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Potential Analysis of Biomass Briquettes from Sugarcane Milling Waste for Boiler and Generator Turbines Stations

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ABSTRACT

The decrease in sugar productivity was due to insufficient process of the sugar production process such as the low efficiency of boiler machine input energy. This study aims to analyze the potential use of Bagasse Briquetting Fuel (BBF) made from sugarcane milling waste at PT Madubaru as an attempt to obtain the optimal efficiency of boiler machine. Analysis of the effect of the adhesive concentration on the BBF quality was carried out to determine the optimal composition of the use of adhesive materials. Economic analysis was also conducted to determine the economic potential of BBF development. The analysis revealed that the BBF from Sugarcane milling waste has Calorific Value of 17,367-19,497 KJ/kg and density of 0.740-0.915 g/cm^3. BBF with an adhesive variation of 1.25% is the BBF with the highest efficiency because it meets the needs of boiler fuel with the least amount of 100.8 tons/day for the operation of 1 boiler machine. The development of BBF from sugarcane milling waste has a selling value of Rp1.390.5,-/kg much lower than the existing biomass fuels found in the market.

1. INTRODUCTION

The Central Statistics Agency of Indonesia noted that the amount of sugarcane production in Indonesia reached 2.42 million tons in 2021. This value is 13.5% higher than the previous year (2020) which amounted to 2.13 million tons. While in the past decade, sugarcane production in Indonesia has tended to decline. The sugar that is widely consumed in Indonesia is produced from sugarcane plants (*Saccaharum officinarum* L.) and the demand is increased each year (Ilhamsyah, 2022). Development of the national sugar industry, in this case the expansion of sugarcane planting areas and sugarcane cultivation techniques need to be improved (Kumalawati *et al*., 2015). The impact of this decline in sugarcane production lead to increase sugar import quantities accompanied by the threat of price increases, raising concerns about Indonesia's dependence on sugar supplies from abroad. This situation poses a high risk to domestic sugar supplies and has tapered off the debate around food sovereignty. To overcome this condition, strategic steps are required to reduce the dependence on sugar imports, strengthen food sovereignty, and better deal with global price fluctuations. One solution to overcome this problem is the revitalization of national sugarcane production management. For on-farm sector, revitalization can be done throughout expanding the area of sugarcane land, while for the off-farm sector, the rehabilitation can be carried out throughout increasing milling capacity, better the factory efficiency, and improving sugar quality (Safrida *et al*., 2020).

PT Madubaru is the only sugar factory and alcohol/ethanol factory with its derivative products in the region of Yogyakarta province. PT Madubaru producing sugar with SHS 1 (Superior Hooft Suiker) or (White Crystal Sugar 1) quality with a milling capacity of 3,500 tons of sugarcane per day which equal to sugar production capacity of 45,000 tons per year (PT Madubaru, 2023). This production is obtained by utilizing sugarcane land of ± 5,300 ha area (Madubaru, 2023). PT Madubaru used bagasse (sugarcane milling waste) as the energy source for sugar production especially at the boiler and turbine station. The bagasse is from sugarcane milling waste which has an inconsistent moisture content due to a decrease in milling efficiency. This lead to the unstable temperature produce in from the boiler which potentially affect the evaporation process of the sugar, that also affect the quality of the sugar produced. In another hand, shifting from bagasse to firewood requires high expense which increase the sugar production cost. an alternative solution should be developed in term of optimize the advantage of baggase as the energy source that provide the stable temperature in the boiler station. The use of renewable energy in the context of energy diversification is very strategic since it is in line with the development of sustainable energy (sustainable development) that is environmentally friendly (low release of greenhouse gas emissions). Base on the regulation of Indonesian Government Regulation No. 5 2006 relates to the National Energy Policy states that one of the alternative energy source with a promising potency is biomass energy. The use of briquette fuel from bagasse waste (Bagasse Briquetting Fuel) can be an alternative solution to increase the efficiency of converting biomass energy into heat in the boiler combustion chamber. This because of the baggase waste it's self has a very low bulk density (at ~120 kg m^{-3}), making it has very high burning speed, so the operator in the boiler station needs to feed it into the chamber in high volume per hour (Stanmore, 2010). The Calorific value shows the value of heat produced by fuel during combustion (Wibowo *et al*., 2017), the higher the calorific value, the better the quality of fuel. Bagasse has a calorific value ranging from 1825 – 1900 cal/g (Ika, 2014), this value is still lower when compared to the calorific value of biomass briquettes standard (Prasetiyo *et al*., 2023). Densification efforts can be done by producing BBF (Baggase Briqueting Fuel) from bagasse and starch as an adhesive component with an optimal percentage.

