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Characteristics of biomass briquettes from coffee husk as sustainable fuel

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Abstract. Coffee husk is a waste from coffee milling, which is usually used by farmers as a natural fertilizer. However, it is not uncommon that coffee husk is entirely discarded despite their potential as fuel briquette. Furthermore, coffee husk may replace tapioca as a non-edible binder alternative to tapioca. As such, this study aims to determine the potential of coffee husk waste as briquette material and binder. Manufacturing parameters that include the particle size, the biomass-to-binder ratio, and the press pressure, were varied, and the briquettes were analyzed based on the high heating value (HHV), and using proximate and ultimate analyses under ASTM standards. In addition, common combustion characteristics, such as flame temperature, ignition time, burning duration, and burning rate were determined. The highest HHV was found in coffee husk briquettes without adhesive at 3811 Kcal/Kg. The combustion characteristic test showed that briquettes with a particle size of 60 mesh and a press pressure of 2 MPa have the most desired combustion characteristics.

1 Introduction

Population growth will make increase energy thermal demand. Thermal energy is commonly sourced from fossil fuels. According to the Ministry of Energy and Natural Resources, Republic of Indonesia, in the next 22 years, natural gas will be completely run out, and solid fuels in the next 65 years [1]. Considering the environmental damage and non-renewable property of fossil fuels, reliance on natural gas and solid fuels as the primary source of thermal energy is unsustainable [2, 3].

Other sources of thermal energy are needed to reduce the dependence on fossil fuels. Biomass has been extensively studied as a sustainable fuel due to its potential to be a CO_2-neutral fuel [4]. Furthermore, it is available from various sources, including industrial waste, algae, wood, civil waste, and animal waste, leading to low costs in obtaining it [4].

A common process that uses the energy contained in biomass is through direct combustion [5]. However, direct combustion needs certain conditions. For instance, the high water content in biomass hinders efficient combustion, and biomass usually has high water content [6]. Therefore, it is important to treat biomass to reduce its moisture content.

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Another weakness of direct combustion is logistics. Due to its low bulk density, biomass requires a lot of space and is expensive to transport [7].

The shortcomings of the direct burning of biomass can be overcome by processing it into briquettes. Briquettes have a better bulk energy density, better calorific value, better energy properties, and lower water content [7-9]. Furthermore, the energy obtained using briquettes is larger than the total energy required to change biomass into briquettes [10]. Briquettes are beneficial to society by alleviating energy shortages and providing additional income, especially for those living in rural areas [4,11].

Briquettes are a substitute for fossil fuels and can be made from different types of biomass such as sawdust, agricultural waste, food waste, and paper waste. In the production of waste briquettes, it is common to use plant waste or fruit waste as the main ingredient [12]. There are some studies on briquettes that have been published by Anggono, et al. [13,14]. Production of briquettes from leaf trash by Nurhiral, et al. [15] studied the composition of briquettes that are used tapioca as a binder and made from mahogany waste.

Coffee is one type of plantation plant that has long been cultivated and has a fairly high economic value [16]. The world coffee bean trade is dominated by two types of coffee, namely Arabica, and Robusta. Arabica has a market share of 70% while Robusta has 30%. Indonesia's coffee production 2020 reached 762 tons from 1.2 million hectares [17]. The large production of coffee beans resulted in coffee husk waste, which is usually used by farmers as natural fertilizer or discarded entirely. Since coffee husk still has the potential to be combusted for energy, the use of coffee husks to produce briquettes as an alternative fuel needs to be considered to help with fossil fuel dependencies.

Research on biomass briquettes and their characteristics has been carried out previously by testing the characteristics of briquettes from the waste of leaves and twigs of Pterocarpus indicus. The raw material for briquettes is made from the leaves and twigs of Pterocarpus Indicus that have fallen and become the municipality trash. Making briquettes using a 25 mm diameter mold and a briquette weight of 20 gr. The results of the Proximate Analysis test showed that water content was 5.2%, carbon content 15.3%, ash content 6.2%, volatile matter 73.3%, total sulfur 0.25%, and a calorific value of 4648.15 Kcal/Kg [6]. Similar studies using Samanea waste leaves with broken papaya as the binder has also been carried out [19]. Another study found that briquettes using sawdust had the highest calorific value compared to coffee husk, khat waste, and dry grass [20].

