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The Utilization of Bottom Ash Coal for Briquette Products by Adding Teak Leaves Charcoal, Coconut Shell Charcoal, and Rice Husk Charcoal

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Abstract - The limitations of the availability of energy sources especially fuel oil has become a serious threat for the society. The use of coal for energy source as the replacement of fuel oil, in one hand, is very profitable, but on the other hand, will cause problem which is the coal ash residue. This coal ash is a by-product of coal combustion. This coal ash contains bottom ash. Through this observation, the bottom ash can be processed to be charcoal if added by teak leaves, coconut shell, and rice husk. Also, this observation needs to add binder materials for further processing in order to form briquette. It can be used as alternative fuel, the utilization of bottom ash and biomass will give positive impact to the environment. This observation was conducted by using compositions such as bottom ash, teak leaves, coconut shell, and rice husk. The treatment was using comparison 100%:0% ; 80%:20% ; 60%:40% ; 50%:50% ; 40%:60% ; 20%:80% ; 0%:100%. The result that the best briquette was on the composition of 20% bottom ash : 80% coconut shell. The characteristic values from that composition were moisture content of 3.45%, ash content of 17,32%, calorific value of 7.945,72 Cal/gr, compressive strength of 2,18 kg/cm^2, level of CO of 105 mg/m^3, and heavy metals Cu of 29,83 µg/g and Zn 32,99 µg/g. The characteristic value from each briquette composition treatment showed that the increasing usage proportion of biomass as added material for briquette was able to increase its moisture content and calorific value. Besides, it is also able to decrease its ash content and compressive strength.

Key words: bottom ash, teak leaves, coconut shell, rice husk, briquette.

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INTRODUCTION

The use of charcoal as fuel is spreading out for varies industries. The use of charcoal nowadays is not only dominated by PLTU but also has spread to many industries such as textile. From the use of charcoal, it will create bottom ash charcoal for 2 tons per month. Bottom ash is a waste of coal combustion products in which the numbers will continue to grow as long as the industry continues to produce (Ristinah, 2012).

From the observation conducted by Samadhi (2008), it was mentioned that the height of constant carbon level in the bottom ash of textile factory gave a quite high of calorific value which is 3.324 Ccal/kg. The calorific value is equivalent to the calorific value of low calorie charcoal (21,4 Mj/kg). Given the potential from the calorific value of bottom ash, this usage, through repeated burning routes, is seen as the alternative solution which worthy to be reviewed in order to increase the efficiency of energy usage, especially by small until middle industries.

One solution that can be done in reburning the coal bottom ash is to use it as briquettes. Briquettes with good quality properties such as smooth texture, not easily broken, hard are safe for humans and the environment as well as having the properties of a good ignition. The properties of a good ignition such as flammable, burning time long enough, do not cause soot, little smoke and quickly disappear and the calorific value is high enough (Jamilatun, 2008).

From the initial characteristics of the test results performed on samples of bottom ash in a textile factory in Ungaran, Semarang, the bottom ash obtained calorific value of 610.012 calories/gram. To be used as briquettes, the heating value of the bottom ash is not yet meet the standards that exist according to SNI 01-6235-2000 about Quality Requirements Wood Charcoal Briquette 5.000 calories/gram. That's why, to increase the calorific value, it needs other potential sources of calories, which is the biomass. Biomass, which is used as an alternative fuel, is more environmental friendly, easier to obtain, and more economical (Maryono, 2013). There are some biomasses which have considerable potential such as wood waste, rice husk, straw, bagasse, coconut shells, palm shells, animal manure (Nurainy, 2013)

Based on the preliminary tests conducted on each biomass of dry teak leaves, coconut shells and rice husks, the potential values are 2.419,9 calories/gram, 4.027,8 calories/gram, 3.221,08 calories/gram. With the potential of the biomass, this research will investigate to what extent the influence of each adding composition can increase the calorific value of the briquettes so that the existence of coal bottom ash can be minimized. The purpose of this study was to utilize the bottom ash as useful and economically valuable product which are the briquett.

