Characteristics of Woody Cutting Waste Briquette with Paper Waste Pulp as Binder

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Abstract. The current research aimed to increase the calorific value of woody cutting waste briquette with paper waste pulp as binder. There were three different binder variation used in this study, they are 5 %, 10 %, and 15 %. To create a briquette, a cylindrical iron mold with diameter of 3.5 cm and height of 3 cm and a hydraulic press with 2 t power were applied. The physical characteristics of the combination woody waste briquette and paper waste pulp, such as moisture content, ash content, volatile matter and carbon fix were examined using proximate analysis. The calorific value of briquetted fuel was tested by bomb calorimeter. The combustion test was performed to determine the combustion characteristic of briquettes, for example initial ignition time, temperature distribution, and combustion process duration. The general result shows that the calorific value of briquette stood in the range of 4 876 kCal kg^{-1} to 4 993 kCal kg^{-1}. The maximum moisture content of briquette was 5.32 %. The longest burning time was 105 min.

Keywords: Calorific value, waste renewable energy, waste to energy

1 Introduction

Universitas Internasional Semen Indonesia (UISI) disposes abundant amount of woody waste every day. This waste is directly transported to final landfill site in Gresik without any extra treatment to elevate the value. Based on numerous literature, agriculture and forestry waste could be utilized as energy source [1, 2]. To rise the usage of these biomass residues in both heat and power generation, briquetting technology can be applied [3]. Moreover, this technology can also play a role in improving thermal characteristics [4].

In the last research [5] made briquettes containing flamboyant wood twigs (*Delonix regia* (Boj. ex Hook.) Raf.), angsana leaves (*Pterocarpus indicus* Willd.) and pine flowers (*Pine* L.) and had calorific value around 3 475.86 kCal kg^{-1} to 4 731.77 kCal kg^{-1}. Also, the finding [6] produced biomass briquettes made of hay and switch grass. The final results suggested that the briquettes had similar performance and combustion emission to other

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woody briquettes. Đerčan et al., [7] found that wood briquette had notable energy potential based on the comparison result to other fuels (such as coal and distilled oil) as well as a lower amount of ash compared to coal. The previous research related to the present study utilized the woody waste in UISI as briquette with three different ratio between the waste and tapioca flour binder. The ratio 90 % : 10 % (woody waste : tapioca flour binder) had the highest calorific value which showed only 3 630 kCal kg^{-1}. However, this value was still far below the Standar Nasional Indonesia (SNI) requirement which the minimum calorific value of a briquette as a fuel should be 5 000 kCal kg^{-1} [8].

Besides tapioca starch as a binder in a briquette making process, there were some options showing another material used as a binder. Following [9] applied the blend of coal tar pitch with phenolic resin in coke breeze briquettes. The result showed that their strength increased from 50.45 MN m^{-2} to 71.85 MN m^{-2}. The carbonization temperature was 950 °C. Based on [10] used palm oil mill sludge to bind the rice husk briquette. The finding showed the addition of palm oil mill sludge could dramatically affect the physical and combustion properties of the briquettes produced.

UISI also produces paper waste from administrative and learning activities. Paper waste in UISI is still not utilized properly. According to Porteous [11], 1 t of waste paper could produce 9.8 GJ of heat energy. Paper contains lignocellulose compounds in sufficient quantities. Lignocellulose is composed of cellulose, hemicellulose, and lignin. Paper generally contains more than 90 % cellulose. Lignin is a natural polymer consisting of polyphenol molecules that work as a binding of plant cells to one another. Plants containing lignin become hard and rigid. With the presence of lignin in plants, it is possible to make lignin as binder in briquette. Shyamalee et al., [12] compared the energy content between wheat flour binder and paper binder used in saw dust briquette. The result showed that the energy content of briquette using paper binder was 5 418 kCal kg^{-1}. Meanwhile, briquette with wheat flour binder was 5 987 kCal kg^{-1}.

