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PHYSICAL AND THERMAL PROPERTIES OF BRIQUETTES FROM EMPTY FRUIT BUNCHES AND PALM KERNEL SHELL BY MIXING TAPIOCA FLOUR AND MOLASSES

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Abstract. West Java has the potential of palm oil wastes such as empty fruit bunches (EFB) and palm kernel shell (PKS) that can be used for fabrication of briquettes as raw materials. Briquette as a solid fuel and as a substitute for fossil fuel must have a good quality to be accepted in the market, such as having a good thermal and good physical properties. This research, reviewing the effect of particle size parameter and the effect of adding adhesive on briquette to heating value, thermal properties and physical properties. Briquettes were determined by using varying EFB and PKS biomass ratios of 50:50 and by adding 7% adhesive from tapioca flour or molasses of the total mass of the briquette. Particle size variations are set for 20 mesh and 40 mesh. The best heating value was found at 5,898 cal/g in the sample briquette by using 40 mesh particle and tapioca flour adhesive. The thermal properties test shown the combustion rate of 0.34 g/minutes and combustion lenght of 111 minutes found in 40 mesh briquette sample by using tapioca flour adhesive. The physical properties test shown the best density value of 0.215 g/cm^3 and shattering resistance of 66,23% found in the 40 mesh briquette sample by using tapioca flour adhesive. The best durable value found in sample briquette with 20 mesh particle with tapioca flour adhesive which is 54.35%. The result was indicated that briquette with 40 mesh particle size and tapioca flour adhesive gives the best result of heating value, thermal properties and physical properties.

Keywords: briquette, palm oil, thermal properties, physical properties, tapioca, molasses

Abstrak. Briket merupakan salah satu alternatif bahan bakar biomassa sebagai pengganti energi fosil. Jawa Barat memiliki potensi sebagai penghasil limbah kelapa sawit seperti tandan kosong kelapa sawit (TKKS) dan cangkang kelapa sawit (CKS) yang dapat digunakan sebagai bahan baku pembuatan briket. Briket sebagai bahan bakar padat dan sebagai alternatif pengganti bahan bakar fosil harus mempunyai kualitas yang baik agar dapat diterima di pasar seperti memiliki sifat termal dan sifat fisik yang baik. Dalam penelitian ini mengkaji bagaimana efek ukuran partikel dan penambahan perekat terhadap nilai kalor briket, sifat termal dan sifat fisiknnya. Briket yang dibuat dengan mencampur bahan biomassa TKKS dan CKS dengan perbandingan 50:50 dan menambahkan 7% bahan perekat dari total massa briket. Bahan perekat yang digunakan yaitu tepung tapioka dan molase. Ukuran partikel yang digunakan yaitu 20 mesh dan 40 mesh. Nilai kalor terbaik 5,898 kal/g pada sampel briket dengan 40 mesh dengan perekat tepung tapioka. Sifat termal didapatkan dengan laju pembakaran terbaik 0.34g/menit dan lama pembakaran 111 menit pada sampel briket dengan 40 mesh dengan perekat tepung tapioka. Sifat fisik didapatkan dengan densitas terbaik 0.215g/cm^3 dan shattering resistance 66,23% terdapat pada pada sampel briket dengan 40 mesh dengan perekat tepung tapioka. Dan durabilitas terbaik terdapat pada sampel briket dengan 20 mesh dengan perekat tepung tapioka yaitu 54.35%. Hasil menunjukan bahwa briket dengan 40 mesh dengan perekat tepung tapioka memberikan hasil terbaik terhadap nilai kalor, sifat termal dan sifat fisik briket.