MATERIALS AND METHODS

A. Equipment and Materials

The tools used in this study include furnace, collision (pestle), oven, electric cooker, alumunium foil, desiccator, porcelain cup, mold briquettes, *bomb calorimetry, the AAS (Atomic Absorption Spectrophotometer), CO Digital Analyzer, Compression Testing Machine* etc. The materials used in the study were the coal bottom ash, teak leaves, coconut shell, rice husk, distilled water and starch

B. Procedure Research

1. Drying The Raw Materials

In this process, the biomass cleared in advance from material impurities. Furthermore, biomass was cut into smaller sizes and dried to ease during the authoring process.

2. Carbonize the Raw Materials

The dried teak leaf was carbonized by using a furnace temperature of 350°C for 1 hour while coconut shells and husks of dried rice, charred by using a drum kiln. Complete combustion marked by the coming out of the diminished smoke. Next, the charcoal was cooled down for 1 hour. The charcoal that has been formed in the carbonization process then smoothed by using a pestle / blender and sieved to obtain charcoal powder with a mesh size of 50 passes.

3. Mixing with Raw Materials

Starch adhesive is made by cooking starch with water at a temperature of 150°C to form a gel. Starch adhesive that has been formed is then mixed with charcoal powder evenly to form dough. The bottom ash and charcoal of teak leaves, coconut shell, rice husk were mixed up with the average ratio of 100%: 0%; 80%: 20%; 60%: 40%; 50%: 50%; 40%: 60%; 20%: 80%; 0%: 100% as well as an adhesive in the form of starch with fixed variation of 5% of the total material.

4. Printing the Briquette

The results of dough briquettes placed in a cylindrical mold with a diameter of 2,54 cm and a height of 5 cm and then compacted by means of presses.

5. Drying the Briquette

Charcoal briquettes produced were then dried in an oven at 120° C for 4 hours; it aims to reduce the water content which contains in the briquettes.

6. Determination of Quality Briquette

a. Water Content

The determination of water content is done by using a *moisture meter*.

b. Levels of Ash

The ash content can be determined by weighing the residue (residual) complete combustion of the sample. Ash content can be calculated using the following equation:

$$\%\ \text{Ash content} = \frac{A-B}{C} x 100\% \quad (3.1)$$

Specification:
A = weight of dish and ash (g)
B = weight of empty cup (g)
C = weight of sample (g)

c. Compressive Strength

The principle of compressive strength testing is to measure the strength of briquettes to give emphasis to the briquette until it's broken. The determination of this compressive strength can be calculated using the following equation:

$$Kt = \frac{P}{L} \quad (3.2)$$

Specification:
Kt = Load Compressive Strength (kg/cm^2)
P = emphasis Load (kg)
L = Surface Area

d. Calorific Value (ASTM D2015)

The calorific value is determined by burning the sample in the *bomb calorimeter*.

e. Levels of Carbon Monoxide (CO)

This research analysed air pollutants produced during the briquettes burning prrocess. This test was done for the parameter of Carbon Monoxide (CO) by using CO *Digital Analyzer*.

f. Heavy Metal

This research is Analyzing the content of heavy metals contained in the rest of the ash briquettes. The test is performed for Cu and Zn parameters by using AAS (*Atomic Absorption Spectrophotometer*).