The current research aimed to increase the calorific value of woody waste briquette with paper waste pulp as binder. There were three different binder variation used in this study, they are 5 %, 10 %, and 15 %. The woody waste was carbonized at temperature ± 286 °C. This biochar was then sieved into 50 mesh to 100 mesh. The briquettes were created in a briquetting hydraulic press-BHP, with 2 t power. They were dried using a furnace at ± 100 °C for 8 h. Several test were performed to understand the characteristic of briquettes, for example proximate analysis comprising the detection of moisture content, volatile content, ash content and fixed carbon, calorimetry test and also combustion test.

2 Methodology

Fig. 1. Pulvurizer machine

Woody cutting waste in UISI was collected and dried under the sunlight for eight hours over three days. It was then carbonized at around 400 °C. The result of this carbonization process was crushed using pulvurizer as seen in Figure 1 and was continued until achieving 50 mesh to 100 mesh. Meanwhile, paper waste pulp was made by cutting it into a smaller piece and sunk for 1 h as illustrated in Figure. When paper waste was sinking, there was some part of paper floating on the top surface. It would be taken and used as a binder.

There were three variations of binder percentage observed in the study. The composition percentage of water, bio char, and binder can be seen in Table 1. The briquette was molded using a briquetting hydraulic press – BHP, with 2 t power and dimension used was 3.5 cm × 3 cm (diameter x height). Subsequently, the briquettes were dried naturally and also by utilizing an oven operated at ± 100 °C for 8 h. This process used to decrease the moisture content.

Fig. 1 Process of making paper waste pulp

Several test was performed to understand the characteristics of the briquette which consisted of proximate analysis, combustion test and bomb calorimeter. Proximate test and bomb calorimeter was conducted by TEKMIRA laboratory, Bandung. Meanwhile, the combustion experiment was completed as illustrated in Figure 3 in order to obtain the ignition time, burning time, and briquette surface temperature. Combustion characteristics of briquettes were observed using an infrared thermometer and camcorder.

Table 1. Composition percentage

No	Char (%)	Binder (%)	Mass of char (g)	Mass of binder (g)
1	95 %	5 %	19 g	1 g
2	90 %	10 %	18 g	2 g
3	85 %	15 %	17 g	3 g

Several test was performed to understand the characteristics of the briquette which consisted of proximate analysis, combustion test and bomb calorimeter. Proximate test and bomb calorimeter was conducted by TEKMIRA laboratory, Bandung. Meanwhile, the combustion experiment was completed as illustrated in Figure 3**Fig. 2** in order to obtain the ignition time, burning time, and briquette surface temperature. Combustion characteristics of briquettes were observed using an infrared thermometer and camcorder.

The measured data comprised initial and final mass, initial ignition time, briquette temperature and burning time. The combustion test was initially started by heating the zinc plate placed on the stove for ± 5 min or until the heated surface reached a temperature of ± 300 °C to 400 °C. After this condition was fulfilled, the briquette was placed on the zinc plate. If the ember appeared, the stove would be turned off.

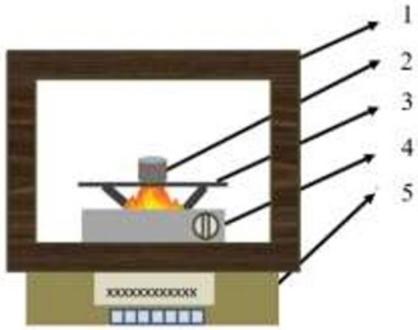

Fig. 2. Combustion test installation scheme
(1): wood box; (2): briquette; (3): iron sheet; (4): gas stove; (5): digital balance)

3 Results and discussion

3.1 Proximate analysis of paper waste pulp briquette

Table 2. Proximate analysis

Physics characteristics	Binder variation		
	5 %	10 %	15 %
Moisture content	4.76 %	5.08 %	5.32 %
Ash content	20.13 %	19.85%	20.53 %
Volatile matter content	22.76 %	22.88 %	23.02 %
Fixed carbon	52.36 %	52.19 %	51.13 %

3.1.1 Moisture content

Moisture content was analysed by heating the briquette in a furnace at 104 °C to 110 °C. As seen in Table 2, the range of moisture content of paper waste pulp briquette stood between 4.76 % to 5.32 %, which briquette with 15 % of binder composition gained the highest moisture content. It occurred since there was much water in this ratio. To produce a good quality fuel, a briquette should have a lower moisture content which can produce a higher calorific value [13]. Based on these result, the briquette could meet the requirement of Indonesian National Standard (SNI 01-6235-2000) which it did not exceed the maximum limit (8 %).

