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Fabrication and characterization of rice husk and coconut shell charcoal based bio-briquettes as alternative energy source

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Abstract. Rice husk and coconut shell have been disposed or burned as waste. As biomass, both of materials are the potential sources of carbon which can be utilized as alternative energy sources. The energy content can be exploited more intensively when packaged in a brief and convenient. In this work, the mixtures of rice husks and coconut shells charcoal were prepared as briquettes. After going through the carbonization process, several measurements have been taken to find out the factors that determine the value of heat energy contains by each component of the charcoals. The basic ingredients briquettes prepared from rice husk and coconut shell charcoal with varying composition and addition of tapioca starch gradually as adhesive material to obtain briquettes in solid with the maximum heat energy content. After going through pressing and drying process, the briquettes with 50:50 percent of composition and the 6% addition of adhesive was found has the highest heat energy content, equal to 4966 cal/g.

1. Introduction

Fossil fuels are still the main energy source of the world today. In 2011, the need for fossil fuels totaled 10,668 million TOE (Tonnes Oil Equivalent) or 82% of the total demand and is expected to increase to 14,898 million TOE in 2035 [1]. Coal contributed 3,773 million TOE in 2011, will reach 44% in year 2035 and in 2020 is expected to take over the role of oil as the highest in the primary energy mix. Fossil fuels are un-renewably energy sources, will run out by the time if continuously used. While the use of renewable energy recorded 1,727 million TOE or 13% of world total usage energy [1]. Biomass is an alternative energy that can contribute to the primary energy mix as a replacement for coal when processed optimally. Biomass is material derived from plants that can be either directly or indirectly be utilized as fuel in huge so that it can be one of the alternative energy source of fuel oil (fossil).

The potential of biomass energy in Indonesia is very large, that is 13,662 MWe, while the installed capacity is only 1,364 MWe2. One of the most prospective biomass materials in Indonesia is rice husk which is agricultural wastes that have been disposed as refuse [2]. Rice production in Indonesia in 2015 is estimated at 75.55 million tons of GKG (Gabah Kering Giling/dry rice unhusked) or increased by 4.70 million tonnes (6.64%) compared to 2014 records [3].

Processing rice husk into bio-briquettes is one way effective packaging rice husk. Rice husk charcoal briquettes can store heat energy average of 4384.043 cal/g [4]. Increased energy content of rice husk charcoal briquettes can be made by adding other kinds of biomass with high calorific value of energy. For example, the average heat energy briquettes rice husk increased to 4526.097cal/kg after being mixtured with wood charcoal. Improving the quality of briquettes can be done at the preparation stage of charcoal such as carbonization, grinding, formulating the optimum composition and the addition of appropriate adhesive material with appropriate levels as well [5,6].

In this research, rice husk charcoal briquettes were fabricated by adding a certain amount of coconut shell charcoal as a substitute for wood charcoal which has rared and is not economically profitable. Tapioca starch was used as an adhesive for quick burning and produces a high caloric. Characterization processes were performed to determine the calorific value and the factors affect the quality of the resulted biobriquettes.

Through the fabrication and characteristics test of briquettes made from rice husk charcoal is expected to be obtained the bio-briquettes production mechanisms and can contribute on how the utilization of waste rice husk as an alternative to fossil fuels.

2. Methods

2.1. Materials and Research Tools

The main materials used are rice husk, coconut and tapioca starch as depicted in the Figure 1. And the main tools consist of heater, softener, filter, briquettes mold and briquette compression tool.

(a) (b) (c) (d) (e)

Figure 1. The Base Materials Used: (a) Rice Husk, (b) Rice Husk Charcoal, (c) Coconut Shell, (d) Coconut Shell Charcoal, (e) Tapioca Starch.

2.2. Materials Preparation

The materials preparation processes were accomplished mostly to get the mixing of rice husk and coconut shell charcoals with definite compositions which were ready to be moulded. Prior made the charcoal, rice husk was dried for 10-15 hours, roasted until dark color and then cooled. The coconut shells charcoal was used from the market. The next process was down-sizeing, the rice husk charcoal smoothed by using a blender while coconut shells charcoal by means of ground. Separately both charcoals are filtered by using a 120 mesh filter.

Mixtures of rice husk: coconut shell charcoal were prepared with the composition-1 (50%:50%) and composition-2 (80%:20%). To each composition, adhesive of tapioca starch was added in vary levels (% mass) which were: A = 4%, B = 6%, C = 8% and D = 10%.