Kata Kunci: briket, kelapa sawit, sifat termal, sifat fisik, tapioka, molase

1. Introduction

Renewable source of energy is the fastest growing source of world energy, with consumption increasing by 3% per year. This is due to its environmental friendliness as against the rising concern about the environmental impact of fossil fuel use and also strong government incentives for increasing renewable penetration in most countries around the world [1]. Briquette is one of the alternative biomass fuel as a substitute for fossil energy. West Java has the potential of palm oil wastes such as empty fruit bunches (EFB) and palm kernel shell (PKS) that can be used as the briquettes raw materials. In 2017, West Java had an oil palm plantation area of 17,420 ha which was able to produce 43,660 tons of CPO (Crude Palm Oil) [2]. In 1 ton processing of oil palm fresh fruit bunches, produced 23% CPO, 7% PKO, 23% EFB and 9% PKS, so that the total EFB and PKS produced by West Java reached 35 thousand tons/year and 13 thousand tons/year. At present, the largest use of both solid waste is used as boiler fuel with a percentage of 63% PKS and 10% EFB as an energy source in palm oil processing plants. Thus, there is still an excess of oil palm EFB and PKS waste which can be utilized as bio briquettes feedstock [3]. Based on the amount of availability of raw materials, EFB has more availability compared to PKS. However, when viewed from the calorific value as one of the fuel quality requirements, the EFB calorific value is lower than the PKS calorific value, which is 4,264.54 cal/g while PKS is 5,637.88 cal/g [4].

Bio briquette as a solid fuel must have a good quality to be accepted in the market, such as having a good thermal and physical properties. The study aims to produce mixed bio briquettes of EFB and PKS ratio 50:50 using adhesive tapioca flour and molasses as the binding agent and to identify the briquette properties, such as heating value, thermal properties and physical properties.

2. Methods

The materials used in this study is oil palm empty fruit bunches and oil palm shells. As for the adhesive using tapioca flour and molasses. This study uses an experimental method with descriptive data analysis. Research begins by carrying out the carbonation process on EFB and PKS. The carbonation process is carried out to remove materials that are not useful in the combustion process and increase the fixed carbon content. The carbonation process of EFB is regulated at 262^{o}C for 4 hours, while the PKS is carried out at 380^{o}C for 5 hours. Determination of temperature and carbonation time is influenced by differences in the lignocellulose composition of the two ingredients [5].

Carbonated charcoal from both materials was carried out uniformly using 20 mesh and 40 mesh sieve. The formulation of mixed EFB and PKS consists of 50:50 concentration treatments. The total mixture of raw materials for EFB and PKS for each bio briquettes is 50 grams. During the process of making briquettes, 7% of the adhesive material will be added which is equal to 3.5 grams, the compression pressure is 50 kg, and the drying temperature is 60 ^{o}C for 3 hours. After homogenization between the three materials, forming was carried out using a mold. The briquettes were formed in a hollow cylindrical mold with an inner diameter of 4 cm, a height of 10 cm and a rod with a 1 cm diameter placed in the center to create a hole in the middle of the briquette. The hole helps to increase porosity and oxygen supply, thereby improving briquette combustion. Composition of the treatment is shown in Table 1.

Tabel 1. Formulate treatment in the Briquetting process

Ratio				Compression Pressure (kg)	Drying Time and Temperature
Adhesive	Particle Size (mesh)	EFB (%)	PKS (%)		
7% Molasses	20	50	50	50	$T = 60^{o}C$ t = 3 hr
	40	50	50	50	$T = 60^{o}C$ t = 3 hr
7% Tapioca Flour	20	50	50	50	$T = 60^{o}C$ t = 3 hr
	40	50	50	50	$T = 60^{o}C$ t = 3 hr

Measurement of calorific value is carried out using a bomb calorimeter using the C 2000 IKA adiabatic calorimeter instrument. The formula for upper heating value (HHV) and lower calorific value (LHV) are as follows:

$$\text{LHV} = \frac{\text{m x Cp x } \Delta\text{T}}{\text{m briquettes}} \quad (1)$$

$$\text{HHV} = (\text{T2} - \text{T1} - \text{Tkp}) \text{ x Cv } \left(\frac{\text{Kj}}{\text{Kg}}\right) \quad (2)$$