3.1.2 Ash content

The observation of ash content was performed by heating the briquette in a furnace at 400 °C to 450 °C, then it was continuously heated until the temperature reached 700 °C to 750 °C for 1 h. Table 2 shows that briquette with 15 % of binder contained the highest content of ash. It was caused by the fact that the higher the paper waste pulp inside the briquette, more ash would be produced. These value were not still in accordance with Indonesian National Standard (SNI 01-6235-2000) and surpassed the maximum ash content allowed (8 %).

3.1.3 Volatile matter content

To get this data, the briquette was heated in a furnace at around 950 °C for 7 min. As given in Table 2, variation of 15 % binder obtained the greatest volatile matter. This phenomenon took place since it had higher binder composition. If the volatile matter contained in the briquette tended to have a high value, the carbon content will be lower and more smoke produced in the combustion process. Compared to Indonesian National Standard (SNI 01-6235-2000), the briquette had not satisfied the regulation for volatile matter, which was over the boundary (15 %).

3.1.4 Fixed carbon content

Fixed carbon was determined by using the following Equation (1):

$$FC = 100\ \% - (MC(\%) + AC(\%) + VM(\%)) \qquad (1)$$

Where:
MC: Moisture Content
AC: Ash Content
VM: Volatile Matter

Based on the result, fixed carbon decreased as the content of moisture, ash, and volatile matter rose. This characteristic affected the calorific value, initial ignition time, and residence time (combustion process duration). Therefore, to increase the combustion quality, the briquette should acquire a greater fixed carbon content. According to [3], fixed carbon works as the main heat generator during burning. However, fixed carbon of the briquettes was found to be around 51 % to 52 % which had not fitted the requirement in Indonesian National Standard (SNI 01-6235-2000).

3.2 Combustion analysis

The analysis consists of initial ignition time, combustion process duration, and combustion temperature. The combustion experiment was conducted using a gas stove as the heater to ignite, until the briquette smouldering. Once it smouldered, the heater was turned off. Combustion process mainly comprised three stages. Firstly, drying and heating stage, which the briquette could not be burned and smoulder directly, it needed a couple of minute to evaporate the moisture. Second step is the briquette devolatilization which could be known by the appearance of smoke on the surface of the briquette. In this step, the chemical bonding was broken. The third stage was combustion process denoted by the increase of smoldering area.

As shown in Figure 4, 5 % of paper waste pulp binder had the shortest ignition time and reached around 138 s. Meanwhile, the ignition time of 15 % of variation was about 170.3 s. Thus, the higher the moisture content, the ignition time would take a longer time. Similar to ignition time, for combustion process duration, briquette with 15 % of binder could be burned in more extensive time which for almost 105 min.

Figure 5 provides temperature distribution over the combustion process. Three types of briquette had maximum temperature reaching 600 °C. Briquette with 5 % binder achieved the highest maximum temperature which was about 608 °C, whereas the lowest binder percentage reached around 600 °C lower. This condition caused the combustion rate decreasing as the binder variation increasing.