RESULTS AND DISCUSSIONS

I. Introduction Analysis

a. Characteristics Analysis of Bottom Ash

Preliminary analysis aims to determine the characteristics of bottom ash. The chemical and physical properties of coal ash are strongly influenced by the type of the coal burned, storage and handling techniques. Based on the results of the preliminary analysis of the characteristics of bottom ash, it can obtain the calorific value of 610,012 cal/g, 2% moisture content, ash content of 83,93%. On the other hand, the test was also carried out on the heavy metal content of bottom ash consisting of Cd, Cr, Cu, Pb and Zn. From the test results, the highest heavy metal content was heavy metals copper (Cu) of 36,296 g/g and Zinc (Zn) of 54,533 g/g. The complete results of the test call be seen Table 1 below :

Table 1. Initial Characteristic of Bottom Ash

Material	Parameter	Unit	Result of Analysis	Method of test
Bottom Ash	Calorific Value	cal/gr	610,012	*Bomb Calorimeter*
	Moisture	%	2	*Moisturemeter*
	Level of Ash	%	83,93	*Furnace*
	Content of Heavy Metals			
	Cadmium (Cd)	µg/g	2,257	AAS
	Chromium (Cr)	µg/g	1,191	AAS
	Copper (Cu)	µg/g	36,296	AAS
	Lead (Pb)	µg/g	undetected	AAS
	Zinc (Zn)	µg/g	54,533	AAS

b. Biomass Characteristics Analysis of The Teak Leaves, Coconut Shell, and Rice Husk

The test was conducted to determine the characteristics of biomass which used as additional ingredient in briquetting. Results of a preliminary analysis of these biomass can be seen in Table 2 . From the result of Biomass characteristics test, it can be seen that the leaves of teak has a calorific value of 2.419,9 cal/g, the water content of 6.9%, and 12.3% ash content. In addition, testing was also done on coconut shells and husks of rice, each of which has a calorific value of 4.027,8 cal/g and 3.221,08 cal/g, the water content of 10.21% and 7.2%, and ash content 3,78% and 13.4%.

Table 2. Initial characteristics of biomass (Teak Leaves, Coconut Shell, and Rice Husk)

Material	Component	Unit	Result of Analysis
Teak Leaves	Calorific value	cal/gr	2.419,9
	Moisture	%	6,9
	Level of Ash	%	12,3
Coconut shell	Calorific value	cal/gr	4.027,8
	Moisture	%	10,21
	Level of Ash	%	3,78
Rice husk	Calorific value	cal/gr	3.221,08
	Moisture	%	7,2
	Level of Ash	%	13,4

II. Characteristics Briquettes

a. Water Content Analysis

The water content from this research can be seen on the figure 1.

The result of the test that has been done, we can get the value of the water content of briquette which mixed with bottom ash briquettes : the identity of *teak* leaves ranged between 1,40% - 5,61%, bottom ash : coconut shell charcoal ranged between 1,77% - 3,96%, bottom ash : rice husk ranged between 1,67% - 4,50%. The lowest water content was obtained in 100% bottom ash briquettes at 1.40%. Meanwhile, the highest water content is at 100% teak leaves charcoal at 5,61%. From the results of these tests, it can be seen / known that bottom ash briquette mixed with teak leaves charcoal has the highest water content. Then, it is followed by bottom ash briquette mixed with rice husk. The last is bottom ash briquette mixed with coconut shell charcoal.

Overall the briquettes produced in accordance with SNI where, according to SNI 01-6235-2000 on wood charcoal briquette quality requirements maximum water content of 8%. In Figure 1, it can be concluded that the more biomass that is substituted into briquettes, the higher the water content. This is because the biomass has water content as well as the ability to absorb water more than the bottom ash which has little water content.

The results of tests that have been carried out showed the ash content of charcoal briquettes bottom ash mixture dried teak leaf has a value of 25,44% - 81,34%, coconut shell charcoal mixture range from around 1,20% - 81,01%, a mixture of rice husk range 43,08% - 82,08%. Based on the test results on the respective ash mixture, briquettes bottom ash mixture of rice husk has the highest value compared to a mixture of charcoal briquettes teak leaves and coconut shell charcoal. The lowest ash content was obtained in 100% briquette charcoal coconut shell at 1,20% while the ash content is highest at 100% bottom ash that is equal to 82,08%. Most briquettes produced are not in accordance with the SNI where, according to SNI 01-6235-2000 on wood charcoal briquette quality requirements are at 8% maximum ash content. In figure 2 it can be concluded that the more bottom ash that is substituted into briquettes, the higher the ash content. The increase in ash content in each variation is due to the silica content that contained within the bottom ash.