2.1. Thermal Properties

The briquettes combustion rate was determined by recording the briquettes mass before combustion and after the briquettes were completely burnt, the rate at which fire consumes the briquette samples were calculated using equation [6].

$$\text{Combustion Rate} = \frac{\text{mass of briquette after burning}}{\text{total burning time}} \quad (3)$$

2.2. Physical Properties

a. Density

The density of briquettes was determined according to ASTM D2395-17 [7]. The density of briquette was calculated by dividing the mass of the briquette by its volume. The density was calculated by:

$$\rho = \frac{\text{m}}{\text{v}} \quad (4)$$

b. Shattering Resistance

This property was determined according to ASTM D440-86. The procedure involved weighing and recording the initial mass of the briquette, followed by subjecting the sample to a gravitation fall from a constant 2 m height. The drop is repeated three times and each time the sample was passed through a sieve (2.36 mm), while the mass of the briquette retained on the sieve was recorded [8]. The shatter resistance of each briquette was calculated by the equation (5).

$$\text{K} = \frac{\text{weight of briquette after shattering}}{\text{weight of briquette before shattering}} \text{ x } 100\% \quad (5)$$

c. Durability

The durability test was determined according to ASAE S269.3, describes a tumbling device made of a rectangular container in aluminium or stainless steel with inner dimensions of (300x300x460) mm. The container rotates on an axis, which is centered perpendicular to the sides of the box. The rotation speed is fixed to 40 rpm [9]. The durability was calculated by the equation:

$$\%\ \text{durability} = \frac{\text{weight of briquette after rotating}}{\text{weight of briquette before rotating}} \text{ x } 100\% \quad (6)$$

3. Results and Discussion

3.1. Biobriquette calorific value

Analysis of calorific value was carried out using the C 2000 IKA adiabatic calorimeter instrument. The results of the analysis of calorific values are shown in Table 2. Table 2 shows the average calorific value of each ratio of material mixtures between EFB and CKS. Based on the test results carried out the highest calorific value was produced from briquette with 40 mesh particle size and tapioca flour adhesive. The calorific value generated from this ratio reaches 5,898 cal/gr. While the lowest calorific value was generated from briquette with 20 mesh particle size and molasses adhesive with the resulting heating value of 5,498 cal/gr. The increase in calorific value may be due to the addition of tapioca flour which is contributes to the total heat value released. The calorific value from all briquettes has complied with Indonesian National Standard (SNI) No.1/6235/2000 which is only 5,000 cal/gr.

Tabel 2. Calorific value of bio briquette from mixture EFB and PKS

	Ratio			
Adhesive	Particle Size (mesh)	EFB (%)	PKS (%)	Average Calorific Value (cal/gr)
7% Molasses	20	50	50	5,498
	40	50	50	5,694
7% Tapioca Flour	20	50	50	5,758
	40	50	50	5,898

3.2. Biobriquette thermal properties

The results of the effect of particle size and the adhesive on the combustion rate are presented in Table 3. The optimum combustion rate was found 0.34 g/minutes in briquette with 40 mesh particle size and tapioca flour adhesive. The effect of adding adhesive to the combustion rate of briquettes was not significant, either using molasses or tapioca flour. From Table 3. the effect of particle size demonstrated direct relationship with the combustion rate of briquette. The study could be attributed to porosity exhibited between inter and intra-particles which enable easy infiltration of oxygen and out of combustion briquettes. Futhermore, the obtained value for finer particle size based on the combustion tests might possibly be attributed to lower porosity and this hindered mass transfer. Consequently, its combustion rates might be reduced. In this study indicated that the combustion rate of the briquettes increased with increase in particle size.