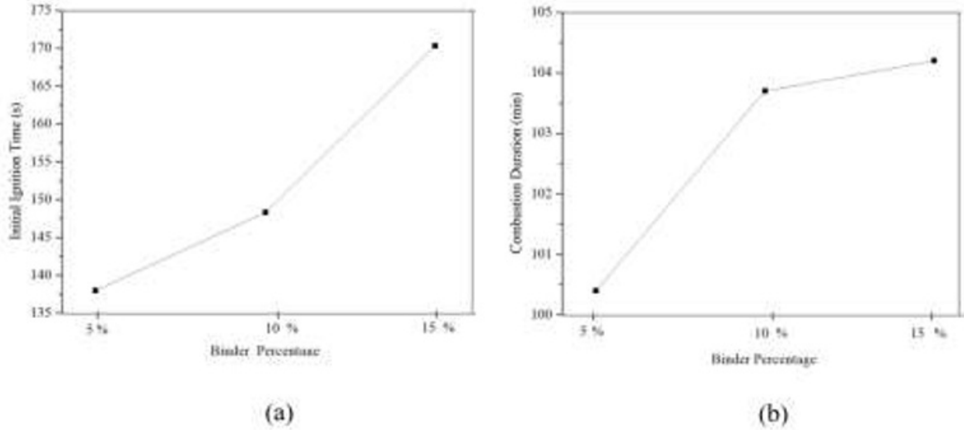

Fig. 3. Combustion Test Result (a: Initial Ignition Time; b: Combustion Duration)

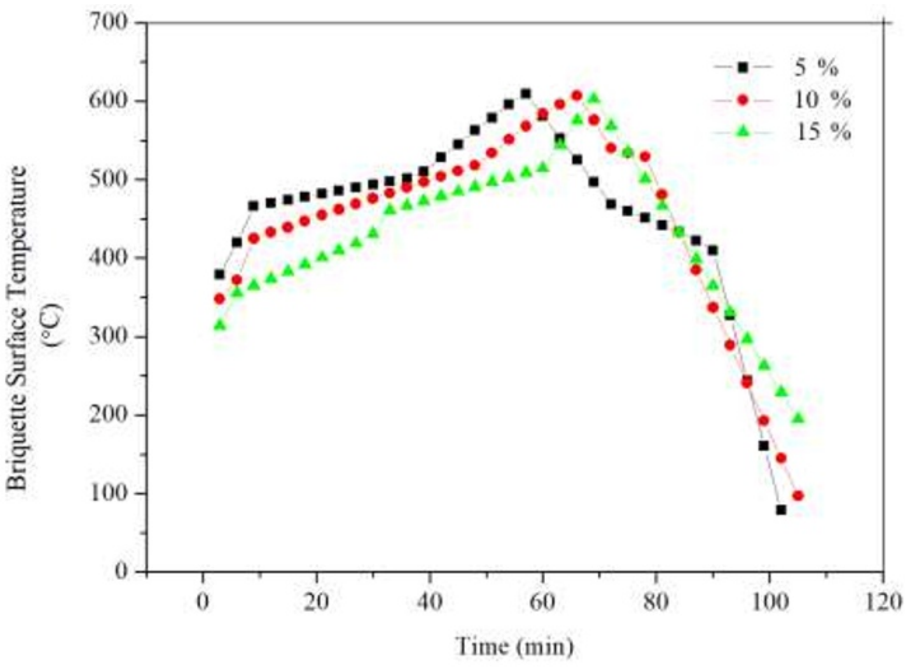

Fig. 4. Temperature distribution on briquette surface during combustion test

3.3 Calorific value

Calorific value between three various of binder yielded a small difference as depicted in Table 3. The highest calorific value was obtained by 5 % of binder variation. Meanwhile, the greatest binder variation gained the lowest calorific value. Compared to the tapioca flour binder, briquette made of woody cutting waste had 1 200 kCal kg^{-1} lower. This was also in accordance with the research performed by [14] which concluded that the calorific value contained in some paper were between 3 500 kCal kg^{-1} to 4 200 kCal kg^{-1}, thus the addition of paper waste pulp as binder can affect the heat value contained in woody cutting waste briquettes. However, this value still could not meet the requirement of Indonesian National Standard (SNI 01-6235-2000) which the minimum value is 5 000 kCal kg^{-1}.

Table 3. Calorific value

	Binder variation		
	5 %	10 %	15 %
Calorific value (kCal kg^{-1})	4 993	4 958	4 876

4 Conclusion

To conclude, paper waste pulp could be used as a binder to create woody waste briquette. The highest calorific value was around 4 993 kCal kg^{-1} and achieved by 5 % of binder variation. The parameter that fulfilled the criteria of a good quality briquette in Indonesian National Standard was moisture content.

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