Producing biomass briquettes also requires adhesives that function to bind biomass powder so that it is easily formed into briquettes. fine natural adhesives to use as binder are sago and tapioca, these adhesives may produce a durable and smokeless biomass briquettes (Shafiyya *et al*., 2022). In their research, the best briquette characteristics obtained in the composition of tea pulp: sago flour of 9 : 1 composition with a calorific value of 12,024 kJ/kg. Bazenet *et al*., (2021) examined the effect of adhesive levels on briquette characteristics, it was found that the higher the adhesive content the lower the quality of briquettes. Based on physical properties, chemical properties, and energy properties, charcoal briquettes with an adhesive percentage of 5% have better characteristics compared to adhesive levels of 10 and 15% with a calorific value of 32,860 kJ/kg. In another study by Aziz *et al*., (2019) it is known that the use of 10% tapioca adhesive is the best treatment because it gives a good appearance with a calorific value of 26,494 kJ/kg. This study aims to analyze the potential of biomass briquette from sugarcane milling waste as the alternative energy source for boiler machine at PT Madubaru sugar production company. The study cover both the potential quality of the biomass briquette as the energy source and the economical potency of the biomass briquettes as the alternative for the biomass briquettes market demand.

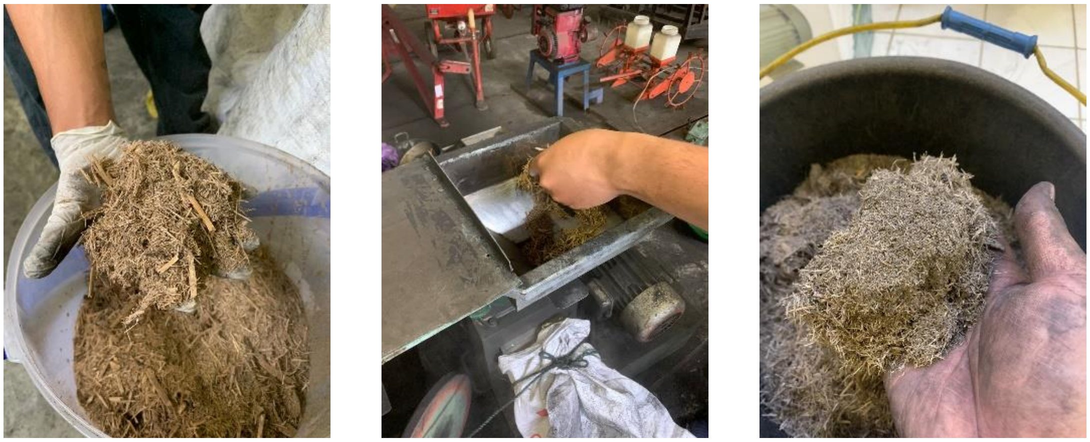
2. MATERIALS AND METHODS

The main material used in this study was a sugarcane milling waste (sugarcane bagasse) from PT Madubaru sugar production company in 2022. While, the adhesive component used in this experiment was a tapioca powder that was obtained from Yogyakarta market. The main tool used in this study was a manual briquette presser with a 10-ton hydraulic system to mold the briquette. Also, a disk mill machine for material grinding purpose equipped with mesh sieve of 80. Calorific value was measured using a Parr 1341 calorimeter bomb.

2.1. Biomass Briquette Sample Preparation

1. Biomass Powder Preparation

Before molding the briquette, the bagasse material is first mashed to reduce the particle size of the material (Figure 1). The bagasse particle size reduction process was carried out using a disk mill machine with a mesh of 80. The biomass must be adequately fine to be able to make good briquettes. The particle size of the material is important in determining the area of contact between the particles of the material which will later determine the final density of the briquettes that have been printed. After mashing, then sieving is carried out to homogenize the particle size of the material using mesh sieve of 140.



(a) (b) (c)

Figure 1. (a) Bagasse before mashing; (b) The milling process of materials; (c) Bagasse after grinding using a disk mill.

