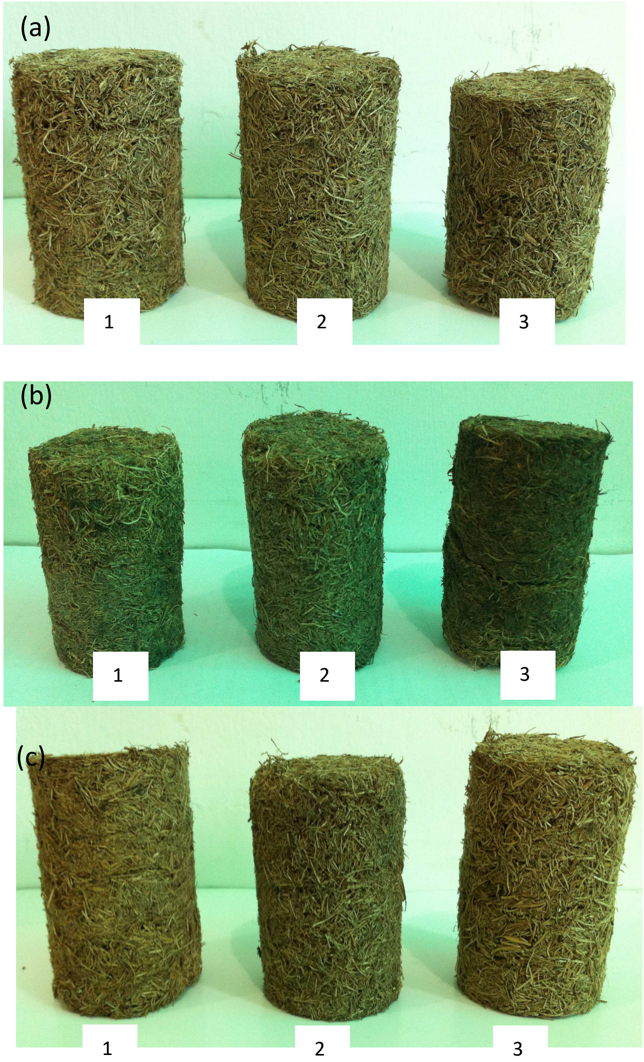

Fig. 11 A sample of cassava flour (a), starch flour (b), and sago flour (c)

Fig. 11 is a sample briquette adhesive cassava flour, starch, and sago. Samples have undergone the same process of treatment. Physically sample bio-briquettes with adhesive cassava (Fig. 11a) have added three samples of varying lengths. Samples 1 and 2 dimensional briquettes grow between 0.6 to 1 cm. While the sample 3 increases of 0.5 cm. Samples briquettes with an adhesive starch and sago (Fig. 11b and 11c), on average the length dimension of between 6 to 8 mm for the third trial samples. In this the research, ratio of the use of water as a diluent adhesive and fiber mixture is 1: 5.

Water plays a dominant role in the particle bonding. Some of the added water escapes through the holes around the mold during the application of pressure, and a thin layer of water is created around the biomass particles which helped to increase the contact between particles. Therefore, the amount of water remains within the briquette is vital for interparticle bonding [11], [12].

Added the long dimension of the briquettes occurs when the briquettes are removed from the mold [13]. This is one of the issues to be addressed for future research.

D. *Macrostructure Fibre*

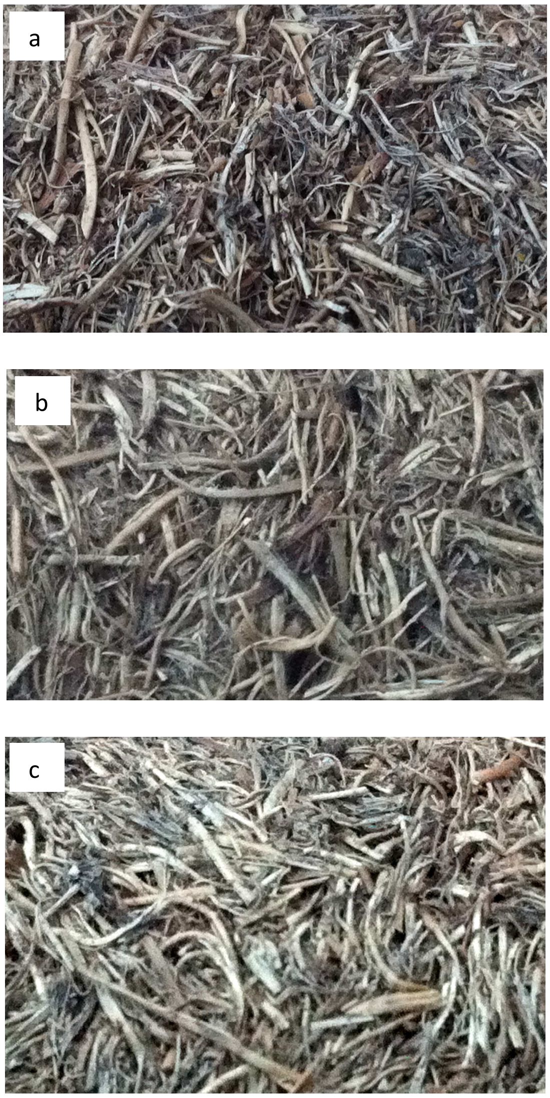

Fig. 12 The macrostructure of briquettes; cassava flour (a), starch flour (b), and sago flour (c). The picture of magnification is 300 X

Fig. 12 are macrostructure briquettes surface morphology after the emphasis on magnification 300x. Structurally, all materials exhibit surface between particles binds to each other by giving 2% of adhesive and the same treatment. The composition of the fiber in the figure 12.a (cassava flour) looks more solid and composed when compared with images 12.b and c.

The fiber particle size in this study is the same average for all materials. In the Fig. 12.a structure and morphology of cassava flour gluten influence on the forces generated as the result of experiments in Table 1.

IV. CONCLUSIONS

The use of cassava flour as an adhesive at 2% with water usage ratio of 1:5 at EFB fiber have resulted in a higher calorific value compared with the use of adhesive starch and sago. The calorific value generated in the adhesive cassava bio-briquettes 3661 cal/g slightly higher than the adhesive sago and starch. However, the calorific value of the three samples produced with different adhesive materials does not show significant calorific value difference between one another.

Strength adhesive samples of briquettes with a percentage of 2%, in general, is still able to hold if tested is dropped at the height of 1 m to 1.20 m. The macrostructure analysis showed that the bio-briquettes with adhesive cassava flour produce a morphological structure denser than the adhesive starch and sago.

NOMENCLATURE

r	radius	cm
m	length	cm
t	high	cm
v	volume	cm^3

Greek letters

ρ	density	g/cm^3
Ø	diameter	cm
π	phi	

Subscripts

B	initial mass of briquette	g
D	density	g/cm^3

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