

Proximate and The Calorific Value Analysis of Brown Coal for High-Calorie Hybrid Briquette Application

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Abstract. A study has been conducted about the quality of young coal (brown coal) briquettes from North Kolaka to determine the effect of varied adhesive on the proximate characteristics and calorific value. The young coal briquettes were made by using adhesives of starch, cassava starch and Castor oil plant starch at a concentration of 5 to 15% of the total mass. The grain size of young coal and the adhesive used were 60 mesh and 100 mesh, respectively. The samples were molded in a cylindrical mold with a diameter of 2.5 cm and a high of 6 cm, and with a pressure of 100 kg/cm². After having been compacted, the young coal samples were then analyzed proximately i.e. moisture content, volatile matter, ash content and fixed carbon, as well as their calorific values calculation. The results showed that the increase of the adhesive could tend to increased the water content and volatile matter, but reduced the ash content, and the fixed carbon tend to constant except coal briquettes using starch adhesive it were increased. The calorific value of the young coal briquettes increased for all kinds of adhesives when the adhesive increased. The calorific value per one gram ranged from 3162.7 cal/g to 4678.7 cal/g. The highest calorific value, 4678.7 cal/g, was observed at the adhesive of 15 % of starch. The characteristics of young coal can be used as a raw material for making high-calorie hybrid briquettes.

1. Introduction

The use of non-renewable energy from fossil continues to rise causing the reserves of this fuel energy sources growingly scarce, and will eventually be finished. On the other hand, the fast increase of world's fuel energy price has impacted on the increase of price of fuel energy including that of fuel and gas in Indonesia. Currently, Indonesian government fuel subsidy is about forty-nine trillion rupiahs per year to meet its community's need of about ten million kilo litre per year [1-3]. Therefore, there needs to be innovative research to develop new energy sources with high calorie as alternative sources of fuel for households and small industries, so the energy inventory well sustains.

One of the alternatives energy sources potential for fuel development is brown coal which can be blended with organic wastes (husk of rice, sago waste, and cashewnut husk). As an agricultural country, Indonesia is riches in agricultural wastes less utilized. Statistical data show that there are 110,498 ha of rice farmland in Southeast Sulawesi producing 423.317 tonnes of dried rice in 2007 [4-5]. In addition to rice husk waste, wastes from sago and cashewnut are also commonly found in this province which is one of the biggest producers of sago and cashewnut in Indonesia. The Agricultural wastes, which are biomass, become the huge source of alternative energy containing relatively high energy These biomass have been processed and utilized as a ceramic and other more valuable materials [6-8].



Southeast Sulawesi has coal potential about 9,000,000 tonnes spreads in Wawonii, Konawe dan North Kolaka [9]. Brown coal has high fixed carbon and it is suitable for briquette application, but contains low volatile matter causing it inefficient in its use, while organic wastes from rice hull, for instance, contain high volatile matter, but has low fixed carbon [10]. To improve the quality of briquette, we can combine the materials or carefully control the processing method [10-11]. For example we can control briquette's microstructure by using certain heating rate or by using appropriate technology such as microwave energy. Application microwave for processing materials have been reported by several scholars [12-14]. By using this waves as an alternative energy for heating, the microstructure as well as mechanical property of ceramics can be improved [15-17]. The use microwave for processing of briquette and other biomass based materials has been performing in Halu Oleo University and will be reported in separated papers.