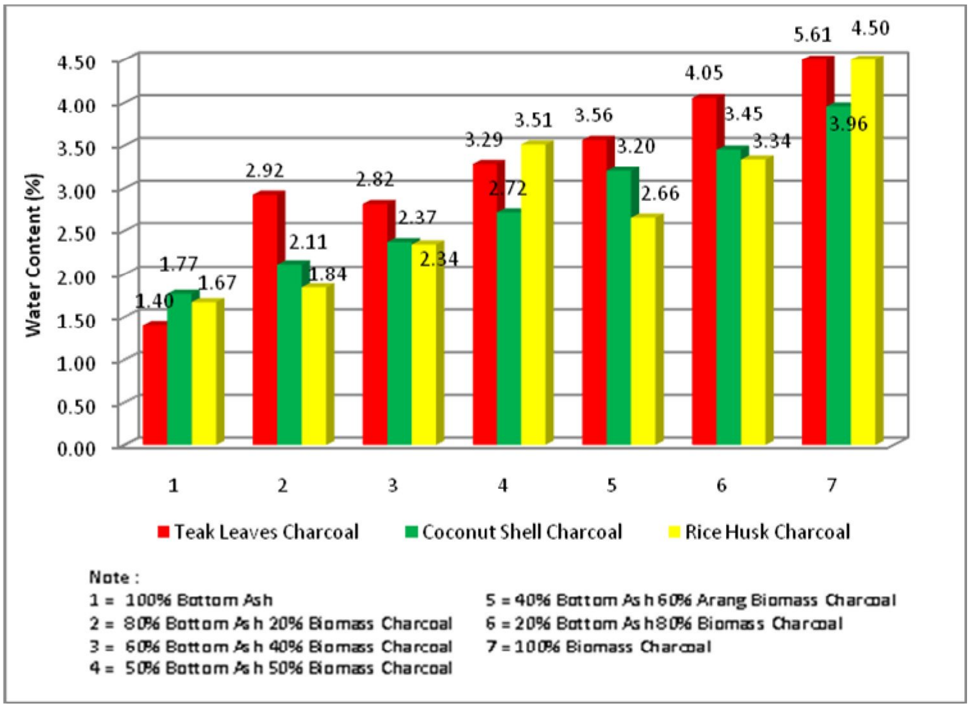

Figure 1 Diagram of Water Content Briquettes Mixed Bottom Ash and Biomass

b. Analysis of Ash Content

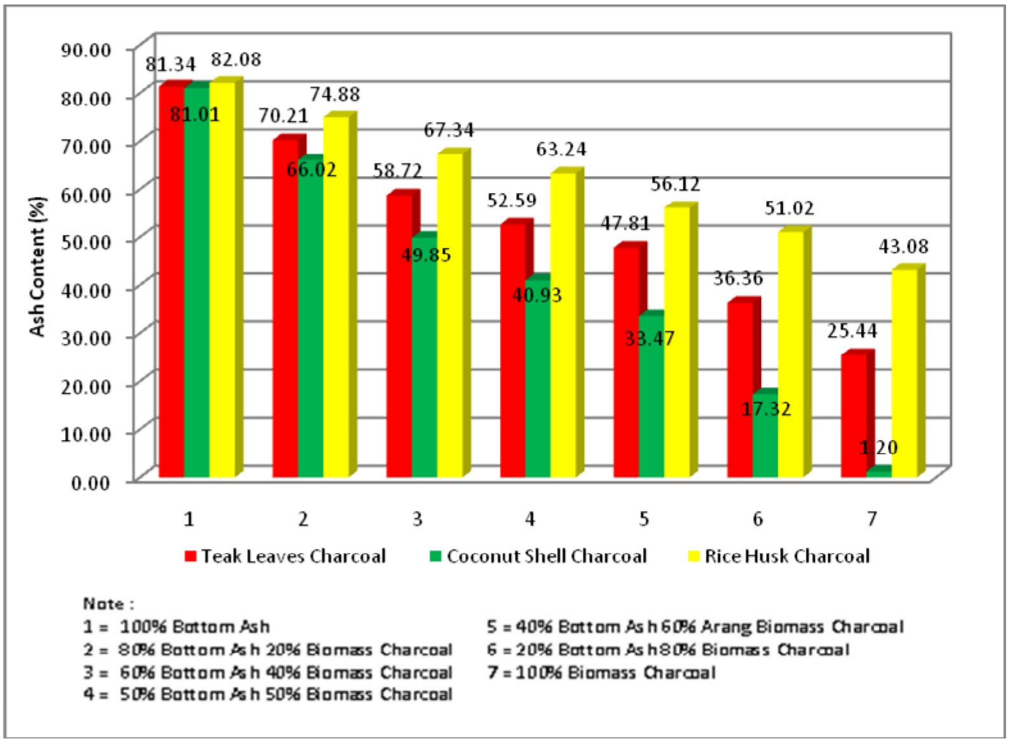

Figure 2. Diagram of Ash Level in Briquette Mixed Bottom Ash and Biomass

c. Compressive Strength Analysis

Briquette compressive strength is the ability to provide durability or compactness to ruptured or collapsed of briquettes if given load on the object (briquettes). The greater the compressive strength value means better durability for the briquettes it self. It would be advantageous in terms of marketing activities that include packaging and transport in the distribution of briquettes. From the results of test, bottom ash added into briquettes, the greater compressive strength given to the briquettes. This is because the use of bottom ash waste produced briquettes higher particle density, so the compressive strength of the briquettes is even higher.

The compressive strength among bottom ash mixture to charcoal teak leaves briquettes, coconut shells and husks of rice has a value that is not much different. This is evidenced by the value of each variation produces compressive strength similar example in the sixth variation of 2,38; 2,18; and 2,04. From the three materials, the lowest compressive strength obtained on charcoal briquettes 100% rice husk at 1,32 kg/cm², while the compressive strength is highest at 100% bottom ash that is equal to 7,28 kg/cm². The results of comparative analysis of the use of bottom ash and biomass compressive strength can be seen in Figure 3.

