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VALUE INCREASING OF REJECT COAL WITH BIOMASS ADDING AS BIO-COAL BRIQUETTE

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ABSTRACT

Aim: This paper aims to explain the added value increasing method of reject coal which has not utilized by the company. **Methodology and Results:** The method to increase added value in this study used the agglomeration process of briquettes form that changing composition by adding biomass. The biomass functions to minimize bottom ash produced from burning briquettes so that the briquettes burn entirely. Stages processes in this study consist of characterization, briquetting, physical test, and chemical test. Based on the analysis, reject coal still has a high calorific value of 5,929 cal/gr. Shapes and sizes that were not following needs of coal market or consumer due to reject coal to be a waste. Briquettes have been successfully produced and meet specification requirements based on applicable regulations in Indonesia. Besides physical properties, the briquette meet density requirements which are greater than or equal to 1 gr/cm3 and shatter index value is less than 0.5%. The gas emission test shows below threshold, which is CO 0-30 ppm, H_2S 0-3.6 ppm, and NOx is not detected. After evaluation, it showed that by adding 30% biomass, ignition time could be decreased and remaining unburned briquettes or bottom ash was reduced as much as 68.68%. **Conclusion, significance and impact study:** The bio-coal briquettes is a strategic solution to environmental problems and alternative energy sources that are environmentally friendly, because CO and H_2S emissions are still below the threshold, even for NOx not detected. Making Bio-coal briquettes as a solution to the utilization of reject coal mining waste to be used as an alternative energy source has been successfully carried out.

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- Bio-coal briquettes
- Biomass
- Bottom ash
- Caloric value
- Ignition time

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1. INTRODUCTION

Indonesia's energy consumption continues to increase. As recorded in 2015, Indonesia's three largest energy users are the household sector (38%), industry and services (29%), and transportation (27%), (IEA, 2017). The government seeks to meet increasing energy consumption with mixing energy from various sources. Indonesia's energy needs are almost 90% supplied from fossil fuels, especially oil and coal (Imaduddin *et al*., 2014; Anindhita *et al.*, 2015; IEA 2017). The highest current fossil energy users are industrial sector (32.17%), and almost all textile industries located in Java have now converted to coal fuel (Sulistyowati, 2013). The development of coal production during the last 13 years (2003-2016) shows a relatively rapid increase, with an average production increase of 11% per year (Haryadi and Suciyati, 2018) due to the ratio of reserves and production of coal (C/P) is for 500 years. It is higher than petroleum only 16 years into the future (Anindhita *et al.,* 2015; Mardansyah, 2008; Sugiyono, 2002; Jusuf, 2012). Even the coal commodities account for 85 % of revenues from the mining sector (Anonymous, 2014, Ghofar *et al.*, 2017).

Some of main parameters to consider for coal using as fuel and steam power plant are moisture content, ash content, volatile matter, calorific value, and Hardgrove Index. One of criteria or standards of consumer requirement is particle size. The crushed coal, which consumers reject, is a by-product of the coal production process, commonly presents as residue of mining, handling and washing processes at the site. This measure is considered to be less economical in coal production because it is believed to cause problems in the process of drying, handling, transportation, and storage. Therefore, in the coal production process, presence of this coal is a form of energy loss as well as one of environmental issues. In the coal production process, which generally produces fine coal of 5% to 10% not to mention the granular form which is larger than total coal production, the processing cost is three times higher. This fact causes the coal mining industry choose to dispose it as waste generated mainly by mechanical processes (crushing) and washing (cleaning). Together with washing water, coal will be disposed into the environment and river or accumulate around the pond, causing water pollution (river) and surrounding soil (Khayatun, 2015; Ozga *et al.*, 2018; Rodliyah and Ardha, 2008; Sonmez *et al.*, 2014). From coal mining area there is also gas pollutant release to the environment, such as H_2S parameter (Sintorini, 2017).