1.1 Coal and Its Classifications

In general, coal is classified into 5 levels (from the highest to the lowest level) based on the relative content of the elements carbon (C) and water (H_2O) contained in coal, namely: anthracite, bituminous, sub-bituminous, lignite and peat (peat). According to Bateman, in anthracite, C content is relatively higher than H_2O , while in bituminous and peat, C content is relatively lower than H_2O . In bituminous, C content is relatively lower than C content in anthracite, whereas in bituminous H_2O content is relatively higher than H_2O content in anthracite [11]. Lignite coal is the softest, and its density is still in the first level. From geological point of view of, lignite coal is the youngest because it is composed of volatile and water content with low levels of fixed carbon. Bituminous coal is also young coal typically used in households and factories because it contains enough volatile matter, but is relatively high in calorific values, so it can produce a higher flame temperature [11]. On the other hand, anthracite coal is the hardest coal and is smoky when burned. One characteristic of the anthracite coal is that it has low levels of hydrocarbons [11]. This type of anthracite coal is the oldest coal from the geological point of view because it is hard coal, comprises of major components of carbon with little volatile matter content and contains almost no water.

Coal is heterogeneous, both in terms of chemical composition and physical features. The physical features of coal include heat value, moisture content, volatile matter and ash. The chemical properties of coal depend on the content of various chemical substances such as carbon, hydrogen, oxygen, and sulfur. The calorific values of coal are different from one mine to another. Anthracite coal's properties are very shiny black and compact, very high in calorific value, in carbon content, and low in water, ash and sulfur content. Bituminous / subbituminous coals are shiny black, but less compact, in their characteristics and high in calorific values with relatively high carbon content, and are little in water, ash and sulfur contents. In contrast, the properties of lignite coal are black and very brittle, low in calorific value with little carbon content, and has a high water content and ash content and sulfur rich [11].

1.2 Coal Briquettes

Coal briquettes are solid fuel made from coal with little mixture of clay, tapioca and cassava starch. The main raw material of coal briquettes are coal sources sufficient for the region of Southeast Sulawesi [1,2]. Briquettes properties are described as follows:

➤ Water Content

The water content is one of the components of solid fuel. The water content of solid fuels is the ratio of the weight of water contained in the solid fuel to the dry weight of the solid fuel. The water content in the solid fuel composed of internal / hygroscopic water and external / mechanical water. The water content will negatively affect the calorific value and combustion characteristics of solid fuel [9].

➤ Ash Content

Ash content is the measure of material contents and a variety of inorganic materials in the material tested. According to Earl [19], ash is the material remaining, for example, in wood heated to a constant weight. Ash content is comparable to the content of inorganic materials in the timber. One of the main elements contained in the ash is silica whose influence is unfavorable on the value of the heat produced. Ash composes of mineral materials such as clay, silica, calcium, magnesium oxide, etc.

➤ Volatile Matter

Volatile matter is material content flammable, and easily forms gas. High levels of volatile matter in agricultural waste indicates that the agricultural waste is easily flammable and burned, even faster burning and difficult to control [20].

Bio-briquette ignition temperature is lower and the burnout time is shorter compared to coal briquettes. When briquettes are heated, the temperature rises, and after reaching a certain temperature, the volatile matter gets out and burns around the briquette. Flame temperature is low if the more volatile matter biomass mixture and biomass flame temperature is lower than that of coal. The addition of

biomass on briquette coal can increase the briquette flame.

➤ **Fixed Carbon**

The component which does not form gas when burnt is "fixed carbon" or FC. [21]. FC has an important role in determining the quality of charcoal because it can influence the amount of calorific value produced. The higher the bound carbon in the charcoal, the higher the calorific value produced. Quality charcoal is the one with high calorific value and fixed carbon.

➤ **Calorific Value**

The number of calorie units released by perfect burn of a mass unit or certain fuel volume is defined as burnt calorific value of the fuel. As for solid fuel like coal, the burnt calorific value is measured with calorimeter bomb [22]. Calorimeter bomb is an instrument used to define the heat released by fuel and oxygen at a constant volume. The instrument was invented by Prof. S. W. Parr in 1912, and therefore, it is often called Parr Oxygen Bomb Calorimeter [9]. Burn calorific value of fuel is defined by means of calorimeter bomb, by deheating the burnt down to initial temperature so as the steam produced in the burning of the fuel will condensed and latent heat of the steam will be released, thus, the total burn calorific value contain heat of the steam [22].

