Combustion quality analysis of briquettes from variety of agricultural waste as source of alternative fuels

S Suryaningsih¹, O Nurhilal¹, Y Yuliah¹, C Mulyana¹
¹ Department of Physics, Mathematic and Natural Science Faculty, Padjadjaran University, Bandung, Indonesia
Email: sri_56@ymail.com,

Abstract. The increasing in world population and the industrial sector led to increased demand for energy sources. To do this by utilizing the agricultural waste as a fuel source of alternative energy in the form of bio briquette. The aim at this study was to obtain data onto the characteristics of a wide variety of biomass briquettes from waste agricultural industry. The basic ingredients used are biomass waste from coconut husks, sawdust, rice husks and coffee husks. Each of these biomass residues are dried, crushed, then mixed with starch adhesives. This mixture is molded and dried using sunlight. Each type of briquettes was characterized and analyzed the physical-chemical properties, including calorific value, water content, fixed carbon content and the results were compared with charcoal and coal that was used as fuel in public. The results showed that bio briquettes from coconut husks get the highest calorific value of 4,451 cal/g.

1. Introduction
Biomass is carbon based complex polymers and is composed of a mixture of organic molecules containing hydrogen, oxygen, and also small quantities of other atoms. Bio-briquettes are compacted combustible material created from biomass used as a form of fuel for heating or cooking in industry and household. Bio-briquettes could be a solution to both global and local efforts in the search for new, renewable energy that are clean, sustainable and environmentally friendly resources. By practicing this technology will bring not only environment and economic sustainability, but also social and political stability, signifying the true long-term sustainability [1].

Limited land for agriculture, such as food crops, herbaceous plants, industrial forest and the increasing land use of human settlement led to a specific land use for energy crops becomes difficult. Another alternative to be used as biomass briquettes is to utilize industrial waste based on existing agricultural industry.

Some of the major agricultural industry in Indonesia produces solid waste that has not been in exploitation. Coconut husks, sawdust, rice husks and coffee husks are the basic material that selected in this study. Each of the briquettes produced from these chosen raw materials is characterized and analyzed and present in this paper as a consideration stuff for the industry.
2. Methods

2.1. Choosing of raw material
Selection of raw materials for biomass briquettes were considered in the availability of the waste in the major agricultural industry in Indonesia and has not been much in exploitation. These wastes include coconut husks, rice husks, coffee husks and sawdust. Especially for sawdust, waste used is a type of acacia tree (*acacia denticulosa*), this species have been selected for fast-growing and widely sold in the market in the form of timber as a pre-construction material in the building construction.

2.2. Preparation of raw material
All selected raw materials are dried using the sun to reduce the moisture content, drying time between 2 to 8 hours depending on ambient temperature and humidity. Except sawdust, all the raw material are crushed into smaller parts to be easily inserted and arranged into the pyrolysis furnace. Carbonization process is performed separately for each raw material. Turning on the stove over medium heat and insert raw material in the pan for about 30 to 180 minutes until it becomes charcoal. After becoming the charcoal, then cooled at room temperature and then crushed into fine particles. Fine charcoal, then filtered with a 120 mesh screen.

2.3. Fabrication of bio-briquettes
The additive substances are made from 20 g of starch (tapioka) in 80 g water solution to achieve a concentration of 4% additives. Mix the starch and water and heated to become an adhesive solution. Then the adhesive evenly mixed and stirred with 100 g of charcoal raw material.

![Figure 1. A picture of cylindrical molding block](image1)
![Figure 2. A picture of hydraulic compression unit](image2)
![Figure 3. A picture of formed bio-briquettes](image3)

The dough is then printed on a cylindrical molding block with 2 cm in diameter (Figure 1), for 10 g per print and pressed with a pressure of 1000 kg/cm² (Figure 2), and keeping dwell time at optimum value of 40 seconds [2]. Figure 3 shows the bio-briquettes before drying process. Ideally bio-briquettes are then dried in the sun for 1 to 2 weeks, but for the needs of this experiment the bio-briquettes are dehydrated in an oven at a temperature of 55 °C for almost 24 hours.

