Sustainable energy development of bio briquettes based on rice husk blended materials: an alternative energy source

S Suryaningsih* and O Nurhilal
Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Jatinagor, Indonesia

*Corresponding author’s e-mail: sri@phys.unpad.ac.id

Abstract. Rice husk as an abundant waste of biomass up to 21 million tons/year, it is unfortunate if it is not utilized. By converting it into bio briquettes, the value of rice husk bio briquettes in some studies before obtaining a relatively low value of 3,221-3,350 cal/g. The purpose of this research is to increase the calorific value of rice husk bio briquettes by mixing with coconut shell charcoal or corncob charcoal at various composition ratios of 50:50 and 80:20, to reach the optimal value that the industrial sector needed. Carbonization process was carried out at a temperature of 250-350 °C for 1.5 hours. From the results of the proximate analysis test using selected carbonization temperature at 300 °C, it can be seen that the best briquette value is made by mixing rice husk and coconut shell charcoal at composition ratio of 50:50, resulting 47.92% fixed carbon, 8.52% moisture content, 23.40% volatile matter and 20.16% ash content. The highest calorific value of 4,886 cal/g at ratio composition of 50:50, is slightly higher than the East Kalimantan coal standard of 4,828 cal/g. Hence, this bio briquettes are suitable for small scale industry application and household community use.

1. Introduction
The largest agricultural commodity in Indonesia is rice, this industry produces rice husks as biomass waste [1]. Indonesia has more than 14,047,936 ha of paddy farming, with an average production rate of 73,150,411 tons/year and an average growth rate of 3.81% in the 2012-2016 period [2]. 20-30% of the waste from rice mills are rice husks [3], that means the waste generated up to 21 million tons/ year. Understanding the waste means having a low economic value or a residual material after the main part of this product is taken for use [4]. Converting this rice husk as a residual material into fuel as bio-briquettes can make this material more economically profitable.

The main ingredients of biomass are a various of chemicals (molecules), most of which contain carbon atoms (C). When the biomass burned, the carbon will be released into the air in the form of Carbon Dioxide (CO2). Rice husk combustion has a neutrality of carbon emissions, in which carbon emissions are generated in a balanced combustion process with carbon reabsorbed in the next planting period [5]. Hence, its not only leads to environmental and economic sustainability, but also long-term sustainable socio-political stability [6].

The problem with the utilization of rice husk as a fuel is the relatively low calorific value, some researchers found that the calorific value of rice husk is about 3,221-3,350 cal/g [7,8], hence it needs further treatment to increase the calorific value. Some characteristics of biomass are studied to make the necessary planning and treatment in their use as bioenergy feedstocks. These properties include moisture...
content, ash content, volatile matter content, and fixed carbon as the principal content of the associated biomass combustion energy.

This research is tries to increase the calorific value of rice husk by mixing with other biomass materials. The addition mixed material selected was referring to the material already investigated by another researcher that is the briquette calorific value of coconut shell is 8,142 cal/g and corn cob is 7,128 cal/g [9]. To achieve optimal results, each rice husk charcoal sample was mixed with other biomass charcoal at a ratio of 50:50 and 80:20.

2. Methods

2.1. Materials Selection and Tools
The material used in this study is rice husk, coconut shell charcoal and corn cob charcoal. Table 1 shows the availability of waste material from crops production in Indonesia: rice husk of 21,945,123 tons/year, coconut shell of 350,479 tons/year and corn cob of 2,521 tons/year. Tapioca starch as an additional material is used as an adhesive agent for printing purpose.

Table 1. Production of biomass waste from crops industry in Indonesia

| Raw Material | Period (year) | Crops Production (tons/year) | Biomass Waste Production | Percentage Compare to Rice (%) |
|--------------|---------------|------------------------------|--------------------------|-------------------------------|
| Rice         | 2012-2016     | 73,150,411                   | Husk 20-30               | 21,945,123                    |
| Coconut      | 2015          | 2,920,665                    | Shell 12                 | 350,479                       |
| Corn         | 2005-2015     | 16,810                       | Cob 15                   | 2,521                         |

The main tools consist of heater, oven furnace, blender as a crusher, manual hammer, 120 filter mesh, briquettes molding and compression tool.