Tabel 3. Combustion rate of bio briquette from mixture EFB and PKS

Ratio					
Adhesive	Particle Size (mesh)	EFB (%)	PKS (%)	Lenght of Combustion (minutes)	Combustion Rate (gr/minutes)
7% Molasses	20	50	50	98	0.36
	40	50	50	93	0.35
7% Tapioca Flour	20	50	50	112	0.35
	40	50	50	111	0.34

3.3. Biobriquette physical properties

It was observed from the Table 4. that the maximum density was found 0.2150 g/cm3 in briquette with 40 mesh particle size and tapioca flour adhesive. The low bulk density was found 0.1864 g/cm3 in in briquette with 40 mesh particle size and tapioca flour adhesive . These results suggest that the density of the briquettes produced increases with decreasing particle size. The smaller particle size is likely to have higher relaxed density than those with larger particle size. In briquetting, when a large proportion of the raw material is of smaller particles, the briquette produced will have a higher density [10]. The effect of adding adhesive on the density of briquettes was not significant, either using molasses or tapioca flour.

Tabel 4. Density of bio briquette from mixture EFB and PKS

Ratio				
Adhesive	Particle Size (mesh)	EFB (%)	PKS (%)	Density (g/cm^3)
7%Molasses	20	50	50	0.1996
	40	50	50	0.2104
7%Tapioca Flour	20	50	50	0.1864
	40	50	50	0.2150

The Table 5. shows that the shattering resistance of mixed raw biomass was found to be in the range of 49.95 – 66.23 %. The lowest shattering resistance found 41.95 % in briquette with 40 mesh particle size and molasses adhesive. The maximum shattering resistance was found 66.23 % in briquette with 40 mesh particle size and tapioca flour adhesive. The shattering resistance of briquette fuels is increasing with increasing particle size of briquette. Also the shattering resistance of briquette fuels is increasing with adding tapioca flour. This implies that briquettes produced with adding tapioca flour are more durable and resistant to handling stress.

Tabel 5. Shattering resistance of bio briquette from mixture EFB and PKS

Adhesive	Ratio			Shattering Resistance (%)
	Particle Size (mesh)	EFB (%)	PKS (%)	
7%Molasses	20	50	50	41.95
	40	50	50	47.21
7%Tapioca Flour	20	50	50	64.13
	40	50	50	66.23

Table 6 shows the durability found to be in the range of 52.40 – 56.28%. The maximum durability was found 56.28% in briquette with 20 mesh particle size and tapioca flour adhesive. The lowest durability, value found 52.40% in briquette with 40 mesh particle size and molasses adhesive. The briquettes produced from smaller particle size typically depict much higher strength as compared to larger particles [11]. The effect of adding adhesive on the density of briquettes was not significant, either using molasses or tapioca flour. In this study, the shattering resistance of briquette fuels is decreasing with decreasing particle size of briquette. The decrease in briquette may be due to the blending of biomass, a non-combustible substance and the starch used as the binder which does not contribute to the total durability released.

Tabel 6. Durability of bio briquette from mixture EFB and PKS

Adhesive	Ratio			Durability (%)
	Particle Size (mesh)	EFB (%)	PKS (%)	
7%Molasses	20	50	50	55.65
	40	50	50	52.40
7%Tapioca Flour	20	50	50	56.28
	40	50	50	54.35

4. Conclusions

The best heating value was 5.898 cal/g found in sample briquette with 40 mesh particle with tapioca flour adhesive . The thermal properties test with the give combustion rate was 0,34g/minutes and length of combustion was 111 minutes found in briquette with 20mesh particle with tapioca flour adhesive. Physical properties result, the best density value was 0,215g/cm3 and shattering resistance was 66,23% found in sample briquette with 20 mesh particle with tapioca flour adhesive. And the best durability value found in sample briquette with 20 mesh particle with tapioca flour adhesive which is 54,35%. The result was indicated that briquette with 40 mesh particle size and tapioca flour adhesive gives the best result of heating value, thermal properties and physical properties.

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