2.4. Characterization of bio-briquettes

2.4.1 Bulk Density
Each type of bio-briquettes have 10 samples, the mass and dimension are taken individually. The bulk density was obtained by using this equation:

$$\rho = \frac{m}{v}$$

where: $\rho$ = bulk density, $m$ = mass of bio-briquettes, $v$ = cylindrical volume of bio-briquettes.
2.4.2 Proximate Test

Proximate Test analysis is a procedure to determine the components inside the briquettes, including moisture content, volatile matter, ash content and fixed carbon.

The moisture content $MC$ (%) inside the briquette can be evaporated by heating at temperature $100 \, ^\circ C - 105 \, ^\circ C$ for 60 minutes. The equation used to calculate the lost of weight as the moisture content is:

$$MC(\%) = \left[ \frac{m_2 - m_3}{m_2 - m_1} \right] \times 100$$

where: $m_1 = $ weight of empty cup, $m_2 = $ weight of empty cup + sample, $m_3 = $ weight of empty cup + sample after heated. The measurement of moisture content done using ASTM D-3173.

Measurement of the value of volatile matter is done using ASTM D-3175. The volatile matter $VM$ (%) is the amount of the substances that are lost when the briquettes sample are heated in a furnace at a temperature of $900 \, ^\circ C$ for seven minutes. Loss in weight was reported as volatile matter using this equation:

$$VM(\%) = \left[ \frac{m_3 - m_4}{m_2 - m_1} \right] \times 100$$

where: $m_1 = $ weight of empty cup, $m_2 = $ weight of empty cup + sample, $m_3 = $ weight of empty cup + sample after taken from the stage (I), $m_4 = $ weight of empty cup + sample after cooling.

The ash value measurement is done using ASTM D-3174. To calculate the ash content $AC$ (%), bio-briquettes are heated in the furnace at temperature $800 \, ^\circ C$ for 3 hours. Then the furnace is turned off, wait until the temperature below $400 \, ^\circ C$, then the samples are removed from the furnace. Samples will be weighed if it is really cold and calculated using Equation4:

$$AC(\%) = \left[ \frac{m_5 - m_1}{m_2 - m_1} \right] \times 100$$

where: $m_1 = $ weight of empty cup, $m_2 = $ weight of empty cup + sample taken from stage (II), $m_5 = $ weight of empty cup + ash left in the cup.

The fixed carbon, $FC$ (%) is the result of a reduction of 100% sample with volatile matter, moisture content and ash content. The equation used to calculate the fixed carbon is:

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

2.4.3 Calorific Value

Calorific Value is the amount of heat that develops from the mass (weight) in its complete combustion with oxygen in the calorimeter. The bomb calorimeter used is Leco – AC350. Sample preparation for a series of tests using ASTM D 5865, meaning briquettes provided are crushed and refined again and filtered through 60 mesh screen.

By using water as much as 2 liters and a sample to be tested weighed about 1 gram. Before placing the sample into the measuring instrument, oxygen is given with a pressure of 400 psi, then wire length is 8 cm long and fuse combustion heat of 4.1 Btu /cm. Changes in water temperature ($\Delta T$) and the released of heat by burning briquettes will be recorded and calculated using installed program in a bomb calorimeter.

3. Results and Discussions

3.1 Physical properties of bio-briquettes

Average bulk density of bio-briquettes are shown in Table 1 below. The highest value of bulk density is sawdust of 0.89 g/cm$^3$ and the lowest is rice husks of 0.69 g/cm$^3$. 