Figure 1. Picture of main tools used in this study. (a) heater, (b) oven furnace, (c) blender as a crusher, (d) manual hammer, (e) 120 filter mesh

2.2. Determine the Furnace Temperature in Carboniation Process
Preparation of the material is done primarily to rice husk and corn cob by drying using heater for 10-15 hours to reduce water content, while coconut shell charcoal is taken from the products available in the market. Shredding and uniformity of size of the rice husk and corn cobs is crushed with blender, while
coconut shell charcoal by pounding with manual hammer. Separately all the materials are filtered using a 120 mesh sieve.

The carbonization process taken place using oven furnace under limited oxygen condition during 1.5 hours at different temperature 250°C, 300 °C and 350 °C for each sample. Sample 1 is composition 50:50 of rice husk charcoal and coconut shell charcoal and sample 2 is composition 50:50 of rice husk charcoal and corn cob charcoal. The following equation is used to calculate the calorific value ($\Delta U_T$) in cal/g of each sample:

$$\Delta U_T = \frac{-C\Delta T-U_0-U_1}{m}$$

where: $C$ is calorimeter caloric capacity (cal), $\Delta T$ is temperature rise in the adiabatic thermal process (°C), $U_0$ is titration correction factor (cal), $U_1$ is wire correction factor (cal) and $m$ is mass (g).

2.3. Briquette Fabrication from Biomass Blended Material at Difference Composition

After determining the best furnace temperature carbonization, each charcoal, then reproduced using this temperature and treated using various composition ratios. Mixtures of rice husk and coconut shell charcoal was prepared as the composition 1A (50%: 50%) and composition 1B (80%: 20%), and mixtures of rice husk and corn cob charcoal was prepared as the composition 2A (50%: 50%) and composition 2B (80%: 20%).

Determining the ratio of 50:50 is based on the logical reason that the added of the mixing material should not exceed 50%. The 80:20 ratio is the optimum value chosen based on the national availability ratio of raw materials shown in Table 1 where the percentage of additional material is only 1.56% of coconut shell and 0.01% for corn cob compared to the rice husk.

Tapioca starch was added about 8% by mass for each composition. This adhesive material was prepared in advance by mixing the tapioca powder with water in a pan and then heated on the stove until it coagulates. Tapioca starch is selected and used as an adhesive material because it is highly flammable and produces high heat [14].

The mixture of biomass charcoal and adhesive starch are stirred until homogeneous using magnetic stirrer (figure 2a). The dough is further inserted into the cylindrical molding block (figure 2b), then pressed using a hydraulic compression tool with a load strength of 40 kg (figure 2c). Figure 2d show the sample of the dried bio briquettes.

Ideally bio briquettes were dried in the sun for 1 to 2 weeks, except for this experiment the bio briquettes were dehydrated in an oven at a temperature of 55°C for almost 24 hours. This drying process is done to reduce the water content in briquettes, thus ease the combustion process.

![Figure 2](image)

**Figure 2.** (a) magnetic stirrer, (b) cylindrical molding block, (c) bio-briquettes hydraulic compression tool, (d) sample of dried bio briquettes

2.4. Determine the Characteristic of Bio Briquettes

The proximate test and calorific value test were conducted at the Lab. Coal tekMIRA Research Center Bandung. The calorific value was measured using a bomb calorimeter. The heating value obtained is the
higher calorific value (HHV) and the lower heating value (LHV). The calorific value calculation is based on the ASTM standard D. 5865-2013.

