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Production and characterization of briquette from the activated charcoal of corncob

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Abstract. The briquettes made of activated charcoal of corncob (Zea mays, L) have been produced and characterized. The charcoal powder was firstly sieved by a 80-mesh strainer for grain homogenization. Then, it was activated at two different temperatures i.e. 550°C for 30 minutes, and 650°C for 20 minutes by using the electric furnace. The activated charcoals powder were mixed with sago powder as an adhesive agent with mass ratio of 9:1 and under stirring condition using the hot water. In order to investigate effect of compaction pressure, then it was transferred into a cylindrical mould with diameter of 4 cm and pressed at different pressure: 70.33 kg/cm², 94.22 kg/cm², and 117.78 kg/cm². After drying process at temperature of 60°C for 48 hours, the characteristic of the briquettes were investigated. The average density are ranging from 0.40 to 0.64 g/cm³, the moisture content 3.75% to 0.53%, and the ash content 5.03% to 6.97%. The volatile matter varies from 10.06% and 17.37%, consequently the fixed carbon changes from 74.81% to 82.21%. The highest caloric energy produced by the briquette is at the level of 6784.82 cal/gr were achieved at processing temperature of 550°C, and pressure of 117.78 kg/cm². This quality is appropriate for industrial standard of processing briquette.

1. Introduction
Biomass is one of the alternative energy source which are processed from a solid waste and used as a fuel source [1-2]. Here, the biomass resources are converted to be a more valuable material which can be used as a complementary fossil source to some extents [3-4]. By a carefully processing method and optimization of several parameters influencing the quality of briquettes, then it will save for environment with gas emissions, such as sulfur, in amounts far below the threshold. Further waste utilization can reduce both consumption of agricultural products and the rate of forest destruction [5]. The Southeast of Sulawesi island has large abundant of corncobs plant where the waste have not been commonly used as an alternative energy. The corncob waste contains cellulose and lignin about 44.9% and 33.3%, respectively [6]. The high cellulose and lignin contents have been recognized as the indicator of waste can be a source for producing the activated charcoal briquette. The activated charcoal powder was processed by adjustment several parameter such as the particle size, kind and amount of adhesive material, as well as the whole briquette shape and density by using an appropriate pressure in the fabrication process.

The manufacturing process of briquette needs an appropriate method to obtain the briquette with the optimum quality. Sago starch contains about 28% of amylase and 72% of amylopectin on each gram.
It can be used as adhesive material of briquette. In the case of briquette from the activated charcoal corncob, the mass ratio of activated charcoal corncob and sago starch has been optimized and finally at the ratio of 9:1 [7].

In this research, we study effect of the activation temperature and compaction pressure in manufacturing process of briquette. Its characteristics will be investigated by using the proximate analysis involving several parameters such as density, water and ash contents, volatile matter, and the fixed carbon. The burning rate, temperature, time will also be evaluated. We expect that the briquette with a pre-activating process of charcoal source will give a better performance compared to the briquette without activating process.

2. Experimental Methods

2.1. Fabrication of briquettes

The corncob waste (Zea mays, L) as the carbon source was taken from the Tongkuno district of Muna regency while the sago was taken from Ranomeeto district of Konawe Selatan regency. The materials were firstly dried in the electrical oven at temperature of 110°C and for 120 minutes. The corncob was being carbonated using the electrical furnace for 60 minutes and at temperature of 499°C [8]. The charcoal of corncob was mashed to obtain the charcoal powder. The charcoal powder was firstly sieved by a 80-mesh strainer for grain homogenization [9]. Then, it was activated at two different temperatures i.e. 550°C for 30 minutes, and 650°C for 20 minutes by using the electric furnace. The activated charcoals powder was mixed with sago powder as an adhesive agent with mass ratio of 9:1 and under stirring condition using the hot water. In other to investigate effect of compaction pressure, then it was transferred into a cylindrical shape mould with outer and inner diameters are 4 cm and 0.8 cm, respectively, and subsequently pressed at three different pressure: 70.33 kg/cm², 94.22 kg/cm², and 117.78 kg/cm² according to reference [10]. It was then dried for 48 hours in an electric oven at temperature of 60°C.

2.2. Characterization of briquettes

The characterization process determined the density, moisture and ash contents, volatile matter and fixed carbon. Density was directly estimated from mass of sample divided by volume. As for the moisture content, typically, 1 gram of sample was heated at temperature of 105°C in the oven until the constant weight was achieved. The moisture content was estimated from the mass ratio of the evaporated water and the briquette before evaporation process [8]. The evaporated water was estimated from the difference between mass of sample before and after drying process. The volatile matter was determined in the same way as the moisture content but here, the sample was heated at temperature and duration of 750°C and 7 minutes, respectively. Volatile matter was then calculated as the mass ratio of the sample before and after evaporation minus the water content [8]. The ash content of the briquette was determined by heating up 1 gram of sample till the entire sample converted to be ash. The ash content was calculated as the mass ratio of the total ash and the original sample [8]. Fixed carbon was the presentation of carbon i.e. 100% - moisture content (%) – volatile matter (%) – ash content (%) [8]. Finally, in order to determine the ignition time, burning rate and the maximum achieved temperature by the briquette as the real performance of briquette used as a fuel, the briquette was tested by burning process in open space at room temperature. The flame temperature was measured by using the infrared thermometer.