It is important to know the characteristics of the raw materials used as fuel. These characteristics determine the efficiency value of the engine used. The following values are averages and can vary depending on the source of sugarcane bagasse, processing methods, and storage conditions.

Table 1. Properties of bagasse powder

Property	Value
Moisture content	45 - 55%
Density	150 - 200 kg/m^3 (wet)
Particle size	1 - 50 mm (depending on milling process)

These values are averages and can vary depending on the source of the bagasse, processing methods, and storage conditions.

2. Mixing Biomass Powder with Adhesive

The purpose of mixing is to apply a thin layer of adhesive to the surface of biomass particles and to absorb water, forming a dense texture. Using adhesive will improve the arrangement of particles. This stage is crucial and determines the quality of biomass briquettes. Mixing biomass powder with adhesive material was done using a horizontal mixer machine in a dry material base. Prior to this, hot water (100°C) is sprayed onto tapioca flour, gradually adding 10% of the total dough weight, to obtain a sticky solution. Afterward, the adhesive solution and bagasse powder were prepared according to the specified ratio and stirred until it becomes a ready to mold dough.

3. Molding process

Molding stage in the biomass briquette production was done using a compression-type press (Figure 2a). The pressure exerted for the manufacture of biomass briquettes is divided into two ways, namely exceeding the limit of elasticity of raw materials so that the cell structure will collapse and has not exceeded the limit of elasticity of raw materials. In general, the higher the pressure applied will give a tendency to produce biomass briquettes with higher density and compressive firmness. In this study, the press was carried out by utilizing a 10-ton hydraulic jack connected to molding media according to the desired briquette format and size (8 cm of diameter) (Figure 2b) which is equal to 19 MPa. This is of what is recommended by Amrullah *et al*. (2020) in the range of 10 - 20 MPa.

4. Drying process

After molding process, the briquette still contain high water content. In this study, drying was carried out using a dehydrator machine with a setting temperature of 55ºC for 24 h.

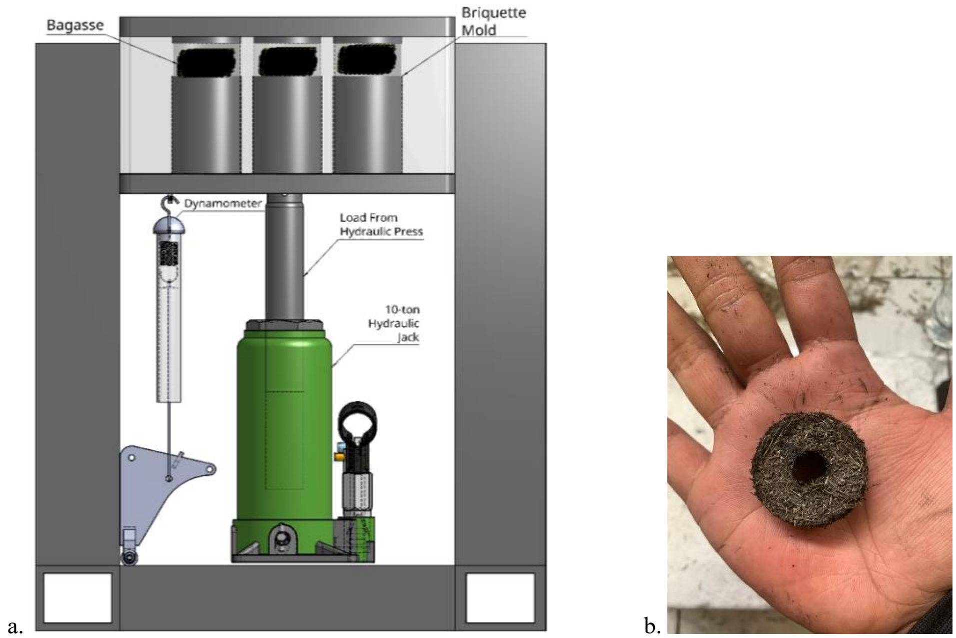


Figure 2. (a) Molding process of the biomass briquette from sugarcane bagasse waste, and (b) Biobriquette from bagasse

2.2. Experiment Design

1. Adhesive Percentage Variation

This research was conducted with 6 different treatments using varying compositions of tapioca flour as a binder and bagasse. The use of this type of binder in this study is based on the research by Sulistyaningkarti & Utami (2017), which showed that tapioca flour binder is better than wheat flour binder. The treatments included: A.1 (bagasse without binder as the control); A.2 (BBF with 1.25% binder of the total weight); A.3 (BBF with 1.5% binder); A.4 (BBF with 1.75% binder); A.5 (BBF with 2% binder); and A.6 (BBF with 2.5% binder). The experiment was conducted with three repetitions to test the density values.