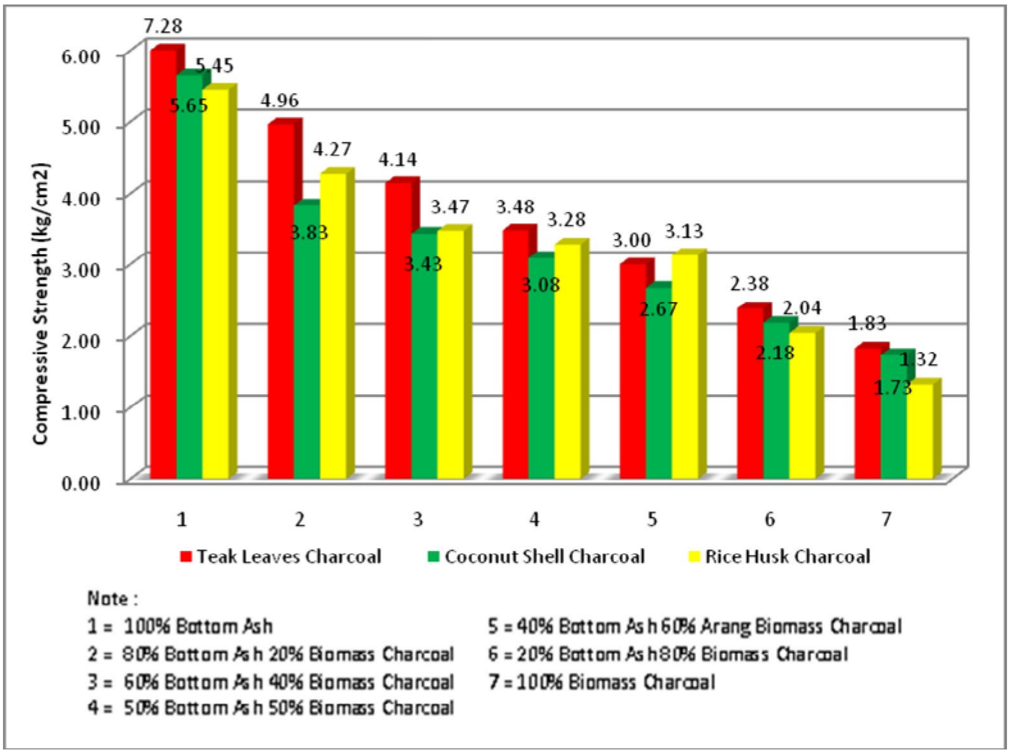

Figure 3. Diagram of the Strength Briquette Pressure of Bottom Ash and Biomass Mixture

d. Calorific Value Analysis

The tests on the calorific value aims to determine the extent to which the calorific value (heat) generated by the briquettes. The calorific value can be analyzed by using *bomb calorimeter*. Based on the analysis it is known that the briquettes bottom ash with a mixture of biomass yield varies calorific value depending on the composition of the raw material mixture. The more composition of biomass is used, the higher value of the heat is produced. From the results of the tests that have been carried out showed the calorific value of charcoal briquettes bottom ash mixture dried teak leaf has a value of 2.003,91 Cal/g - 6.044,80 Cal/g, a mixture of coconut shell charcoal ranges 1.321,33 Cal/g - 8.822,67 Cal/g, a mixture of rice husks ranges 1.056,75 Cal/g - 4.049,41 Cal/g.

The lowest calorific value obtained at 100% bottom ash briquettes at 1.056,75 Cal/g while the calorific value is highest at 100% coconut shell charcoal for 8.822,67 Cal/g. It can be concluded that the briquettes bottom ash mixture of coconut shell charcoal has the highest value compared to the mixture of charcoal briquettes of teak leaves and rice husk. The test result of calorific value can be seen in Figure 4.

III. Determining the Best Variations

Based on the results of the comparison in Table 3 above obtained the best variation is variation in the sixth with 20% bottom ash : 80% biomass. The sixth variation is the best variation due to the nature of the good characteristics and approach the value of the parameter to the SNI 01-6235-2000. From the results of the best variations on each of biomass can be done comparisons to determine the type of biomass that can produce the most optimum briquettes. The comparison can be seen in Table 4.

The main characteristic of the briquetting is the calorific value. From the comparison of these three ingredients, only the coconut shell charcoals meets the standard in SNI 01-6235-2000. Similarly, the water content generated by a mixture of coconut shell charcoal briquettes, the briquettes have fulfilled SNI 01-6235-2000. When compared to charcoal teak leaves, the water content of coconut shell charcoal briquette mixture is lower, but still slightly higher than the rice husk. As for the ash content, a mixture of coconut shell charcoal briquettes produces the lowest ash content compared to charcoal teak leaves and rice husk. Based on SNI 01-6235-2000, ash content of coconut shell charcoal briquette mixture is not yet meet the standards. It can be concluded that the briquettes with a mixture of coconut shell charcoal is the best mix because of the nature of its good characteristics and approaches the value of the parameter to the SNI 01-6235-2000.