2. Material and Method

2.1 Preparation of Brown Coal Briquette

The brown coal was crashed into small pieces, and then put into tins. Further, the coal dried at 150°C for ±2 hours maintaining the oxygen to be at appropriate level, and then removed to cool down, then filtered using 60 mesh sieve.

➤ **Preparation of Adhesive**

Ten grams adhesive (starch, cassava starch, castor oil plant starch) were put into a 250 ml beaker and added with 90 ml of water, then heated in a boiling pot until it forms gel.

➤ **Mixing of Adhesive and Coal Powder**

Sixty-mesh grain coal was mixed with adhesives (starch, cassava starch, castor oil plant starch) each with the composition of 5%, 10% dan 15% consecutively, stirred by means of homogenizer to obtain homogenous mixtures.

➤ **Coal Compaction**

Adhesive-coal mixture was scaled and then put in the briquette cylinder mold, 2.5 cm in diameter and 6 cm high. The Mold was placed under compaction tool, followed by compaction of samples up to 100 kg/cm² pressure.

➤ **Briquette Drying**

The compacted briquettes were then be dried in the open air for four days under the temperature of ± 40°C. After the drying process, analysis of proximate of the briquettes was made.

2.2 Analysis of Brown Coal Briquette

➤ **Water Content**

The water content of brown coal was determined by means of the following equation:

$$\text{Water Content (\%)} = \frac{[BS - (BC + SP(105^{\circ}C)) - BCK] \times 100 \%}{\text{Samples Weight}} \quad (1)$$

➤ **Ash Content**

The ash content of the brown coal was determined by means of tanur heating with the temperature up to 600°C and coolant desiccator. The percentage of ash content was calculated using formula $W1/W2 \times (100 \%)$, where W1 was the weight of ash and W2 was the weight of dried sample.

➤ **Volatile Matter**

The content of volatile matter of brown coal can be determined using the following equation:

$$\text{Volatile Matter (\%)} = \text{volatile content [KZH}(750^{\circ}C)] - \text{water content} \quad (2)$$

$$\text{KZH (\%)} = \frac{[BS - (BC + SP(750^{\circ}C)) - BCK] \times 100 \%}{\text{samples weight}} \quad (3)$$

➤ **Fixed Carbon**

The content of fixed carbon of brown coal can be determined using formula $FC = 100 - (Ka + Vm + Abu)$ where Ka was water content, Vm volatile matter and Ka was ash content.

➤ **Calorific Value**

The calorific value of brown coal was analyzed using Calorimeter Bomb. The calibration of the

burn equipment was done using benzoate acid as the standard to obtain Tare Energy (W). To obtain calorific value of the brown coal briquette the following equation was used:

$$\Delta t = T_2 - T_1 \quad (4)$$

$$W = \frac{6320 \times M}{\Delta t}$$

$$E = \frac{W \times \Delta t}{M} \text{ Cal/gram} \quad (5)$$

Where M was benzoat mass weight, Δt benzoat acid temperature, W energy, E calorific value of the burn and 6320 was calorific value /1 gr benzoat acid.

3. Results and Discussion

3.1 The Quality of Brown Coal

The processing of brown coal into briquettes underwent several steps: brown coal carbonization, smoothing and filtering, mixing adhesive, molding, compacting, and briquette drying. Carbonization is a process to converse raw material into charcoal under the heating process. Carbonization process of coal was done burning coal by supplying limited oxygen. Carbonization aimed to improve the carbon and released volatile matter as well as reducing the water content.

Carbonated coal was made briquette using starch adhesive, cassava starch, and castor oil plant starch. Prior to this, the coal charcoal was filtered 60 mesh to obtain uniform granules. The use of adhesive is intended to placard two objects base on the surface bond so that in the process of briquetting, the coal granules can stick well. In the next step, brown coal was mixed with compaction adhesive at 100 kg/cm² pressure to obtain compact briquettes, in the form of solids with high granule density. Further, the briquettes were dried to reduce their acidity caused by addition of adhesive.