2. Analysis Methods

Calorific value of dry BBF samples was measured using calorimeter bomb (Parr 1341), and was calculated as follows.

$$\text{Calorific Value} = \frac{((t * W) - b)}{m} \quad (1)$$

where t is final temperature in the combustion process (°C), b is the baseline heat value that might be required for the initial process or heat lost (cal), m is mass of the fuel used (g), and W is energy equivalent of the calorimeter (cal/°C).

The effect of adhesive variations was also analyzed on density value of the dry BBF sample. Analysis of boiler energy requirements was conducted based on the calorific value measure. In addition, statistical analysis was carried out to determine the significant influence of experimental variations on test parameters which included the calorific value and density value of biomass briquettes. Economical analysis was also conducted to estimate the market value of the BBF and comparing it to the existing biomass energy in the market.

3. RESULTS AND DISCUSSION

3.1. Effect of Adhesive on Calorific Value of Briquettes

Producing briquettes from biomass waste as the alternative energy must certainly pay attention especially to the calorific value parameter. Calorific value is an important quality parameter for briquettes, the higher the calorific value, better the quality of the briquettes. In this study, variations in the use of adhesives were used with the aim of obtaining the most optimal adhesive composition formula and materials. In this study, all variations including control variables were dried under dry conditions by using an oven at a temperature of 55°C for 24 h. Therefore, all variations were already in a dry state before being tested using a bomb calorimeter.

Figure 3 depicts the effect of adhesive percentage on the calorific value of BBF. According to figure 4, the higher percentage of adhesive used in producing BBF leads to the lower calorific value of the BBF. While, briquetting the sugarcane milling waste can significantly increase the calorific value BBF compared to the controlled sample (A.1: bagasse with no adhesive). The detail calorific value of BBF (biomass briquettes) for each variation in adhesive percentage can be seen in Table 2. According to table 2, the percentage of adhesive in BBF can contibute to a significant effect on the calorific value of BBF. The lower the adhesive percentage can give higher calorific value of BBF. This happened because the calorific value of the the adhesive material is lower than the sugarcane milling waste. Adding more adhesive will decrease the quality of BBF based on the calorific value. However, the optimal percentage of adhesive material should be added to BBF to obtain the a fine looks and density of the briquette.

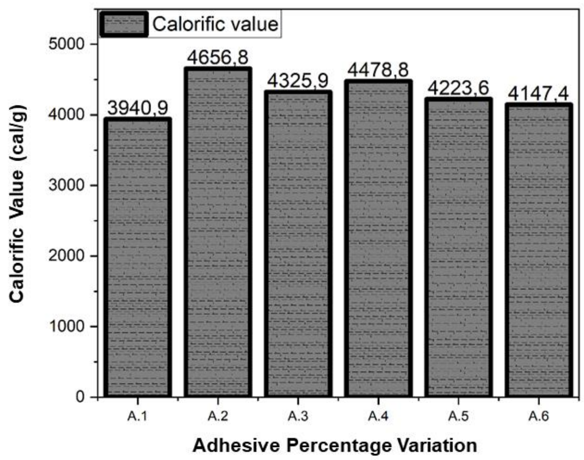


Figure 3. The effect of adhesive percentage on the calorific value of the bagasse briquettes (A.1: bagasse without adhesive; A.2: BBF with 1.25% adhesive; A.3: BBF with 1.5% adhesive; A.4: BBF with 1.75% adhesive; A.5: BBF with 2% adhesive; A.6: BBF with 2.5% adhesive)

Table 2. Calorific Value Calculation Results of biomass briquettes with variations in adhesive concentration.