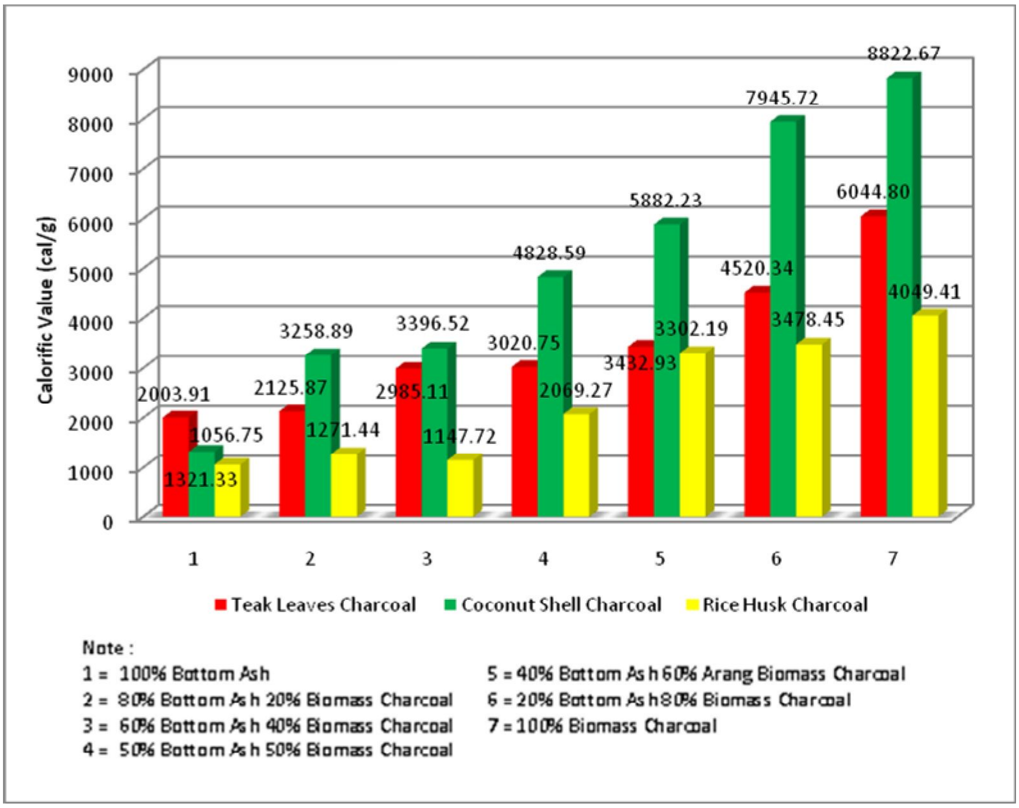

Figure 4. Diagram Calorific Value Briquettes Mixed Bottom Ash and Biomass

Table 3. Comparison of Quality Briquette Mixed Bottom Ash and Charcoal Coconut Shell Based on SNI 01-6235-2000

Parameter	SNI 01-6235-2000	Variation							Conclusion
		1	2	3	4	5	6	7	
Bottom Ash : Teak Leaves Charcoal									
Moisture Content (%)	Max 8%	1,40	2,92	2,82	3,29	3,56	4,05	5,61	all of variation appropriate with SNI
Ash Content (%)	Max 8%	81,34	70,21	58,72	52,59	47,81	36,36	25,44	all of variation not appropriate with SNI
Calorific Value (Cal/g)	Min 5.000 Cal/g	2.033,91	2.125,87	2.985,11	3.020,75	3.432,93	4.520,34	6.044,80	only variation 7 appropriate with SNI
Compressive Strength (kg/cm^2)	-	7,28	4,96	4,14	3,48	3,00	2,38	1,83	-
Bottom Ash : Coconut Shell Charcoal									
Moisture Content (%)	Max 8%	1,77	2,11	2,37	2,72	3,20	3,45	3,96	all of variation appropriate with SNI
Ash Content (%)	Max 8%	81,01	66,02	49,85	40,93	33,47	17,32	1,20	only variation 7 appropriate with SNI
Calorific Value (Cal/g)	Min 5000 Cal/g	1.321,33	3.258,89	11.232,24	4.828,59	5.882,23	7.945,72	8.822,67	variation 3, 5,6,7 appropriate with SNI
Compressive Strength	-	5,65	3,83	3,43	3,08	2,67	2,18	1,732	-