Proximate tests were conducted to determine the standard quality of the briquettes, include fuel power, long flames and determine the standard of the sale value of the briquettes. Proximate tests performed consist of:

2.4.1. **Moisture Content.** Percentage of moisture content is the ratio of the mass of water in a sample of briquette.

2.4.2. **Ash Content.** Percentage of ash content is the mass of incombustible material remaining after burning a given briquette sample.

2.4.3. **Volatile Matter Content.** Percentage of volatile matter is an unstable material that tends to not remain in one state and will rapidly transition to another state, or vaporize.

2.4.4. **Fixed Carbon.** Percentage of fixed carbon is the levels of fixed/bonded carbon contained in the briquettes. Calculation of fixed carbon percentage was done in accordance with ASTM D 3172-13.

3. **Results and Discussion**

3.1. **Influence of Furnace Temperature in Carboniation Process**

Table 2 shows calorific value characteristics consisting of a mixture of rice husk and coconut shell (sample 1), and mixture of rice husk and corn cob (sample 2). The maximum heat value was 4778.42 cal/g produced by samples 1 and 4478.45 cal/g produced by sample 2 at a furnace temperature of 300 °C.

| Unit         | Sample 1 (Rice husk + Coconut Shell) | Sample 2 (Rice husk + Corn cob) |
|--------------|--------------------------------------|----------------------------------|
| Temperature  |                                      |                                  |
| °C           | 250                                  | 300                              | 350                              |
| Calorific Value | 4465.39                             | 4778.42                          | 4346.02                          | 4265.49 | 4478.45 | 4346.12 |

The smallest calorific value for sample 1 was 4346.02 cal/g at furnace temperature 350°C, the smallest calorific value for sample 2 was 4265.49 cal/g at a furnace temperature of 250°C. The reason why the lowest calorific value is obtained at different temperatures for both samples may be due to differences in composition of lignocellulose compounds (cellulose, hemicellulose and lignin) of each additional material, hence its effect to the decomposition temperature and is not included in this study.

3.2. **Proximate Analysis**

The amount of fixed carbon percentage will determine the amount of calorific value of briquettes, in other words the minimum percentage of moisture content, volatile matter and ash content will maximize the percentage value of fixed carbon. Test results which include the determination of moisture content, volatile matter, ash content and fixed carbon in average value are shown in Table 3.

In Table 3, the average percentage value of moisture content from the four compositions is close to the same value of 7.52%, hence it is not a considerable factor and can be ignored. In spite of that, the huge amount percentage of water content could prevent the combustion due to release itself first.

At the composition of rice husk - corn cob (2A, 2B) the percentage of volatile matter and ash content is higher than the composition of rice husk - coconut shell (1A, 1B). In general this will increase the fixed carbon value, specifically, this will increase the calorific value of the briquettes.
Table 3. Proximate Test Results

| Sample of Mixed Charcoal | Sample Name | Comp. Ratio | Moisture Content (% by mass) | Volatile Matter Content (% by mass) | Ash Content (% by mass) | Fixed Carbon (by mass) |
|--------------------------|-------------|-------------|-----------------------------|------------------------------------|-------------------------|------------------------|
| Rice Husk : Coconut Shell | 1A          | 50:50       | 7.52                        | 23.40                              | 21.16                   | 47.92                  |
| Rice Husk : Coconut Shell | 1B          | 80:20       | 7.59                        | 24.63                              | 28.97                   | 38.81                  |
| Rice Husk : Corn Cob    | 2A          | 50:50       | 7.36                        | 26.43                              | 32.73                   | 41.37                  |
| Rice Husk : Corn Cob    | 2B          | 80:20       | 7.36                        | 34.54                              | 37.12                   | 33.69                  |

Ash content does not affect the combustion because ash is an incombustible material, while volatile matter can affect the combustion and it depended on the compound of volatile matter itself, if its combustible material it will help the ignition of the briquettes and increase the flame high, if its an incombustible material it will prevent the ignition process.