3. Results and Discussion

3.1. Density of the briquette

Figure 1 shows density of the briquette made from the activated charcoal of corncob processed at different activation temperature i.e. 550°C (blue line) and 650°C (red line). Density tends to increase from 0.40 g/cm³ to 0.64 g/cm³ as pressure increases from 70.33 kg/cm² to 117.78 kg/cm². The highest
average density was found at the pressure of 117.78 kg/cm². The pressure creates bonding between the charcoal of corncob and adhesive. The pressure also forces the adhesive to spread throughout the briquette body. In this way, the pressure make the binding distance between atoms is shorter. The briquette with high density will have a better mechanical strength. However, in a certain condition, the pressure addition will decrease the mechanical strength [11]. According the British standard, the briquette density should more than 0.48 g/cm³ while the Japanese standard is at a value less than 1.2 g/cm³ [12]. Based on those standards, the as-prepared briquettes from the charcoal of corncobs and sago starch have a good quality.

![Figure 1](image1.png)

**Figure 1.** Density of briquette vs. compaction pressures for two cases of activation temperatures: 500°C (blue line) and 650°C (red line)

![Figure 2](image2.png)

**Figure 2.** Moisture content vs. compacting pressure for activation temperatures of 500°C (blue line) and 650°C (red line)

3.2. **Moisture content of the briquettes**

Moisture content of the briquettes with different activation temperature was plotted as in Figure 2. Here, the blue and red lines were corresponding to the measured moisture content at both cases of activation temperatures: 550°C and 650°C, respectively. The moisture contents tend to decrease as the pressure increases. The moisture contents are ranging from 0.52% to 3.75% for pressure increases
from 70.33 kg/cm² to 117.78 kg/cm², respectively. Lowest average moisture content is obtained for compaction pressure of 117.78 kg/cm². Generally, the moisture content of the briquette is expected to be as low as possible to increase the burning power. The standard value for moisture content is less than 3.6% for British standard, while for Japan standard is up to 8% [12]. In our case, the moisture content fit to these standards.

3.3. Ash content, volatile matter, fixed carbon, and caloric energy

The obtained of ash content, volatile matter and fixed carbon, and caloric energy of the briquette made from the activated charcoal of corncob for different activation temperature are presented in Table 1. Fixed carbon as the remaining solid fuel is expected to be a major contributor to the carbon value of briquettes. From Table 1, we see that the highest value of fixed carbon content and caloric energy is achieved by the briquette prepared at the activation temperature of 550°C and pressure of 117.78 kg/cm². According to the Japanese standard, the values for ash content, volatile matters content and the fixed carbon, and caloric energy of briquette are 3% – 6%, 15% - 30%, and 60% – 80%, 6000-7000 cal/gr, respectively [12]. Ash content, volatile matter, and fixed carbon, as well as the caloric energy are in good agreement with that standard. The highest caloric energy produced by the briquette is at the level of 6784.82 cal/gr were achieved at processing temperature of 550°C, and pressure of 117.78 kg/cm². The caloric energy of briquettes from activated charcoal is greater than the caloric energy of briquette from charcoal. The caloric energy of corncob charcoal briquettes made with compaction pressure 70.33 kg/cm², 94.22 kg/cm², and 117.78 kg/cm² are 5929.49 cal/gr, 5698.26 cal/gr, 5844.06 cal/gr [13]. This may due to activation process that facilitates enough pore size for oxygen to travel through out the briquette body during the burning process [14].

| Activation temperature (°C) | Ash content (%) | Volatile matter (%) | Fixed carbon (%) | Caloric energy (cal/gr) |
|-----------------------------|-----------------|---------------------|------------------|------------------------|
| 550                         | 5.03            | 11.80               | 79.43            | 6467.71                |
|                             | 5.90            | 10.84               | 80.76            | 6532.23                |
|                             | 6.81            | 10.05               | 82.21            | 6784.82                |
| 650                         | 5.48            | 17.37               | 74.81            | 5932.60                |
|                             | 6.47            | 14.13               | 77.95            | 5894.02                |
|                             | 6.97            | 14.74               | 77.76            | 5905.59                |

Figure 3. Burning rate vs. compaction pressure at different activation temperatures
3.4. Briquette burning parameters
Burning parameters such as burning rate, ignition time and the maximum achieved temperature by briquette flame are shown in Figure 3-4. In Figure 3, the average burning rates are plotted for different pressures and two cases of activated temperatures. The blue line stands for the case of activation temperature at 550°C. The red line is corresponding to the case of 650°C as the activation temperature. The lowest burning rate of about 0.117 gr/min is found for the case of 650°C and compaction pressure of 94.22 kg/cm².

The ignition times that describe the time needed by the briquette to start burning are summarized in Table 2. It is found that the lowest ignition time is 0.4 minutes for briquette with the activation temperature of 550°C and the the pressure of 70.33 kg/cm². Adding more pressure causes a reduction in the porosity of the briquette, resulting in reduced ignition time [15]. The highest temperature is 528°C, achieved by the briquette with processing parameter of 550°C and 70.33 kg/cm².

| Activation temperature (°C) | Pressure (kg/cm²) | Ignition time (minutes) | Maximum temperature (°C) |
|-----------------------------|-------------------|------------------------|-------------------------|
| 550                         | 70.33             | 0.40                   | 528                     |
|                             | 94.22             | 0.70                   | 426                     |
|                             | 117.78            | 1.12                   | 476                     |
| 650                         | 70.33             | 0.73                   | 497                     |
|                             | 94.22             | 0.95                   | 445                     |
|                             | 117.78            | 1.25                   | 454                     |

4. Conclusion
The briquettes have been fabricated from the activated charcoal of corn cob waste. The briquette’s characteristics are meeting to the international standard for industrial briquette. The highest caloric energy produced by the briquette was at the level of 6784.82 cal/gr which was being achieved at processing temperature of 550°C and pressure of 117.78 kg/cm².

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