Then, the water content, ash content, volatile matter, fixed carbon, and calorific value of the coal briquettes, which has been dried, were analyzed. Coal briquette analysis results are shown in Table 1.

❖ Water Content

Water content of the brown coal briquettes are influenced by the type of adhesive used. The adhesive of the starch contain lower water compared to the adhesive of cassava starch as well as castor oil plant starch at the composition of 5 % and 10 % adhesive. At the composition of 15 % adhesive, the highest water content was in starch. Figure 1 shows the result of water content of the brown coal briquettes.

Table 1. The Result of Proximate Analysis and Calorific Value of the Brown Coal Briquettes

Test Para-meter	Types of Adhesive	The composition of Adhesive in Briquette (%)		
		5	10	15
Water content (%)	Starch	2.00	2.67	3.33
	Cassava starch	2.33	2.67	3.00
	Castor oil plant starch	2.33	3.00	3.00
Ash content (%)	Starch	8.33	7.33	5.00
	Cassava starch	12.33	8.33	7.67
	Castor oil plant starch	14.00	11.67	9.67
Volatile matter (%)	Starch	16.67	16.67	18.33
	Cassava starch	14.33	18.00	18.33
	Castor oil plant starch	14.33	16.00	18.33
Fixed carbon (%)	Starch	73.00	73.33	73.34
	Cassava starch	71.01	71.00	71.00
	Castor oil plant starch	69.34	69.33	69.00
Calorie (cal/gr)	Starch	4595.9	4645.8	4678.7
	Cassava starch	3256.9	3925.9	4291.7
	Castor oil plant starch	3405.3	3162.7	3445.1

The bigger the adhesive composition of the water content of brown coal briquettes the bigger it is for all types of adhesive. The water content was high because the adhesive used was not dried before used.

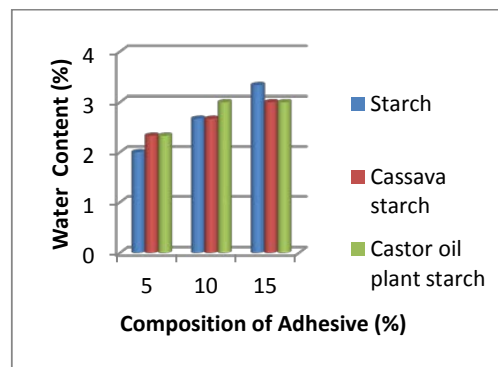


Figure 1. Water content of brown coal briquettes

❖ Ash Content

The ash content of the brown coal briquettes is influenced by adhesive composition, in the sense that the bigger the adhesive composition the higher the ash composition. This is because the adhesive contains high organic matter resulting in a high ash when baking is done. Figure 2 shows brown coal briquettes' ash content for the three types of adhesives.

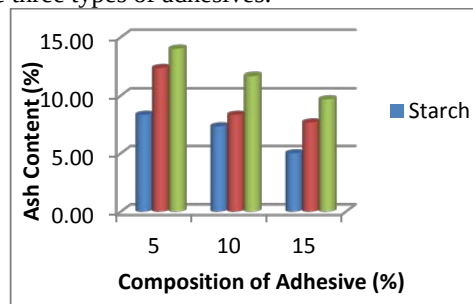


Figure 2. Ash content of brown coal briquettes

❖ Volatile Matter

Volatile matter content in the adhesive contributes positively to brown coal briquettes. The greater the adhesive composition of the greater the volatile matter composition is. The composition of the volatile matter in the brown coal briquettes can improve the quality of the briquette. However, if excessive, the composition can reduce the quality of the briquettes. Of the three types of adhesives, starch is the one that provides most volatile matter, i.e. 18.33%. Figure 3 shows the volatile matter of brown coal briquettes for three adhesive compositions.