The highest percentage of fixed carbon occurs at 50:50 composition. The blended material of rise husk and corn cob (2A) has fixed carbon value of 41.37% and the blended material of rise husk and coconut shell (1A) has fixed carbon value of 47.92%.

3.3. Calorific Value Analysis

The results of the calorific value test of the samples of bio briquette compared to East Kalimantan coal standard and coal standard issued by Ministry of Energy and Mineral Resources Republic of Indonesia are shown in the Table 4 below:

Table 4. The calorific value of rice husk blended bio briquettes compare to the calorific value of various coal standard

| Sample of Blended Rice Husk Bio Briquettes and Coal Standard | Sample Name | Ratio | Calorific Value Test 1 (cal/g) | Calorific Value Test 2 (cal/g) | Average Calorific Value (cal/g) |
|--------------------------------------------------------------|-------------|-------|---------------------------------|---------------------------------|---------------------------------|
| Rice Husk : Coconut Shell                                    | 1A          | 50:50 | 4,884                           | 4,888                           | 4,886                           |
| Rice Husk : Coconut Shell                                    | 1B          | 80:20 | 4,100                           | 4,107                           | 4,104                           |
| Rice Husk : Corn Cob                                         | 2A          | 50:50 | 4,557                           | 4,562                           | 4,560                           |
| Rice Husk : Corn Cob                                         | 2B          | 80:20 | 4,152                           | 4,167                           | 4,160                           |
| East Kalimantan Coala                                        |             |       |                                 |                                 | 4,828                           |
| Low Rank Coal Standardb                                       |             |       |                                 |                                 | <5,100                          |
| Medium Rank Coal Standardb                                    |             |       |                                 |                                 | 5,100 - 6,100                   |
| High Rank Coal Standardb                                      |             |       |                                 |                                 | >6,100                          |

* S. Rahayu, F. Findiati and F. Aprilia [15]

* Ministry of Energy and Mineral Resources Republic of Indonesia [16]

In Table 4 shown, the four samples of bio briquettes are categorized as low rank based on standard issued by Ministry of Energy and Mineral Repulic of Indonesia. The highest value of the four sample is sample 1A with the calorific value 4,886 cal/g and the lowest value is sample 2B with the calorific value 4,160 cal/g.

The added of coconut shell charcoal or corn cob charcol at compisition ratio of 50:50 (1A, 2A) could increase in calorific value significantly. Sample 2A gets the calorific value of 4,560 cal/g near the standard calorific value of East Kalimantan coal standard of 4,828 Cal / g, while the sample 1A get the
calorific value of 4,886 cal/g has the calorific value exceeds East Kalimantan coal standard. Hence, these bio briquettes (sampla 1A and 2A) are suitable application for small scale industry.

If we compare the calorific value of these briquettes using ratio composition of 50:50 (1A, 2A) to the calorific value of sample 1 and sample 2 in the previous test in Table 2, it seems that these values are slightly higher. Thus, because of added treatment like pressure while printing, homogeneous dough when stirred and added starch material that also could increase the calorific value.

4. Conclusion
Optimal carbonization temperature for rice husk and coconut shell / corn cob mixture occurs at temperature 300 °C. The difference of the lignocellulose compound of each additional material will affects its decomposition temperature. The minimum calorific value in rice husk and coconut shell mixture occurs at the highest temperature of 350 °C, while the minimum calorific value on rice husk and corn cob mixture occurs at the lowest temperature of 250 °C.

This research showed that the addition of coconut shell material or corn cob on rice husk base material can increase the value of rice husk briquette significantly. This is because the higher calorific value of each additional material (coconut shell, corn cob, including the adhesive agent) will increase the overall calorific value of rice husk briquettes. Treatment in fabrication processes such as homogeneous dough during stirring, pressure while printing and added the adhesive materials will affect the whole quality of the briquettes.