Sample Code	t (°C)	b (°C)	m (g)	W	Calorific Value (cal/g)	Specific Heat (KJ/kg)
Bagasse	1.074	20.24	0.6560	2426	3940.9[a]	16.500
1.25%	1.647	15.41	0.8547	2426	4656.8[f]	19.497
1.50%	0.989	20.93	0.5498	2426	4325.9[d]	18.111
1.75%	1.741	21.16	0.9383	2426	4478.8[e]	18.752
2.00%	1.242	9.2	0.7112	2426	4223.6[c]	17.683
2.50%	1.58	8.74	0.9221	2426	4147.4[b]	17.364

These results show that BBF with all variations of adhesive percentage is in accordance with SNI 8021:2014, namely with a standard of calorific value ≥ 4,000. The highest calorific value and the lowest calorific value were obtained from BBF with adhesive percentage of 1.25% and 2.5%, respectively. The carbon content of baggase is higher than the binder powder, so that, adding more binder into the briquete lowering the carbon content. The addition of binders can reduce heat because it has thermoplastic properties, so it is difficult to burn, and carries a lot of water so that the heat generated is first used to evaporate water on briquettes (Gandhi B, 2010; Aziz *et al*., 2019). Binders are also thermophilic because they contain carbon elements (Aziz *et al*., 2019), the burning speed of briquettes is influenced by the carbon content of binder present in briquettes, the low carbon content causes briquettes to burn longer. The higher the percentage of carbon bonded, the higher the calorific value (Aziz *et al*., 2019). However, for the control sample (without binder), the briquette has a very low density and lead to farther distance between particles. These phenomena possibly contribute to a lower caloric value of the control sample.

When observing the calorific value based on the composition of briquettes, there are differences between the theoretical calorific value and the measured calorific value in briquettes made from a mixture of tapioca flour and bagasse. This due to several factors, first, heat or energy losses during measurement may not be detected by the measuring instrument. Second, the quality and homogeneity of the mixture affect the final results, with non homogeneous mixtures resulting in variations in calorific value. Lastly, there is a possibility of other additives in the briquette mixture. Densification process increase the density of briquettes. Samples with higher density contain more solid fuel in a given volume compared to low density briquettes, resulting in more total energy when it is burned.

3.2. Effect of Adhesive Percentage on Briquette Bulk Density

Bulk density (ρ) is the ratio of total mass to the total volume of a material, including the empty space between material particles (Andriani *et al*., 2013). Density has a significant influence on the rate of combustion, so the quality of briquettes is highly determined by density of briquettes. The combustion rate is the speed at which the briquette burns, meaning that the greater the value of the combustion rate, the faster the briquette will run out (Aljarwi *et al*., 2020), so that to produce an optimal combustion rate, an appropriate density value is needed. Based on Figure 4 and Table 3, bagasse briquettes with an adhesive percentage of 1.75% have the highest bulk density value, while briquettes with adhesive percentage of 2% have the lowest bulk density value. The bulk density of briquettes can be influenced by the size and homogeneity of the briquettes. According to Altuntas & Yildiz (2017), the smaller the particle size, the higher the density value. Based on this explanation, bulk density has an inversely proportional relationship with particle size. When the particle size is small, the pores between particles will also shrink. This can cause the total volume of material to be smaller. When the volume of the material is smaller, the bulk density value will be even greater.

Detail of bulk density value measurement for each biomass briquettes produced using several variations in adhesive percentage is presented in Table 3. The percentage of adhesive component give significant effect on the bulk density of the BBF. The density of biomass briquettes is above the wood density range, which is between 800 - 1,100 kg/m^3 (Liliana, 2010). Based on Table 3, only biomass briquettes with an adhesive variation of 2% do not correspond to the density value range. Furthermore, this can be caused by contamination from other materials in the briquette constituents so that the level of particle uniformity is low. This can have an effect on measuring particle volume which will have an impact on the density value of the material.

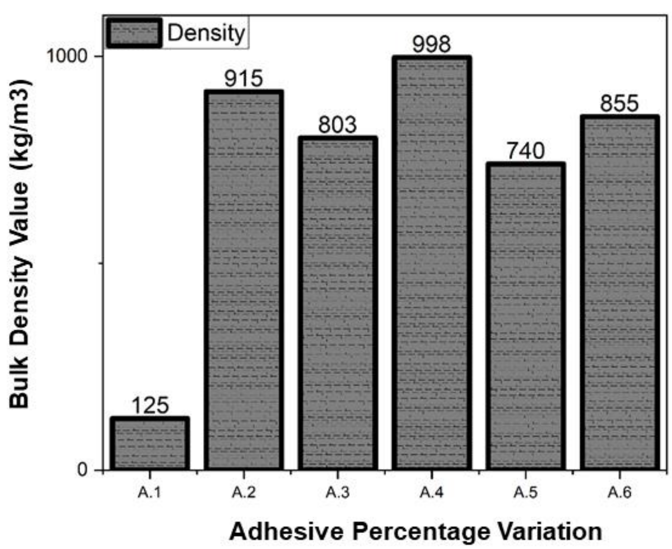


Figure 4. The effect of adhesive variations on the density value of briquettes

Table 3. Calculation of density value in variations in adhesive use

Sample Code	kg/m³	g/cm³
Bagasse	125[a]	0.125
1.25%	915[e]	0.915
1.50%	803[c]	0.803
1.75%	998[f]	0.997
2.00%	740[b]	0.740
2.50%	855[d]	0.855