Considering the fact of increasing energy from coal sources by government, we need to find

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the method for adding value of reject coal (mining waste). This is required to provide solutions in the mining sector and overcome environmental problems. So this study purpose to explain how fine coal utilization efforts can be done to reduce production loss as well as solutions to environmental problems, for both soil and water pollution. The method of this study used the briquetting of mixture fine coal and biomass (Bio-coal briquettes) to minimize unburnt briquette and shorten the ignition time.

Utilization of coal waste into briquettes or coal briquettes formation is a process to convert coal powder into a specific shape with a binder support. This technology widely used by many countries for both domestic cooking and industrial applications. This process is a common way to maintain its function as an energy source due to its relatively high heat content (Ozga *et al.*, 2018; Rodliyah and Ardha, 2008, Habib *et al.,* 2014; Raju *et al.,* 2014).

However, coal briquettes are often problematic at the time of ignition and also leave the remaining briquettes not completely burned. This is because coal has a low volatile matter, not enough to burn all the carbon present in coal, so it is necessary to add biomass which has a high volatile matter. Volatile matter from the biomass will facilitate the ignition time and will minimize the remaining combustion of the briquette.

Mixed briquettes between biomass and coal waste have improved the performance of coal waste itself. Its performance has included having a physical property and a higher combustion rate than the raw material, making it easier for handling, packaging, transportation and storage. The briquettes could be used to increasing the bulk density (Oladeji, 2016; Assis *et al.,* 2019).

Previous researchers have used biomass as an alternative source of energy, including rice husk, cider mumps, sawdust, coconut shells, wood chips, sago pith waste, forest waste and so on (Petabang, 2012; Fretes *et al.,* 2013; Muhammad *et al.,* 2013; Karim *et al.,* 2014; Oladeji, 2016; Suhartoyo and Sriyanto, 2017; Marafon *et al.,* 2019; Vieira *et al.,* 2019; Saghir *et al.,* 2019). In this study, biomass used was animal waste namely cattle waste from Lembang-West Java. The Lembang Cattle waste is supposed to have contaminated the Citarum River which river strategic in West Java-Indonesia (Marganingrum *et al.,* 2013). Therefore, using of the cattle waste can decrease the Citarum river pollution.

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2. RESEARCH METHODOLOGY

The three provinces that have the most extensive coal resources in Indonesia are South Sumatra, South Kalimantan, and East Kalimantan. For this study, samples were taken from the coal mining waste in Bayah, Lebak District-West Java as a case study (Figure 1).