Table 1. Average bulk density of bio-briquettes

| Bio-briquettes     | Bulk density (\(\rho\)) g/cm\(^3\) |
|--------------------|-----------------------------------|
| Coconut Husks      | 0.76                              |
| Rice Husks         | 0.68                              |
| Coffee Husks       | 0.71                              |
| Sawdust            | 0.89                              |

3.2. Proximate analysis of bio-briquettes

By using equation 2 to equation 5 the collected data can be presented in Figure 4 below. Figure 4 shows all the results of the test sample of all type of bio-briquettes.

![Figure 4](image)

Figure 4. Proximate analysis test results of bio briquettes

Ash content of bio-briquette of coffee husks has lowest ash content of 0.60\%, rice husks has a highest value of 15.63\%. The lower the value of the ash content, the greater calorific value it has.

The moisture content of the coconut husks has the lowest value of 1.56\%, rice husks has a highest value of 7.38\%. The smaller the value of the water content in the bio-briquette is the better, if too much water, when used to fuel, the bio-briquettes will evaporate the water at first, and it should be avoided.

The volatile matter of bio-briquette from coconut husks has the lowest value of 22.11\%, rice husks has a highest value of 58.20\%.

The fix carbon of coconut husks bio-briquettes that have a high value of 65.96\%. The higher the value of fixed carbon, the quality of bio-briquettes getting better. Because the amount of fixed carbon acts as a major generator of heat during combustion.

3.3. Calorific Value

Table 2 shows the test results calorific value bio-briquette from coconut husks has the highest calorific value is 5267 cal/g, but its lower compared to coal (6158 cal/g) and higher compared to woody charcoal (3158 cal/g). The higher the calorific value of the bio-briquette the higher quality it has.
Table 2. Calorific value of the four types of bio-briquettes compared to woody charcoal and coal

| Bio-briquettes       | Calorific Value cal/g |
|----------------------|-----------------------|
| Coconut Husks        | 5267                  |
| Rice Husks           | 3350                  |
| Coffee Husks         | 4045                  |
| Sawdust              | 4247                  |
| Woody Charcoal*      | 3158                  |
| Coal (Carbonized)*   | 6158                  |

Source: * provided by Siti Jamilatun [3]

Figure 5 showed that the increasing amount of fixed carbon percentage will increase the calorific value, that means the fixed carbon gives a rough estimate of heating value of the briquettes. In Figure 6, moisture content percentage shows increased at rice husks and coffee husks, hence the calorific value of these briquettes decreased. Moisture content is not only increased the heat loss, due to evaporation and superheating of vapor but also aids radiation heat transfer.

Figure 5. Fixed carbon - calorific value analysis

Figure 6. Moisture content - calorific value analysis

Ash is an impurity that will not burn and caused reduces the burning capacity, besides it will effect in combustion efficiency. In Figure 7 showed the percentage of the ash content of rice husks is high and calorific value is low or vice versa, but it's not significant with coffee husks and sawdust. This may be because there are other impurity that affects such as volatile matter.

Figure 7. Ash content - calorific value analysis

Figure 8. Volatile matter - calorific value analysis

Figure 8 showed that percentage of volatile matter in coffee husks and sawdust are significantly high. Volatile matter contains the composition of methane, hydrocarbons, hydrogen and carbon monoxide,
and incombustible gases like carbon dioxide and nitrogen, that means volatile matter could demonstrate high ease of ignition bio-briquettes or vice versa, it depended on what composition is in.

4. Conclusions
High percentage of volatile matter doesn’t mean will decrease the burning capacity. If its composition contains flammable gas, it will increase burning capacity by proportionately increases flame length, and helps in easier ignition of coal. But if its composition contains non flammable gas, it will decrease burning capacity.

Coconut husks bio-briquette has the highest calorific value, the volatile matter also low in percentage, percentage of water content and the ash value is at least. The calorific value of coconut husks higher than charcoal and lower than coal. With respect to use for fuel, it is preferable to utilize coconut husks bio-briquette than three other types of briquettes.

References
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