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Characteristics and Energy Potential of Bio-Briquettes from Cassava Peel, Water Hyacinth, and Sawdust

Sabarudin Akhmad*[1], Shofi Fitrotis Salimah[2], Anis Arendra[3]

[1,2]Department of Industrial Engineering, University of Trunojoyo Madura, Indonesia
[3]Department of Mechanical Engineering, University of Trunojoyo Madura, Indonesia
Email: [1]sabarutm@gmail.com, [2]shofi.fitrotis@trunojoyo.ac.id, [3]anis.arendra@trunojoyo.ac.id

Abstract

Abstract. Agricultural waste biomass direct burning to generate heat in industrial applications is inefficient. In addition, the difficulty in shipping and storage is due to its large volume and non-uniform shape. One approach to overcome this problem is by compacting the biomass to increase density, improve calorific value, and save a better combustion rate. In this study, the screw extruder machine was designed to compress, heat, and extrude bio-briquettes to form a hollow hexagon cross-section with an inscribed circle diameter of 52mm from biomass waste. The water hyacinth and cassava peel biomass were each dried and chopped into small particles before being mixed with sawdust. Cassava peel flakes also act as a binder in this mixture. We investigated the effect of biomass composition and extruder heating temperature on the calorific heating value and burning rate of bio-briquettes. We complete the experiments at three temperature levels and three levels of biomass composition. The results of the study found that there was no significant effect of the heating temperature factor on the calorific value and the rate of combustion of briquettes. While the composition of biomass impact significantly on the calorific value and burning rate of bio-briquettes. The calorific value reached 19.16 MJ/kg in the 50% sawdust, 30% water hyacinth, and 20% cassava peel bio-briquettes composition with a burning rate of 1.49 g/min. Water hyacinth and cassava peel waste recovery as an energy source not only turns waste into valuable resources but again becomes a solution to the problem of water hyacinth pest invasion and even provides economic and ecological benefits.

Keywords: *bio-briquettes, biomass, calorific value, experiments.*

1. INTRODUCTION

Refers to the government regulation of the Republic of Indonesia number 79 of 2014, Indonesia has set a target for the primary energy mix. The target was a prime energy mix composition of at least 23% coming from new and renewable energy in 2025 and then increasing to a minimum of 31% in 2050. One of the renewable energy sources is biomass from agricultural waste, and Indonesia has great potential in this regard. The acceleration of achieving the energy mix target was recently encouraged by the Presidential Regulation of the Republic of Indonesia Number 112 of 2022. One of them is by utilizing biomass energy sources for power generation. Sources of biomass for renewable energy should be easy-to-grow vegetation, agricultural by-products, or forestry by-products of low economic value and do not compete with food sources [1,2]. Particular vegetation that is easy to grow and even produces high carbohydrates in sub-optimal land is cassava (Manihot esculenta) [3]. Indonesia is the fourth largest producer of cassava in the world after Nigeria, Thailand, and Brazil, with a production of 20 million tons per year [4]. The main cassava-producing provinces in Indonesia are Lampung, Central Java, East Java, West Java, and the Special Region of Yogyakarta. One of the wastes of cassava that has the potential as renewable energy biomass is cassava peel waste [5–9].

As a source of biofuels, cassava peel can be processed into bio-oil [8], charcoal [5], briquettes [6], bio-gas [7], and bioethanol [9]. Cassava contains a lot of total dry matter (38.6%) and has the smallest water footprint compared to all other crops. Based on these characteristics, cassava is very promising in biofuel production. Previous research, cassava dregs from tapioca flour industry waste can yield bioethanol through delignification, hydrolysis, and fermentation [9]. Another by-product is cassava peel which can generate bio-oil with a calorific value of up to 27.43 MJ/kg through pyrolysis processing [8]. Another study used cassava peels with cow manure to produce biogas using a biogas reactor [7]. Another way to increase energy density is by torrefaction and briquetting processes to make solid fuels from biomass [5,6].

Another biomass that can be a source of biofuels is water hyacinth [10–14]. Water hyacinth (Eichhornia crassipses) is a floating aquatic plant, and it's considered a species that threatens the environment [15], causing environmental degradation and becoming an economic burden in treating the problem [16]. It is also known as the most invasive pest due to its high growth rate and adaptability in a wide aquatic ecosystem variety [17]. The negative impact of overgrown water hyacinths in the waters causes deterrents to fishing equipment, diminishes fish catches, declines dissolved oxygen levels in the water, and blocks sunlight penetrating the water, thereby perturbing aquatic biota [18]. But on the other hand, because of its fastest growth, water hyacinth is considered a potential source of biomass as a renewable energy source and an alternative to fossil fuels [14]. Water hyacinth biomass was proven to deliver calorific values up to 14.46 MJ/kg [10]. Previous studies have produced biogas from water hyacinth juice and biomass pellets from water hyacinth pulp [11]. In other research, hydrolysis and fermentation processes have also succeeded in water hyacinth processing into bioethanol [13]. Water hyacinth utilization as an energy source not only turns waste into valuable resources but again becomes a solution to the problem of water hyacinth pest invasion and even provides economic and ecological benefits.