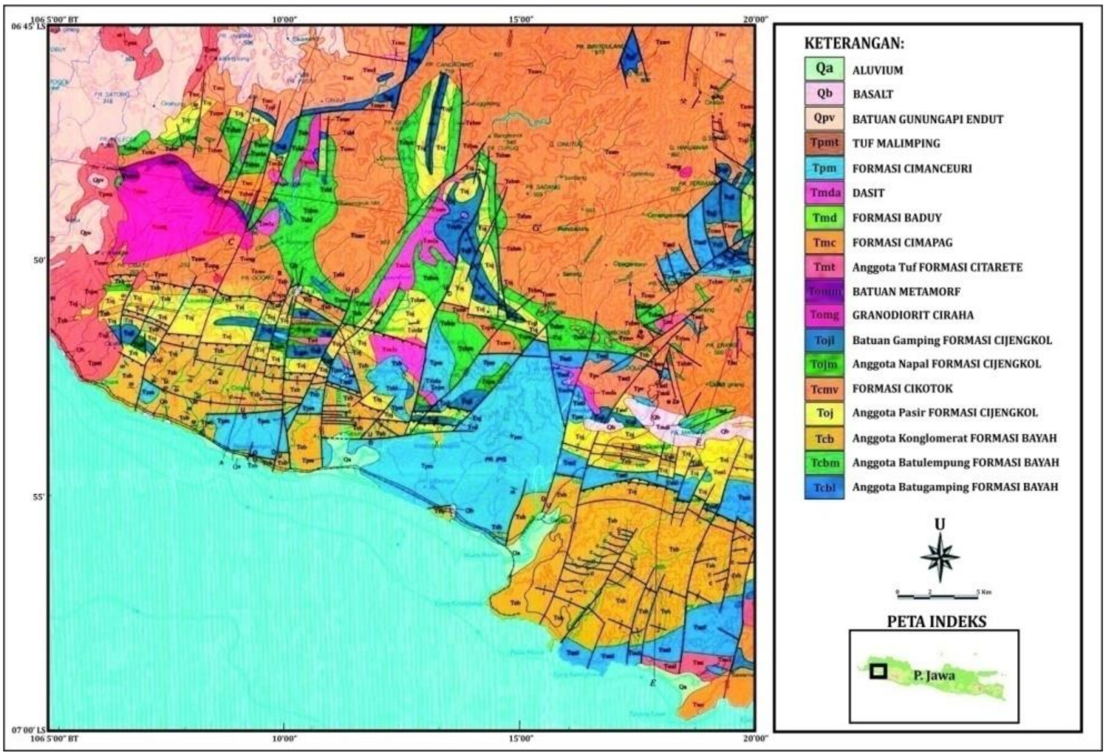

Figure 1 Geological maps of Bayah surrounding (Sujatmiko and Santosa, 1992)

The method used in this study is analytical. The analytical processes consists of several steps namely characterization, formulation and briquetting, physical testing and chemical testing. Analysis is done by comparing between briquette without biomass and briquette with adding biomass. The explanations for steps are following:

a) **Characterization** was carried out to determine the chemical composition of reject coal Bayah and Biomass. Reject coal from Bayah mining was used due to its abundance and caloric value (Fatimah *el al.,* 2016). While biomass used in this study was cattle waste from Lembang to reduce their generations so not pollute surrounding waters. The cattle waste

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lembang is one of pollutant sources of Citarum River (Marganingrum, 2013). In this characterization step we used proximate and ultimate values analysis.

b) **Formulation and Briquetting** was done firstly by mixing the ingredients, based on specific formula until they were homogeneous. Then it was put into mold, which has a height of 5 cm and a diameter of 5 cm with a pressure of 100 kg/cm^2.

c) **Physical Test** was carried out on briquette products that had been produced. Physical properties test conducted in this research include density test and relaxed density and shatter index test.

1. There are two kinds of specimen density testing. They are initial density after leaving the mold (initial density) and density after relaxed for one week (relaxed density). The test was carried out according to ASAE S269.4 DEC 96 standard using direct measurement method with the calipers tool. The test procedure is as follows:
    a. Measuring specimens (diameter and length) at the outset of the mold and after relaxing for one week using the calipers to calculate the volume.
    b. Considering specimen and recorded as masses.
    c. Calculating the density by dividing the mass of specimen by its volume.
    d. Averaging the result of tests, carried out on three specimens.
2. Shatter index testing was done to test the resistance of briquettes to impact. This test was carried out to verify how strong the briquettes produced against the impact caused by altitude and how much material is lost or released from briquettes due to being dropped from a height of 6 ft (1.8 meters). If the particles are losing too much, it means that the briquettes made are not resistant to impact.

d) **Chemical Properties Test**

In addition to its physical properties, the briquettes produced were also tested for their chemical properties. Chemical properties tested in this study include proximate, ultimate, and heating value analysis, and combustion character test.

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3. RESULTS AND DISCUSSION

To increase the added value of reject coal is not only done by changing composition but it also must meet the requirements of specifications to utilize. Therefore, it is necessary firstly to know the characteristics of each raw material before the mixing process between coal and biomass.

Table 1 is the result of the characterization of coal and biomass, shows that the reject coal from Bayah mining has a high caloric value (5,929 calory/gram) even it's useless due to the particle size is not requirement standard. Fatimah *et al.,* (2016) stated that fine coal from Bayah had a potential to be used as fuel in the form briquettes and can be used as an alternative energy source. Therefore the briquetting form is choice in this study.