3.3. Calculation of Boiler Fuel Requirements

Fuel consumption of Boiler machine refers to the amount of fuel that enters the boiler (kg/h). To find this value, the calorific value of low heating value (LHV) fuel should be calculated, so that heat demand in the boiler (Q) can be estimated. After that, fuel consumption is calculated by dividing the heat requirement (Q) of boiler machine by the LHV value of fuel (Ginanjar *et al*., 2022). Calorific value is the amount of heat energy obtained from the combustion of fuel and is divided into two as follows:

- High heating value (HHV) is the amount of heat produced in combustion, without any water content in the fuel. It is obtained by using the test method in the laboratory using a calorimeter.
- Low heating value (LHV) is the amount of heat produced in combustion and some of it is used for evaporation so that the water content in the fuel will run out. Hasibuan & Napitupulu (2013) stated that the lower calorific value (LHV) can be calculated by the following formula:

$$LHV = HHV - 3{,}240 \quad \text{(kJ/kg)} \tag{2}$$

The level of boiler performance obtained from the comparison between energy transferred to or absorbed by the working fluid in the boiler by entering heat energy from fuel is an elaboration of boiler efficiency. Boiler efficiency is one of the important factors in calculating fuel needs. The fuel requirement of the boiler is calculated as the following:

1. Water requirements in boiler machine: 110% x steam required = 17,6 ton/h
2. The energy required by the boiler machine at 30% efficiency was calculated using the following formula:

$$Q = \frac{m \times C \times \Delta T}{30\%} \tag{3}$$

where m is boiler water requirement (kg), C is heat specific of water (4,200 J/kg°C), ΔT is temperature difference between water vapor (598.15 K) and feeding water to boiler (403.15 K), and 30% is the boiler efficiency assumption. Using this formula, Q value required by the boiler machine was estimated to be 48,048,000 kJ/h.

3. The number of sacks that need to be put into the boiler burner can be calculated by dividing the energy (Q) required by the LHV value (KJ/kg) The low heating value (LHV) assuming the quality of the fuel produced by the milling station of 70% can be calculated using the following formula:

$$LHV = (HHV - 3{,}240\ \text{KJ/kg}) \times 70\% \tag{4}$$

Using this formula, the LHV value is obtained at 9,273.6 kJ/kg. The amount of bagasse needed for the operation of one boiler can be calculated using the following formula:

$$m = \frac{Q}{LHV} = \frac{48{,}048{,}000\ \text{KJ/h}}{9{,}273.6\ \text{KJ/kg}} = 5{,}181.1\ \text{kg/h} = 5.2\ \text{t/h}$$

The need for bagasse for the operation of 5 boilers at the boiler station and turbine generator at PT Madubaru with a steam capacity of 16 tons is 25.9 t/h or 621.7 t/day. Milling capacity of PT Madubaru is 3500 TCD (ton cane day). Based on the literature by PT Madubaru (2023), the value of sugarcane bagasse, imbibition water, bagasse, and raw sugarcane juice produced can be calculated using mass balance. This study assumes the lowest sugarcane pulp production value to be 16% and the highest to be 32%. Assuming 32% bagasse produces 1120 tons/day while for 16%

bagasse assumption produces 560 t/day. The assumption of 16% bagasse as not been able to meet boiler fuel needs, and also the emissions resulting from the combustion process are still too high. By being converted into biomass briquettes, the emissions produced will be lower so that they are more environmentally friendly. In this study, bagasse was processed into biomass briquettes using adhesive componentas a binder material (in this case using tapioca powder) with treatment variations of 1.25%, 1.50%, 1.75%, 2%, and 2.50%. Based on the calorific value produced in each variation of adhesive, the following is the amount of biomass briquette required to run the boiler machine is presented in Figure 5.