Table 1. Rice Husk : Coconut Shell Charcoal Briquettes Sample Identification

No.	Sampel ID	Charcoal Composition (%)		Adhesive Content (%)
		Rice Husk	Coconut Shell	
1.	1A	50	50	4
2.	1B	50	50	6
3.	1C	50	50	8
4.	1D	50	50	10
5.	2A	20	80	4
6.	2B	20	80	6
7.	2C	20	80	8
8.	2D	20	80	10

2.3. Briquettes Fabrication

The dough of each briquette was prepared from 80 g of the any charcoal composition and 60 ml of water and adhesive materials according to the its percentage level. The adhesive material was prepared in advance by mixing the tapioca with water in a pan and then heated on the stove until it coagulates. The charcoal then pour on the dough and stirring until blended. The doughs were then set up into a cylindrical mold with 2 cm of the diameter and then pressed using hydraulic compression tool with 3 ton of the power (21 swings). The last step was drying process to reduce the moisture content of the briquette so that make it easy to light when burned. All briquettes that have been printed were dried in an oven at a temperature of 55 ° C for one day.

2.4. Characterization

Characterization of briquettes conducted were included determination of water content lost in the heating process, the average density, the calorific energy of the briquettes resulted and proximate test [7].

Determination of calories energy value and proximate test were conducted at the Lab. Coal tekMIRA Research Center Bandung. The calories energy value was measured using a bomb calorimeter. Proksimate tests were conducted to determine standards quality of the briquettes produced include, fuel power, long flames and determine the standard of the sale value of the briquettes.

Test proximate tests performed consist of:

- Water Content Test
  The test results of water content can also be used to characterize other properties such as air-dry moisture lost.
- Volatile Matter Content Test (Fly Substance)
  This test intended to determine the content of volatile matter contained in briquettes produced. Value of volatile matter affects the perfection of combustion and flame produced which determine the marketability of briquettes.
- Ash Content Test
  Ash content test was performed to determine the levels of ash generated by the briquettes after burning.
- Fixed Carbon Determination

Intend to determine the levels of fixed/bonded carbon contained in the briquettes. Calculation of fixed carbon percentage was done in accordance with ASTM D 3172-13.

3. Results and Discussion

3.1. Briquette Fabrication

Briquettes have been made from mixtures of rice husk and coconut shell with two different compositions (50:50 and 80:20). For each composition, four adhesive content variations (mass % of tapioca): 4%, 6%, 8% and 10% were used. Each variant herein after are identified as Samples ID in the Table 1.

Figure 2. Rice Husk: Coconut Shell Charcoal Briquettes

Overall 8 variant cylindrical briquettes with 2 cm diameter of the surface are shaped same a like the example in Figure 2. The high of cylinders vary greatly depending on the composition and content of the adhesive. For samples with composition-1, the heights are ranges between 1.94 cm to 2.39 cm and for samples with compositions-2 are between 1.73 cm to 3.13 cm.

Table 2. The Water Content Lost and Dendity of Rice Husk:Coconut Shell Charcoal Briquettes

No.	Sampel	Charcoal Composition (%)		Adhesive Contain (%)	Water Content Lost (%)	Density (g/cm)
		Rice Husk	Coconut Shell			
1	1A	50	50	4	32.04	0.81
2	1B	50	50	6	32.09	0.79
3	1C	50	50	8	33.33	0.81
4	1D	50	50	10	32.37	0.82
5	2A	20	80	4	36.01	0.76
6	2B	20	80	6	37.70	0.68
7	2C	20	80	8	35.42	0.78
8	2D	20	80	10	28.56	0.84

3.2. Results of the Characterization

3.2.1. Properties of the Briquette

The physical properties of the resulted rice husk: coconut shell charcoal briquettes are shown in the Table 2. It appears that the level of water lost average increase linearly with starch content variation for each composition. With increasing levels of water lost, density briquettes are reduced. In some samples was obtained significant relationships that density with a high gluten content show a linear but not as a result with the water content. There are differences that are not linear on any variation of the levels of starch. It is because the nature of starch and charcoal those are not resistant to moisture so it is easy to absorb water from space [6].

Comparing the water content lost on the composition of charcoal briquettes with 50:50 and 80:20, it seem the composition 50:50 has higher water content. This is caused by the composition of coconut shell charcoal that is more than the composition of 80:20. Silica content is high enough in this composition supposedly resulting in high water levels due to the nature of silica itself is absorbing water. Silica content of rice husk was 16.98% while the silica content in the coconut shell charcoal is 52% [8].