Parameter	SNI 01-6235-2000	Variation							Conclusion
		1	2	3	4	5	6	7	
(kg/cm²)									
Bottom Ash : Rice Husk Charcoal									
Moisture Content (%)	Max 8%	1,67	1,84	2,34	3,51	2,66	3,34	4,50	all of variation appropriate with SNI
Ash Content (%)	Max 8%	82,08	74,88	67,34	63,24	56,12	51,02	43,08	all of variation not appropriate with SNI
Calorific Value (Cal/g)	Min 5000 Cal/g	1.056,74	1.271,44	1.147,72	2.069,27	3.302,19	3.478,45	4.049,41	all of variation not appropriate with SNI
Compressive Strength (kg/cm²)	-	5,45	4,27	3,47	3,28	3,13	2,04	1,32	-

* Note: 1 = 100%: 0%; 2 = 80%: 20%; 3 = 60%: 40%; 4 = 50%: 50%; 5 = 40%: 60%; 6 = 20%: 80%; 7 = 0%: 100%

Table 4. Comparison of Characteristics on Top of Third Biomass Variation

Biomass	Biomass Characteristics at Best Variations (20% Bottom Ash : 80% biomass)			
	Water Content (%)	Level of Ash (%)	Compressive Strength (kg/cm²)	Calorific Value (Cal/g)
Teak Leaves Charcoal	4,05	36,36	2,38	4.520,00
Coconut Shell Charcoal	3,45	17,32	2,18	7.945,72
Rice Husk Charcoal	3,34	51,02	2,04	3.478,45

IV. Levels of CO and Heavy Metals in Briquette Best Variations

a. CO levels.

The measurement of levels of air pollutants such as carbon monoxide (CO) is used to determine levels of CO that released from briquettes in burning process. Measurements of CO carried out by means of briquettes burned with the help of as a fire trigger. Briquettes then burned for 5 minutes and the CO emissions are measured using a gas analyzer. In this test the measurements of CO is only applied on the best variation briquettes. The test results of CO levels in a mixture of bottom ash coal briquettes are: the charcoal teak leaves is 61,84 ppm, coal bottom ash: coconut shell charcoal is 105 ppm, coal bottom ash: rice husk is 84 ppm.

b. Heavy Metals Cu and Zn.

The test on the levels of heavy metals in briquettes made on the best variation, this testing is done by using AAS (*Atomic Absorption Spectrophotometer*). The Heavy metal testing conducted on ash briquettes, where the ash was destructed and tested using AAS to determine the metal content contained.

The testing Results Cu in bottom ash: teak leaf is 34,377 mg/g, bottom ash : coconut shell 29,825 mg/g, bottom ash : rice husk 36,332 mg/g. While heavy metals Zn bottom ash : teak leaves 48,613 mg /g, bottom ash : coconut shell 32,992 mg/g, bottom ash : rice husk 16,258 mg/g. When the heavy metal content of coal bottom ash before the briquetting (Cu at 36,296 g/g and Zn at 54,533 g/g), it can be concluded that the decreased levels of heavy metals is after briquetting.

CONCLUSSIONS

1. Variation of bottom ash and biomass affect combustion of calorific value, combustion of ash content, moisture content, and compressive strength in the manufacture of briquettes. The more bottom ash can lower the calorific value and moisture content, where as the more bottom ash, it can increase the levels of ash and compressive strength. The more biomass can increase the calorific value and moisture content; on the other hand it can reduce the ash content and compressive strength.
2. The best variation of the three materials used in the manufacture of briquettes are at 20% bottom ash : 80% coconut shell charcoal with water content test result of 3,45%, 17,32% ash content, calorific 7.945,72 cal/g, strong press and 2,18 kg/cm², pollutants CO 105 mg/m³, Cu 29,83 mg/g and Zn 32,99 mg /g.

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