In this study, coffee husk waste which is already in powder form was made into briquettes through a pressing process. Various biomass-to-adhesive ratios were studied based on the physical results of the briquettes after the pressing process and the high heating value (HHV) results from the mixture. Proximate analysis and ultimate analysis tests were conducted to determine the characteristics of coffee skin when used as a fuel source. To the best of the author's knowledge, there is still no literature that observed briquette from coffee husk waste and variating the particle size, the pressure, and the biomass-to-adhesive ratio. Through this research, it is hoped that the analysis and testing results can show the potential of coffee husks as briquettes. Besides that, the novelty of this research is to produce briquettes that do not require a binder whereas almost all briquettes require a binder.

2 Experimental method

The steps for making briquettes start with getting the coffee husk waste. Coffee husk waste was obtained from coffee entrepreneurs in Purwodadi District, Pasuruan, East Java, Indonesia. The coffee grounds were crushed and separated into 3 particle sizes, namely 20, 40, and 60 mesh (figure 1). The coffee husk waste that has been separated was then mixed with adhesive, which is also made from coffee skin. Next, this mixture of materials and adhesives is compressed on a press machine in a mold to form briquettes. After obtaining the briquettes, each sample was analyzed for various parameters such as high heating value (HHV), proximate and ultimate analyses, coals temperature, ignition time, burning duration, and burning rate.

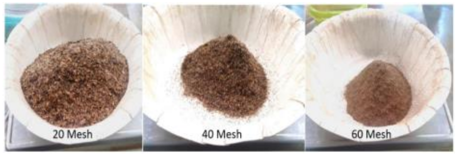

Fig. 1. Sieving results of coffee husk for various particle sizes.

In studying the effect of the particle size of the coffee husk waste briquettes, three different particle sizes were used, which are 800 μm (20 mesh), 425 μm (40 mesh), and 250 μm (60 mesh). The varying particle size was investigated to determine its effect on the strength and combustion characteristics of coffee husk waste briquettes. To study the effect of compaction pressure in briquettes, two pressure levels were used. These two-level pressures are 1 MPa and 2 MPa. Pressure is applied by means of a hydraulic machine to the mold. The mold uses a piston model that has an inner diameter of 25 mm with a weight of 10 grams per sample. The pressing process can be seen in.

Briquettes made from two pressure variations and three particle sizes were tested to determine the optimum pressure and particle size to produce coffee husk waste briquettes. The influence of these parameters on combustion characteristics was examined. The combustion characteristics studied were the temperature of the coals, ignition time, duration of combustion, and rate of combustion. The temperature that was evaluated on the surface of the briquettes when combustion occurs is the temperature of the flame. The measured time for the briquettes to self-ignite is referred to as ignition time. While the time it takes for the briquettes to become ash is called the duration of combustion. The rate of change in the mass of briquettes is referred to as the rate of combustion.

3 Result and discussion

After various experiments were carried out to determine the ratio of the mixture of coffee husk waste and its adhesive, it was found that after the pressing process, briquettes could still be formed without any adhesive. It highlights the strong potential of the coffee husk as a briquette when compared to various types of biomasses since previous studies have reported that a higher proportion of adhesive reduces the heating value of the briquettes [6, 19-20]. After finding the ideal adhesive composition, proximate analysis and ultimate analysis were carried out to determine the composition of the compounds and elements present in the coffee husk waste. Table 1 and Table 2 respectively show the results of the proximate and ultimate analysis of coffee husk waste without adhesive.