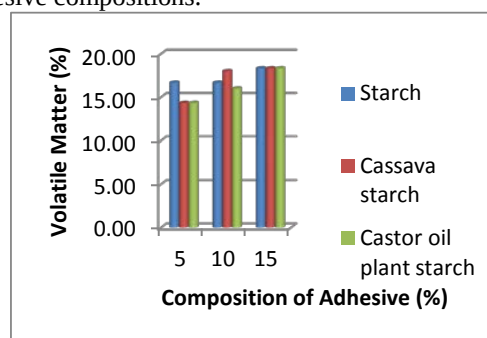


Figure 3. Volatile matter of brown coal briquettes

❖ Fixed Carbon

Fixed carbon content of the briquette determines the calorific value. The addition of adhesive does not directly influence the increase of fixed carbon, but rather due to changes in water content, ash content, and volatile matter of brown coal briquettes. Figure 4 shows the fixed carbon of brown coal for some of the adhesive compositions.

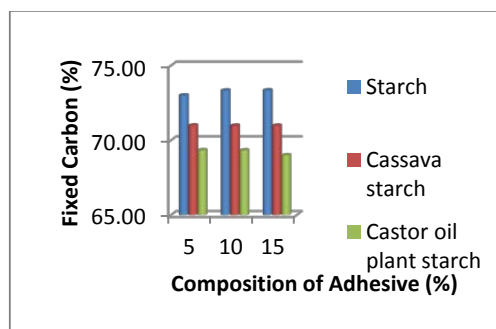


Figure 4. Fixed carbon of brown coal briquettes

3.2 Calorific Value of the Brown Coal Briquettes

The results of the analysis of the coal briquettes using Bomb Calorimeter is presented in Table 1. From the results of this analysis, it is found that the highest calorific value of brown coal briquettes is in the composition of 15% for starch adhesive with a calorific value of 4678.7 cal/gram. The high calorific value in that composition was influenced by the low water content, ash content, and volatile matter values of the briquettes.

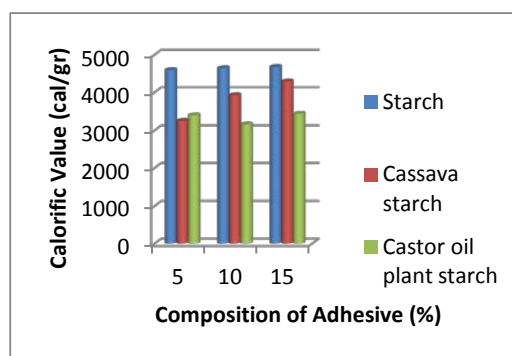


Figure 5. Calorific value of brown coal Briquettes

The relatively small size of the granules of brown coal briquettes (60 mesh) indicated that the pores were so small that the briquettes' moisture (water content) contained in them was difficult to evaporate during the drying process. Consequently, the water content in the briquette was getting higher. High water content reduces the calorific value since briquette's heat is first used to evaporate water that existed prior to radiation emission used as the heat of combustion. Starch and cassava starch adhesives have the highest calorific value, 4678.68 cal/g and 4291.68 cal/gram consecutively, at adhesive composition of 15%. Figure 5 shows the calorific value of brown coal briquettes in various types and composition of adhesive.

Figure 5 shows that the addition of adhesive causes an increase in calorific value. However, the addition of adhesive at higher concentrations reduces calorific value instead [20]. This is because an increase in the volume of adhesive causes the decline of fixed carbon. Thus, it is necessary to determine the optimum composition of the adhesive to obtain the maximum calorific value.

4. Conclusion

The percentage of adhesive affects the calorific value of brown coal briquettes, where higher level of adhesive increases calorific value, that is at the composition of 5% to 15%, the calorific value is 4678.68 cal/gram. Starch adhesives provides the greatest calorific value in all adhesive compositions, of which they are 4595.91 cal/gram, 4645.77 cal/gram, and 4678.68 cal/gram subsequently, for the composition of 5%, 10% and 15%.

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