Agricultural waste biomass direct burning to generate heat in industrial applications is inefficient. In addition, the difficulty in shipping and storage is due to its large volume and non-uniform shape. One approach to overcome this problem is by compacting the biomass to increase density, improve calorific value, and save a better combustion rate [19]. Briquetting is a method of biomass compaction that produces briquettes with a higher density than the raw materials that compose them. With a higher density, briquettes have a better volumetric calorific value. Uniform shape of briquettes, making it easier to handle shipping and storage, saving costs. If produced at a low cost, briquettes can be an alternative substitute to firewood, charcoal, or coal for domestic cooking use, heating needs, and industrial operations. Even some briquettes are capable of operating industrial blast furnaces [20]. Currently, two high-pressure compaction technologies for briquetting are screw extrusion and piston press [19]. Piston press briquetting processes discretely to produce completely dense briquettes. Screw extrusion briquetting continuously produces homogeneous briquettes that have concentric holes. The concentric holes in these briquettes increase the combustion area and provide better combustion characteristics. Bio-briquettes in this research use biomass from sawdust, cassava peel, and water hyacinth as raw materials to produce through a hot screw extrusion process. Then We study the effect of biomass composition and extrusion temperature in this work.

2. METHOD

Preparation of Bio-briquette Materials

We collect biomass from three sources for the preparation of bio-briquette materials. Cassava peels collected were from the waste of cassava chip producers in Madura. The cassava peel was sundried for two days to reduce the moisture content, then chopped using a chipper shredder machine. The ground cassava peel is then sieved to collect particles less than 4mm in size. Meanwhile, the water hyacinth fetched was from a water flood reservoir in Madura. The water hyacinth was squeezed and dried in the sun for two days to reduce the moisture content, then chopped using a chipper shredder machine. The chopped water hyacinth was then sieved to collect particles less than 4mm in size. The sawdust obtained was from the furniture industry in Madura. This sawdust comes from the waste of rosewood and mahogany sawmill operations.

For this work, the biomass materials mixed in bio-briquette production are with three composition levels. The first composition (DryMix1) prepared 150 kg of biomass blend consisting of 50% sawdust, 30% dried water hyacinth flakes, and 20% dried cassava peel particles. The second and third compositions also prepared 150 kg of blend with the respective mass fraction of 40%: 40%: 20% (DryMix2) and 30%: 50%: 20% (DryMix3) sawdust, dried water hyacinth flakes, and dried cassava peel particles.

Bio-briquette Making Method and Machine.

The dry biomass mixture is then formed into bio-briquettes using a hot screw extruder machine with a 12 kW electric motor and 3 kW barrel heating power. This process takes place continuously. The cross-section of the extruder molding barrel is in the form of a hexagon with an inscribed circle diameter of 52 mm, and 400 mm long. The screw uses a root diameter of 60 mm with a taper angle of 3o, a helix angle of 15o, and a channel depth of 30 mm. The screw rotates at 400 rpm producing a mass flow rate of 60 kg/h. Biomass compaction occurs due to the pressure build-up of screw rotation in the molding chamber, with high heat generated by the friction of the screw extruder and electric heating producing bio-briquettes which are much denser than the original biomass material. For this study, the extruder barrel temperature set was at three levels: 250 oC, 300 oC, and 350 oC. This work performed were at the Industrial Engineering Manufacturing Systems Laboratory at Trunojoyo University.

Bio-briquette Testing Methods and Equipment

The calorific value, representing the amount of energy liberated from complete combustion per unit mass of briquettes, is also a significant parameter in fuel selection and economic value judgment. The calorific value of bio- briquettes tested was using an adiabatic bomb calorimeter. The calculated density of bio-briquettes was by dividing the mass and volume of the briquettes. The briquettes dried for 30 minutes at a temperature of 100 C, then burned entirely on top of a furnace to analyze the burning rate. The burning rate of bio-briquettes was determined by mattering the combustion time of the bio-briquette mass quantity to become ash. The hypotheses

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to be tested in this experiment are: 1) The biomass composition affects the calorific value of bio-briquettes. 2) The composition of biomass affects the burning rate of bio-briquettes. 3) Extruder heating temperature affects the calorific value of bio-briquettes. 4) Extruder heating temperature affects the burning rate of bio-briquettes. 5) The interaction of biomass composition and extruder heating temperature affects the calorific value of bio-briquettes. 6) The interaction of biomass composition and extruder heating temperature affects the burning rate of bio-briquettes. This laboratory work performed was at the Chemistry Laboratory at the Faculty of Education, Trunojoyo University