Table 1 This is an example of the table constructed correctly

Parameter	Reject Coal of Bayah	Biomass	Unit	Basis
Proximate:				
Moisture	4.92	15.00	%	adb
Ash	16.40	23.47	%	adb
Volatile matter	35.25	48.64	%	adb
Fixed carbon	43.43	12.89	%	adb
Ultimate:				
Total Sulfur	2.18	1.03	%	adb
Carbon	59.59	32.69	%	adb
Hydrogen	4.89	4.97	%	adb
Nitrogen	1.22	3.99	%	adb
Oxygen	15.72	33.85	%	adb
Caloric value	5.929	3.030	cal/g	adb

Table 2 and Table 3 are the result of burning characterization of briquettes before the biomass was added and the combustion efficiency respectively. The results will be compared to briquettes after adding biomass (Bio-coal briquettes). The ignition time is the time required to ignite the briquettes until briquettes start to smolder. This ignition is influenced by the composition of briquettes.

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Table 2 Burning characterization of briquettes (without biomass)

Parameter	Unit	Value
Water Boiling Test	minute	5
Burning Time	hour	4:33
Ignition Time	minute	3
Burning rate	g/sec	0.016
Flame Temperature	^{o}C	300 - 500

Table 3 shows that the combustion efficiency of briquette without biomass is 86.72%. The remaining unburnt briquettes are 13.28%. These results indicate that briquettes without biomass were not completely burned. The proximate analysis was applied to the unburned briquettes to determine the cause.

Table 3. Combustion efficiency of briquettes (without biomass)

Parameter	Unit	Value
Briquettes	Gram	251.04
Ash	%	8.55
Unburnt briquettes	%	13.28
Burnt Briquettes	%	86.72

Table 4 is the result of the proximate analysis of unburned briquettes during the combustion process. Table 4 shows that unburnt carbon as fixed carbon is 52.57%, while the volatile matter is 6.83% so that the available volatile matter is not sufficient to burn coal briquettes.

Table 4 Proximate analysis of unburnt briquettes

Parameter	Value	Unit	Basis	SM
Moisture	3.04	%	adb	1
Ash	37.56	%	adb	2
Volatile Matter	6.83	%	adb	3
Fixed Carbon	52.57	%	adb	4

Noted: SM=Standard Method; 1=ASTM D.3173; 2= ASTM D.3174; 3=ASTM D.3175; 4= ASTM D.3172

The problem is the remaining fix carbon. Therefore, in this study we mixed reject coal with biomass fermented as mixing briquette for providing value added of reject coal Bayah. Besides

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using of remaining fix carbon, adding biomass also to improve the character of burning (ignition of briquettes and unburnt briquettes). According Regulation of Energy and Mineral Resources Ministry Number 047 in 2006, the biomass combined to bio-briquettes was between 10-40% as recommended. In this study we used 30% biomass adding. This process is expected to create easier briquettes ignition and to make the briquettes can burn completely, but still meet the specifications of the briquettes. Table 5 is the result of coal briquette density measurement after biomass was added (Bio-coal briquettes). Table 6 shows the results of its shatter index test.

Table 5 and Table 6 show that after changing composition, bio coal briquettes appropriated to the specifications of coal briquette where the specific gravity which was greater or equal to 1 is required for storage, treatment, and displacement. The briquettes in this study had a small index shatter value ranging from 0.03 % to 0.09%. It's mean that these briquettes will not easily destroy.

Table 5 Measurement of bio coal briquette density

No. Briquette	Weight (gr)	Diameter (cm)	Height (cm)	Width (cm^2)	Volume (cm^3)	Density (gr/cm^3)
1	34,26	5	1,6	19,625	31,4	1,091
2	33,94	5	1,6	19,625	31,4	1,081
3	34,28	5	1,6	19,625	31,4	1,092
4	33,94	5	1,6	19,625	31,4	1,081
5	33,98	5	1,5	19,625	29,4	1,154
6	34,09	5	1,6	19,625	31,4	1,086
7	33,97	5	1,5	19,625	29,4	1,154
8	21,72	5	1,0	19,625	19,6	1,107

Table 6 Shatter index test of *bio-coal* briquette

No.	Briquettes before dropped (gr)	Briquettes after dropped (gr)	Loss of Weight (gr)	Loss of Weight (%)
1	34.01	33.98	0.03	0.09
2	34.26	34.25	0.01	0.03
Average	34.14	34.12	0.02	0.06

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After the physical test, then the bio-coal briquettes were tested for combustion character. For this purpose, as much as 250 grams of bio-coal briquettes were prepared. The results obtained are shown in Table 7. Table 8 shows the efficiency of the combustion process.