The result of the average density calculation of the briquettes in Table 2 shows that for samples with starch content of 10% (sample D) has the highest density among other treatments for each type of briquettes composition, that the higher the levels of starch, the higher density briquettes. This happens because the briquettes pores will decrease due to the adhesive holding capacity increase highly [6]. The increase in density tends linear except at the sample B for each composition, the density appears to have declined.

If the density compared to each of the constituent composition of the briquettes, the briquettes with a 50:50 composition of greater density than the briquettes with a composition of 80:20. This is caused by the high density of coconut shell charcoal compared to the density of rice husk. Then the charcoal briquette compositions which more will make the briquettes have a high density as well.

3.2.2. Proximate Test Results.
The proximate test results which include determining of the water content, volatile matter, fixed carbon, ash content and calorific value of the average are shown in Table 3.

Table 3. Proximate Test Results and Calorific Value Average

Sampel	Water Content (% adb)	Volatile Matter (% adb)	Ash Content (% adb)	*Fixed Carbon* (% adb)	Calorific Energy Value (cal/g)
1A	7.92	21.70	20.75	49.63	4955
1B	7.63	23.12	20.21	49.04	4966
1C	8.52	23.40	20.16	47.92	4886
1D	8.52	24.46	19.92	47.10	4860
2A	7.52	21.88	30.44	40.16	4124
2B	7.59	22.91	29.66	39.84	4132
2C	7.59	24.63	28.97	38.81	4104
2D	6.27	25.61	29.24	38.83	4132

The water content of the briquettes were affected by the type of base material, type of adhesive and testing methods employed [6]. From the table above it appears that the greater the levels of starch, the higher the water content. Extra adhesive higher causes the water contained in the adhesive would go in and bound in the pores of charcoal, besides the addition of adhesive that the higher will affect the briquettes have a density higher the briquettes pores getting smaller and when drained of water trapped in the briquette pore hard to getaway.

The high water content was shown in the sample composition-1 with the starch content of 6% (sampel 1B) and 10% (sampel 1D). While the low water content in the sample composition-2 with a starch content of 10% (sampel 2D).

When viewed from the composition of the constituent materials, the composition-1 of rice husk and coconut shell charcoal has higher water content than the briquettes with the composition-2. This is thought to occur due to the silica content in the composition-1 is greater than the briquette with composition-2. The nature of the silica itself is hygroscopic, to absorb water very well, and therefore the amount of silica that is pretty much it causes the water absorption from the air. The adhesive or the water content of the material itself is still high as a result of carbonization less than perfect bound to the silica and causes the water content in the briquettes is getting higher. The cause of the silica content in the briquette composition-1 higher is because the levels of coconut shell charcoal is high, since the silica content in the coconut shell charcoal is higher than the rice husk. Silica content of rice husk is 16.98% while the silica content in the coconut shell charcoal is 52%.

Water levels resulting from this research meets the standards set by the government which, according to Minister of Energy and Mineral Resources of Indonesia Republk (ESDM RI) No. 047 In 2006, the maximum moisture content should be available for charcoal briquettes is 20%, and briquettes resulted in this research has a moisture content ranging from 6.27% - 8.52%.

Volatile matter or content of volatile matter is a substance that can be evaporated as a result of the decomposition of the compounds that are still present in the briquettes in addition to water, carbon bonded and ash [6]. From Table 3, comparing volatile matter content of the levels of starch show that the greater the levels of starch, the greater the levels of the volatile matter. This means that the addition of starch levels can make the content of volatile matter in briquettes increases. This is caused by the presence of volatile substances contained by an adhesive, such as CO, CO_2, H_2 and CH_4 [6]. The higher levels of starch, the amount of these substances were olso increase.

The most high volatile matter are owned by 10% starch levels, sample 2D that is equal to 25.61% and the lowest levels held by the sample 1A that is equal to 21.70%.

If we compare the levels of volatile matter for each composition, then the composition of rice husk and coconut shell charcoal 80:20 was higher in comparison with the composition of 50:50. When viewed from the silica content, composition briquettes 80:20 higher silica content than the composition of 50:50. Prof. Dr. Muhammad Zarlis, M.Sc found that the more the silica content in the briquette it causes more content of the volatile matter. This supposedly caused by a defective process of carbonization of rice husk. High and low a level of substance evaporates/volatile matter in briquettes caused by the perfection of the carbonization process and is also influenced by the time and temperature at the authoring process. The greater the temperature and time of composing the more substance evaporates wasted so those at the time of assay substance will obtained evaporate lower levels of substance.