Table 1. Characteristics of bio-briquette combustion

Biomass blend	**Extruder molding temperature**	**Calorific Heating Value (MJ/kg)**		**Burning Rate (g/min)**	
		Avg	sd	Avg	Sd
DryMix1 (50% sawdust: 30% water hyacinth shred: 20% cassava peel flakes)	250 ºC	19.16	0.36	1.49	0.078
	300 ºC	18.76	1.40	1.49	0.065
	350 ºC	19.11	0.79	1.45	0.039
DryMix2 (40% sawdust: 40% water hyacinth shred: 20% cassava peel flakes)	250 ºC	18.20	1.18	1.41	0.018
	300 ºC	17.98	2.14	1.47	0.008
	350 ºC	18.59	2.11	1.34	0.081
DryMix3 (30% sawdust: 50% water hyacinth shred: 20% cassava peel flakes)	250 ºC	16.76	0.86	1.46	0.091
	300 ºC	17.19	1.15	1.43	0.043
	350 ºC	16.41	1.31	1.42	0.043

3. RESULT AND DISCUSSION

We have put through water hyacinth and cassava peel bio-briquettes from three biomass blends with three levels of extruder heating parameters. Our factorial experiment examined the characteristics of the calorific heating value and burning rate of nine experimental treatment combinations (Table 1). To test the research hypotheses, we conducted an Analysis of Variance. The Analysis of Variance assesses the importance of one or more factors by comparing the mean of the response variables at different factor levels. Based on the bio-briquettes calorific heating value measurement, the Analysis of Variance proves that biomass composition has significantly affected the bio-briquettes calorific heating value. Meantime, the extruder heating temperature has no significant effect on the calorific heating value of the bio-briquettes. Likewise, the interaction of the extruder heating temperature with the biomass composition has no substantial impact on the calorific heating value of bio-briquettes. The results of the Analysis of Variance on the measurement of the bio-briquettes burning rate show that the biomass composition has a notable impact on the burning rate of bio-briquettes. Despite the extruder heating temperature having no significant mark on the bio- briquettes burning rate. Likewise, the interaction of the extruder heating temperature factor with the biomass composition does not significantly affect the bio-briquette burning rate.

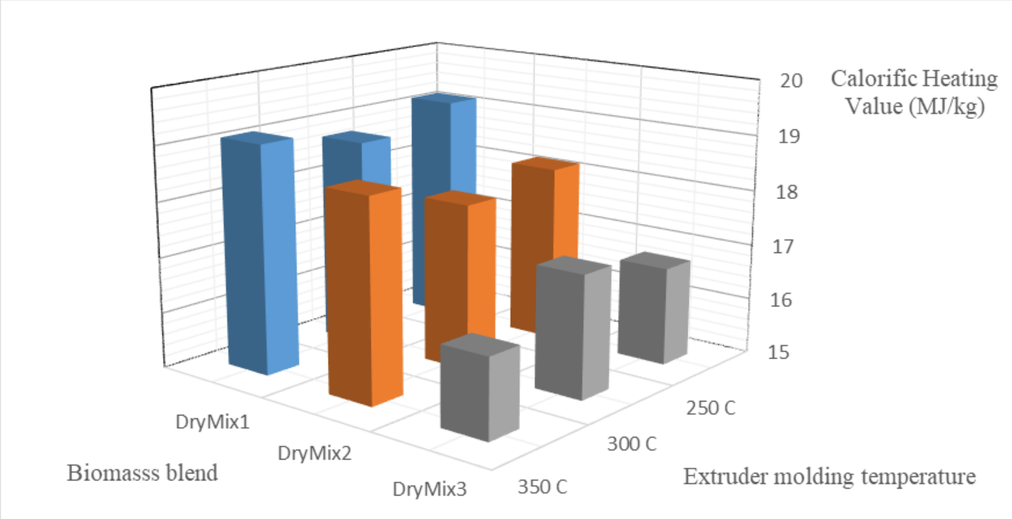

Figure 1. Calorific Heating Value of Bio-briquette

The Analysis of Variance results corroborated was by the calorific heating value data-graph remark (Figure 1). The calorific heating value of the bio-briquettes made from DryMix1 was always higher than the calorific heating value of the bio-briquettes from DryMix2 and DryMix3. In addition, there are significant differences between the data series DryMix1, DryMix2, and DryMix3. The figure shows the tendency of the calorific heating value to decrease along with the reduced sawdust mass fraction in the biomass blend. Meanwhile, the extruder temperature data series shows a flat trend. Even though the extruder temperature is an essential factor in the bio-briquette forming process, the bio-briquettes calorific heating value was not affected by the extruder heating temperature.

4. CONCLUSION

Dried water hyacinth combined with sawdust and cassava peel was formed into bio-briquettes successfully. Cassava peel flake in this biomass blend also serves as a binder. This research succeeded in utilizing waste converted into energy sources. In bio-briquette manufacturing, the parameter of extruder molding temperature has no significant effect on the calorific value and burning rate of the resulting bio-briquettes. Meanwhile, the biomass composition blend on the bio-briquette compound significantly affects its calorific value and burning rate of the bio-briquettes. Bio-briquettes with the highest calorific value of 19,16 MJ/kg delivered were from DryMix1 (50% sawdust, 30% water hyacinth, and 20% cassava peel).

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