The effect of pressure and particle size on the flame temperature of the fuel is shown in Figure 2(a). The flame temperature becomes high if the pressure is high and the particle size is also high. The highest flame temperature was obtained with a value of 570 °C. This temperature is obtained from briquettes that have 60 mesh particle size and compacted with a pressure of 2 MPa.

The effect of pressure and particle size on ignition timing is shown in Figure 2(b). The ignition time becomes long if the pressure is high and the particle size is small. The longest ignition time duration was obtained with a value of 145 seconds. This ignition time is obtained from coffee husk waste briquettes which were made with 60 mesh particle size and compacted with a pressure of 2 MPa.

Table 1. Proximate Analysis Results.

Parameters	Unit	As Received	Dried Basis	Test Method
Total Moisture	%wt	15,13	-	ASTM E 871 – 82
Ash Content	%wt	5,87	6,92	ASTM D 3174 – 12
Volatile Matter	%wt	60,94	71,80	ASTM D 3175 – 20
Fixed Carbon	%wt	18,06	21,28	ASTM D 3172 – 13
Total Sulfur	%wt	0,13	0,15	ASTM D 4239 – 18
Gross Calorific Value	Kcal/kg	3811	4490	ASTM D 5865 – 19

Table 2. Ultimate Analysis Results.

Parameters	Unit	As Received	Test Method
Carbon	%wt	41,18	ASTM D 5373 – 21
Hydrogen	%wt	4,49	ASTM D 5373 – 21
Nitrogen	%wt	1,13	ASTM D 5373 – 21
Oxygen	%wt	32,07	ASTM D 3176 – 15

The effect of pressure and particle size on the duration of combustion is shown in Figure 2(c). The briquettes will burn long if the pressure is high and the particle size is small. The longest duration of burning time was obtained with a value of 1533 seconds. This duration is obtained from coffee husk waste briquettes which were made with 60 mesh particle size and compacted with a pressure of 2 MPa.

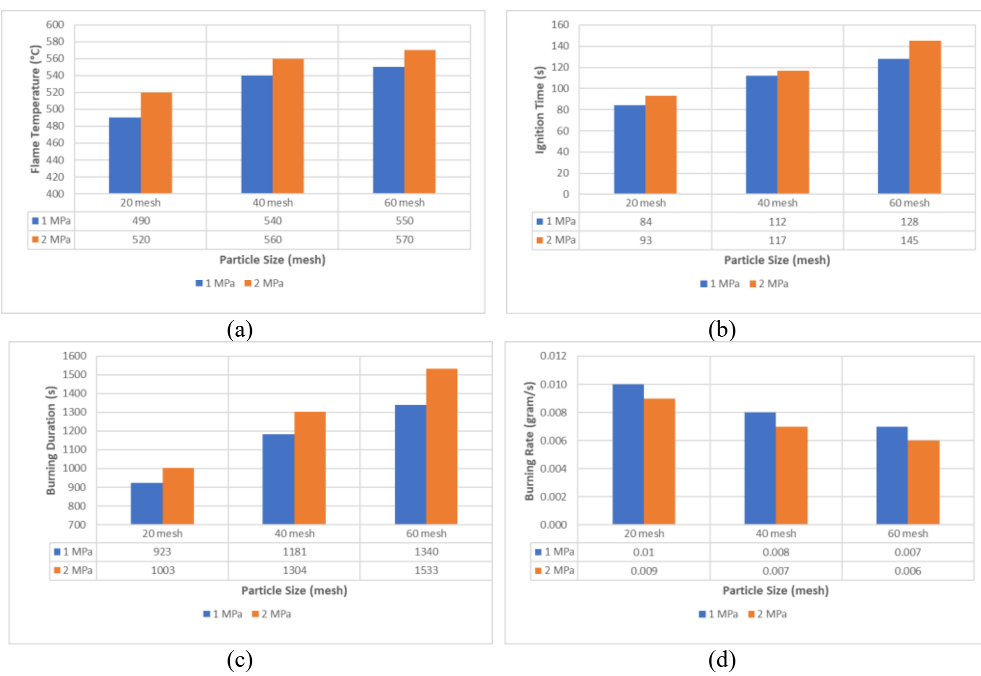

Fig. 2. Combustion characteristics at various particle sizes and pressures. a.) characteristics of flame temperature, b.) characteristics of ignition time, c.) characteristics of burning duration, d.) characteristics of burning rate.