Table 7 Characterization of burning bio-coal briquettes

Parameter	Unit	Value
Water Boiling Test	minute	6
Burning Time	minute	3:21
Ignition Time	minute	2
Burning rate	g/sec	0,016
Flame Temperature	^{o}C	300 - 500

Table 8 Combustion efficiency of bio-coal briquettes

Parameter	Unit	Value
Briquettes	Gram	192,3
Ash	%	20,35
Unburnt briquettes	%	4,16
Burnt Briquettes	%	95,84

The proximate analysis for moisture content was 7.83% (Table 9). While the threshold value, according to the regulation of the Minister of Energy and Mineral Resources number 047 in 2006 about the guidelines for the manufacture and utilization of bio-coal briquettes, is 15% (Menteri Energi dan Sumber Daya Mineral, 2006). The water content parameters were eligible. For volatile matter, its value was adjusted to its original coal and with its raw materials (biomass) which were 35.25% and 48.64% while the volatile matter content of the bio-coal briquette was 40.81%. The conclusion is that the briquettes were already qualified for the volatile matter.

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Table 9 Results of analysis proximate, ultimate and calorific value bio-coal briquettes

Parameter	Value	Unit	Basis
Proximate			
Moisture	7.83	%	adb
Ash	18.94	%	adb
Volatile matter	40.81	%	adb
Fixed carbon	32.42	%	adb
Ultimate:			
Total Sulfur	1.40	%	adb
Carbon	50.88	%	adb
Hydrogen	5.31	%	adb
Nitrogen	2.13	%	adb
Oxygen	21.34	%	adb
Heating value	5.017	Kal/g	adb

The threshold value of total sulfur content in various types of briquettes is 1%. Total sulfur content for briquettes result in this study was 1.4% (Table 9). Even sulfur content of this study are not yet eligible, but it reduced the sulfur content from raw coal which has a sulfur content of 2.18% (Table 1). The threshold of caloric value for bio-briquettes according to the Regulation of the Minister of Energy and Mineral Resources is 4,400 calory/gram. The result of caloric value in this study was increased to 5.017 calory/gram.

The results of combustion test using an ordinary stove showed the value of CO, H2S and NOx were 0-30 ppm, 0-3.6 ppm, and not detected respectively. The emission for CO sometimes exceeded the threshold. This was caused of incomplete combustion and occurred only for about 3-4 seconds. In generally, this method changed waste coal to be valued with biomass adding.

Table 10 Results of gas emission test analysis of bio-coal briquette burning

Type	CO (ppm)	H_2S (ppm)	NOx (ppm)
Bio-coal Briquettes	0-30	0-3.6	not detected

4. CONCLUSION

The *bio-coal* briquettes are the result of research as a strategic solution to environmental problems and alternative energy sources that are environmentally friendly. Making *Bio-coal* briquettes as a solution to the utilization of reject coal mining waste to be used as an alternative energy source has been successfully carried out. This *Bio-coal* briquette was successfully made

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by fulfilling some specifications according to the regulation of the Minister of Energy and Mineral Resources number 047 of 2006, concerning the guidelines for making and utilizing coal briquettes and coal-based solid fuels. Besides that the physical properties of briquettes have fulfilled the requirements, good density for briquettes are greater or equal to 1gr / cm^3. The result of the shatter index for this briquette is very small (less than 0.5%), its meaning that the briquette is impact resistant when dropped. And after being evaluated, by adding biomass, it can reduce the flame time and reduce unburned briquettes to 68.68%. The *bio-coal* emissions of briquettes are environmentally friendly because CO and H_2S emissions are still below the threshold, even for NOx not detected.

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