Briquettes of rice husk blended material using ratio composition of 50:50 have the highest calorific value of 4,886 cal/g for rice husk: coconut shell and 4,560 cal/g for rice husk: corn cob, hence it can be used for small scale industrial applications. For economic reasons, the briquettes of rice husk blended material using ratio composition of 80:20, where a calorific value of rice husk: coconut shell of 4,104 cal/g and rice husk: corn cob of 4,160 cal/g is more suitable for household community use.

5. References
[1] Encyclopedia of the Nations 2011 Indonesia-Agriculture http://www.nationsencyclopedia.com
[2] Ministry of Agriculture Republic of Indonesia 2016 Outlook Komoditas Pertanian Padi (Jakarta: Pusat Data dan Sistem Informasi Pertanian)
[3] Dani S and Bukhory F 2015 The Tensile Strength Properties Effect Of Rice-Husk Ash As On The Composite Of Plastic Drinking Bottle Waste Int. Journal of Scientific & Technology Research 4 4 6-69
[4] Pari G, Hendra D and Hartoyo H 1990 Beberapa Sifat Fisis dan Kimia Briquet Arang dari Limbah Arang Aktif Jurnal Penelitian Hasil Hutan 7 2 61-67
[5] Sugathapala A G T and Chandak S P 2013 Technologies for converting waste agricultural biomass to energy (Osaka : United Nations Environmental Programme)
[6] Shen D, Xiao R, Gu S and Zhang H 2013 The overview of thermal decomposition of cellulose in lignocellulosic biomass (Cellulose-Biomass Conversion InTech)
[7] Syafrudin S, Zaman B, Indriyani I, Erga A S and Natalia H B 2015 The Utilization of Bottom Ash Coal for Briquette Products by Adding Teak Leaves Charcoal, Coconut Shell Charcoal, and Rice Husk Charcoal Waste Technology 3 1 14-21
[8] Suryaningsih S, Nurhilal O, Yuliah Y and Mulyana C 2017 Combustion quality analysis of briquettes from variety of agricultural waste as source of alternative fuels IOP Conf. Series: Earth and Environmental Science 65 1 012012
[9] Nuriana W and Anisa N 2014 Synthesis Preliminary Studies Durian Peel Bio Briquettes as an Alternative Fuels Energy Procedia 47 295-302
[10] Ministry of Agriculture Republic of Indonesia 2016 Tree Crop Estate Statistics Of Indonesia 2015-2017 (Directorate General of Estate Crops)
[11] Ministry of Agriculture Republic of Indonesia 2015 Outlook Jagung (Jakarta : Pusat Data dan Sistem Informasi Pertanian)
[12] Wijaya Y 2012 *Dampak Teknologi Pirolisis Pembakaran Tertutup Terhadap Kualitas Lingkungan dan Nilai Tambah Produk Tempurung Kelapa* (Lampung : Universitas Lampung)

[13] Zhang Y, Ghaly A E and Li B 2012 Physical properties of corn residues *American Journal of Biochemistry and Biotechnology* **8** 2 44-53

[14] Maryono S and Rahmawati *Pembuatan dan Analisis Mutu Briket Arang Tempurung Kelapa Ditinjau dari Kadar Kanji* (Makasar : Universitas Negeri Makasar)

[15] Rahayu S S, Findiati F and Aprilia F 2016 Indonesian low rank coal oxidation: The effect of H2O2 concentration and oxidation temperature *IOP Conf. Series: Materials Science and Engineering* **162** 1 012025

[16] Masafumi U 2015 Situation of Coal Industry in Indonesia *JCOAL Journal* **32** 5-6

**Acknowledgments**

We would like to thank to the Directorate of Research, Community Engagement and Innovation (DRPMI) – Universitas Padjadjaran in accordance with the Implementation Agreement No. Research. 855/UN6.3.1/PL/2017, dated March 8, 2017, the funds provided for this research.