Levels of volatile matter generated from this study do not meet the standards set by the government which, according to Minister of Energy and Mineral Resources of Indonesia Republik (ESDM RI) No.047 of 2006 levels of volatile matter that should be available for a maximum of charcoal briquettes is 15%, while briquettes research has a moisture content ranging 21.70% - 25.61%.

The next component of proksimate test is ash levels. The ash is metal oxides in a charcoal composed of minerals that can not evaporate in the carbonization process. The ash content is very influential to the quality of briquettes are made. The higher the ash content owned briquettes then the lower heat will be produced. From this research, it was found that the addition of starch concentration resulted in a decrease in ash content. According to research conducted by Maryanto et al in 2013 that the addition of starch levels cause increased levels of ash, because of the addition of starch levels will result in the addition of inorganic substances in briquettes, such as silica, Fe, MgO, and Fe2O3. So it can be said that the study does not prove the results Maryanto colleagues who say that the higher the levels of starch will result in increasingly high levels of ash produced.

When compared to the ash content of the briquettes with a composition of 50:50 and 80:20, then the composition of 80:20 has more ash content compared with the composition of 50:50. If the terms of the amount of silica contained in both types of briquettes, the silica content in the composition of 80:20 more than the composition of 50:50. According to research conducted Aditia Warman in 2005 and Prof. Dr. Muhammad Zarlis, M.Sc in 2009 stated that the more the silica content in a briquette, the ash produced will be more and more, because the residual silica materials including non-coumbustible. When compared to this study, the results of this research are not in accordance with the results of research conducted by two researchers.

When viewed from the water content, the water content of the briquettes with a composition of 50:50 compared to 80:20 lot more. This means that should the composition of the ash content 50:50 produce higher compared with the composition of 80:20.

Ash generated from this study do not meet the standards set by the government which, according to Minister of Energy and Mineral Resources of Indonesia Republk (ESDM RI) No. 047 2006 maximum ash content of charcoal briquettes that can be owned is <5%, while in this briquette research has a moisture content ranging from 19.92% - 30.44%.

By evaluation the fixed carbon content to the variation of starch levels it seem that the greater the level of starch, the smaller the bound carbon content is contained in the briquettes. This is due to the greater levels of starch, the higher the water content. Carbon content will be low if the levels of volatile matter and water content increase. One of the characteristics is, a good briquette have a high fixed carbon value, because it is what carbon compounds will produce heat when burned.

If the comparisons take between the briquettes with 80:20 rice husks and coconut shell charcoal composition with the composition 50:50, The 50:50 briquettes composition has a higher fixed carbon content. This is caused by the ash content and low levels of volatile matter. The existence of bonded carbon in charcoal briquette is affected by the ash content values and levels of substance evaporate. Levels of bound carbon are high when the value of ash content and levels of substance evaporates at charcoal briquettes are lower.

Fixed carbon levels resulting from this study did not meet the Indonesian National Standard (SNI) No. 1/6235/2000 namely briquette should have a fixed carbon content of at least 77%, while briquette research has a moisture content ranging from 38.81% - 49.63%.

Results of the determination of the calorific value of the average energy above shows that the addition of starch content causes decreased energy calorific value. This happens because the higher the water content contained in the briquettes with increased levels of starch, so that the heat generated in advance is used to evaporate water in the briquettes.

If the comparison between the type of sample to the composition of rice husk: coconut shell charcoal = 50:50 and 80:20 clearly seen on the graph that the type 1 (composition of rice husk: coconut shell charcoal = 50:50) has a value of more heat energy high compared with other types of briquettes 2 (composition of rice husk: coconut shell charcoal = 80:20). This is due to the silica content is pretty much on the composition of the briquettes 50:50. The high silica levels have led to higher water content for this silica absorbs water so that the briquettes are hygroscopic.

4. Conclusion

Bio-briquette models made from the mixtures of rice husk and coconut shell charcoal have been successfully created in this research. The highest calorific value of energy is possessed by the sample-1B with 4966 cal/g and the lowest is at sample-2C with 4104 cal/g.

Factors that might affect the content of heat energy value are moisture, volatile matter content, ash content, and the levels of carbon bonded/fixed carbon. Moisture, volatile matter content and ash content result in the higher will lower calorific energy value and vice versa. While higher levels of fixed carbon will result in increasing the calorific of briquettes.

Briquettes that have the optimal calorific / high value of energy is a sample in which the composition of rice husk: coconut shell charcoal is 50%:50%, a starch content of 6%, the water content of 7.63% adb, ash content of 20.21% adb, volatile matter content of 23.12% adb and level of fixed carbon 49.04%.

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