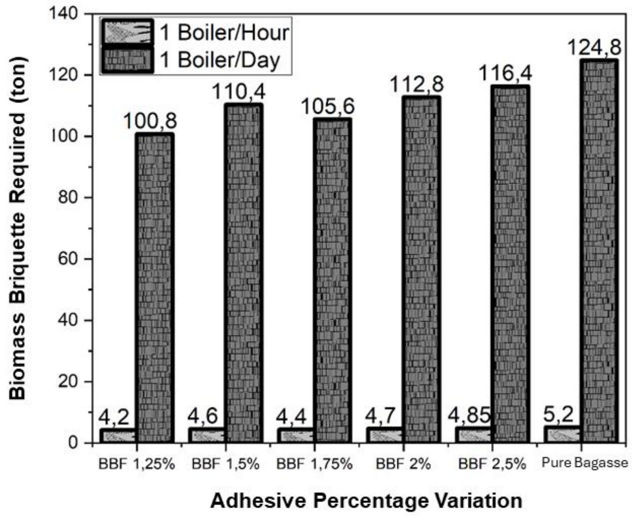


Figure 5. The amount of bagasse briquette required by boiler machine for each variation in adhesive percentage

Based on the calculation of the amount of fuel needed by the boiler assuming the calculation of the calorific value of the test results (figure 5), it can be seen that biomass briquettes with an adhesive variation of 1.25% make the boiler consume the least amount of fuel, which is 504 t/day while briquettes with an adhesive variation of 2.5% make the boiler consume the most amount of fuel which is as much as 582 t/day. Based on this, there is potential to be able to convert bagasse into biomass briquettes with the amount of raw material (bagasse) released by the milling station, which is 560 - 1120 t/day assuming (30 - 32%) pulp from total sugarcane mill of 3500 t/day.

3.4. Economic Analysis

a. Estimated Manufacturing Cost

Cost analysis is carried out to calculate the costs needed in the Baggase Briqueting Fuel (BBF) production process where its results then used as a reference to determine the selling price of the product. The cost of goods produced (COGS) method is used as cost estimated method, by including all components of production costs as elements of cost of goods which include direct material costs, direct labor costs, machine depreciation costs, and factory overhead costs. In this study, the annual calculation is based on the milling period at PT Madubaru, which is 4 months. Marasabessy *et al.* (2019), stated that in determining the cost of goods produced (COGS), several costs that are used as the basis for determining production costs are as follows:

Direct Material Costs. Direct material cost is the expense incurred for the main raw materials during production. This cost is obtained by multiplying the quantity of bagasse needed each month by the price of bagasse, and then adding it to the quantity of tapioca flour needed each month multiplied by the price of tapioca flour. As detailed in Table 4, the total direct material costs is Rp9,652,500,000/month or Rp38,610,000,000/year.

Direct Labor Costs. The direct workforce consists of 10 machine operators and 9 workers in raw material preparation. The raw material preparation department is responsible for preparing sugarcane bagasse raw materials for crushing, tapioca flour, and water, and transferring briquettes from production. Each machine raw material preparation workers

Table 4. Direct material costs

Information	Sum	Unit
Working People's Day	30	Day/Month
Production capacity	16,500,000	kg/Month
Bagasse Price	500	Rp/kg
Tapioca Flour	206,250	kg/Month
Tapioca Flour Price	6,800	Rp/kg
Water	0	Rp/kg
Total	**9,652,500,000**	**Rp/Month**

Table 5. Direct Labor Costs

Information	Sum	Unit
Weekdays of the month	30	Day/Month
Working days for 4 months	120	Day/Year
Number of Workers	19	People
Machine operator wages	161,250	Rp/People/Day
Preparation worker wages	107,500	Rp/People/Day

receive a daily wage of Rp107,500. This is based on a total of 30 working days per operator receives a daily wage of Rp161,250, while month. As detailed in Table 5, the total direct labor costs reach Rp77,400,000/month or Rp309,600,000/year.

Factory Overhead Costs. Factory overhead consists of machine maintenance costs and electricity needs over months and years. Factory overhead costs achieve a total of Rp1,125,600,000/year with details presented in Table 6.