The effect of pressure and particle size on the combustion rate is shown in Figure 2(d). The burning rate will be low if the pressure is high and the particle size is small. The lowest combustion rate was obtained with a value of 0.00609 gram/second. This burning rate is obtained from briquettes composed of 60 mesh particle size and compacted with a pressure of 2 MPa.

4 Conclusion

From testing and analyzing briquettes made from coffee husk waste, it was found that the components that generate the highest HHV are 100% coffee husk (without adhesive), with a value of 3811 Kcal/Kg. In the combustion characteristic test of the briquette samples, the smaller the particle size, the higher the flame temperature, the ignition time, and the duration of combustion. Also, the higher the briquette press pressure, the higher the flame temperature, the ignition time, and the duration of combustion. This research finds out that coffee husk briquettes can be made without using binders like other briquettes.

References

1. Katadata.co.id, Bahan bakar fosil menipis, ESDM dorong transisi energi (2020)
2. J. Kotcher, E. Maibach, W.T. Choi, BMC Public Health **19**, 1079 (2019)
3. K. Handayani, Y. Krozer, T. Filatova, Energy Policy, **127** (2019)
4. P. Sugumaran, S. Seshadri, Shri AMM MCRC (2010)
5. P. Thipkhunthod, V. Meeyoo, P. Rangsunvigit, B. Kitiyanan, K. Siemanond, T. Rirksomboon, Fuel, **84** (2005)
6. W. Anggono, Sutrisno, F.D. Suprianto, J. Evander, IOP Conf. Ser.: Mater. Sci. Eng., **2** (2017)
7. S.H. Sengar, A.G. Mohod, Y.P. Khandetod, S.S. Patil, A.D. Cendake, Int. J. Ene. Eng., **2** (2012)
8. T.H. Mwampamba, M. Owen, M. Pigaht, Ene. Sust. Dev. **17** (2013)
9. M.J. Stolarski, S. Szczukowski, J. Tworkowski, M. Krzyżaniak, P. Gulczyński, M. Mleczek, Renew. Eng. **57** (2013)
10. C. Sakkampang, T. Wongwuttanasatian, Fuel **115** (2014)
11. J. Hu, T. Lei, Z, Wang, X. Yan, X. Shi, Z. Li, X. He, Q. Zhang, Energy **64** (2014)
12. A. Brunerova, H. Roubik, M. Brozek, D. Herak, V. Sleger, and J. Mazancova, Energies **10** (2017)
13. W. Anggono, F.D. Suprianto, Sutrisno, A.W. Kasrun, JIRAE **11** (2016)
14. W. Anggono, Sutrisno, F.D. Suprianto, F.X.Y. Arifin, G.J. Gotama, 10^{th} Int. Conf. on Future Env. and Ene. **581** (2020)
15. O. Nurhilal, S. Suryaningsih, S. Nusi, J. of Powder Tech. and Adv. Func. Mat. **11** (2018)
16. P. Rahardjo, Kopi (2020)
17. Badan Pusat Statistik Indonesia, Badan Pusat Statistik (2021)
18. Y. Hilario, I. H. Sahputra, Y. Tanoto, G.J. Gotama, A. Billy, W. Anggono, IOP Conf. SeriesL Earth and Env. Sci. **1094** (2022)

19. G.J. Gotama, W. Anggono, Sutrisno, F.D. Suprianto, N. Jonoadji, F.X.Y. Arifin, IOP Conf. Series: Mat. Sci. and Eng. **1034** (2021)
20. T. Kebede, D.T. Berhe, Y. Zergaw, J. of Ene. (2022)