Table 6. Factory overhead costs

Information	Monthly Cost	Annual Cost
Factory building rental	0	0
3 briquette presses with a capacity of 10 tons/h	Rp900,000,000	Rp900,000,000
Machine Maintenance	Rp27,800,000	Rp111,200,000
Electricity	Rp28,600,000	Rp114,400,000
Total		Rp1,125,600,000

3.5. Cost of Goods (COGs) Produced

The cost of goods produced is obtained by adding up all costs incurred to produce BBF. Summing up all annual costs including direct materials cost (Rp38,610,000,000), direct labor cost (Rp309,600,000), and factory overhead costs (Rp1,125,600,000) results in cost of goods (COGs) of Rp40,045,200,000 annually. With production capacity of 16,500,000 kg/month or 66,000,000 kg/year for 4 months/year effective working time, this means COGs of Rp606.7/kg. An assumption of a 50% margin of cost of goods produced is used, which is a percentage of costs incurred by the company ranging from transportation costs, promotions, taxes, and other costs, so that these briquette products reach consumers. In addition, in the 50% margin the company has included the profit factor that the company wants to get. Adding the bagasse price of Rp500/kg, then the selling price of BBF per kg equals to the following:

Briquette selling price per kilogram = Rp606.7 + (50% × Rp606.7) + Rp500 = Rp1,410.

The BBF selling price is calculated from the cost of goods produced for bagasse briquettes for the production of briquettes per year or in the milling period, which then the cost of goods produced during the milling period is divided by the amount of briquette production during the milling period. With affordable COGS, there is potential to sell these briquettes assuming the briquettes used use adhesive variations of 1.25%. With the selling price of briquettes Rp1,410/kg, it will certainly be able to compete with biomass briquette prices in the market. Figure 6 shown a price

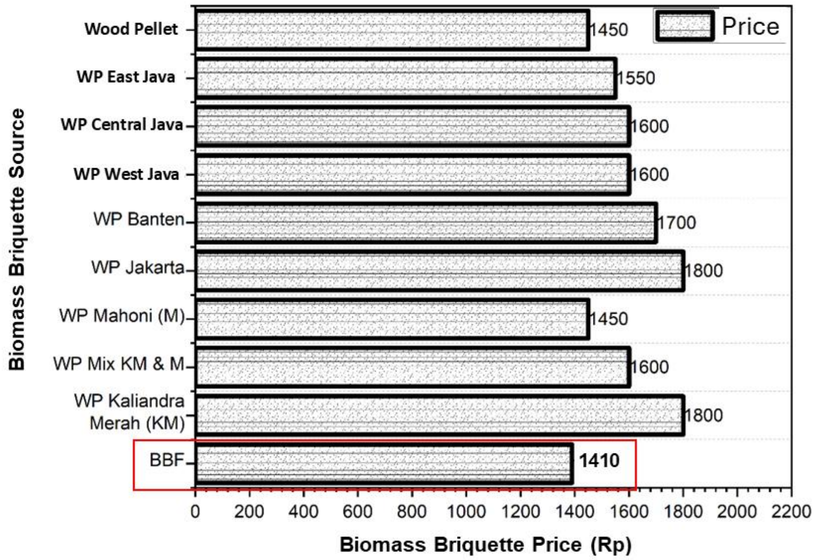


Figure 6. Comparison of BBF price to biomass briquettes or pellets in the market

comparison of BBF with briquettes on the market. Based on the boiler requirements of 506.6 t/day, while the BBF production reaches 720 t/day, there are 214 t/day of briquettes available for sale. With the total calculation of briquettes that can be sold and the profit that the company can obtain during the milling period of 25,680 tons, it amounts to Rp36,208,800. In the first year, this value shows a negative result due to the factor of briquette printing machine procurement. In this economic analysis, the emphasis on investment in BBF production equipment is not taken into account in detail. This results in a lack of representation in the overall profit potential. Therefore, further research is needed that focuses on comprehensive production calculations.

4. CONCLUSION

This research succeeded in showing the potential of alternative fuels by utilizing sugarcane milled waste into BBF. Product development was carried out varied, found a physical prototype of briquettes recommended with an adhesive variation of 1.25%. Based on the results of calorific value testing and density calculations, BBF with a binder variation of 1.25% has the highest efficiency because it can meet the fuel requirements for operating 5 boilers totaling 504 t/day. With a calorific value of 19.4973 kJ/kg and a density value of 0.9153 g/cm³. Based on cost of goods produced, the cost to produce 1 kg of briquette is Rp606.7.

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