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The Fabrication and Characterizations of Coal Briquettes Composed by Charcoal – Clay – Rice Husk Ashes and Adhesive

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Abstract. Coal briquettes are solid materials that can be used as fuels. The composition of this solid fuels are mixed by clay as the ashes binder, rice husks powder as flame additives, and starch flour as adhesive materials. These materials were prepared in different ratio to be mixed homogeneously which are determined accordingly. The fabrication was conducted by mixing methods, and pressed by hydraulic press within 3100 KPa. The results were placed inside an oven to be dried for 24 hours within 85°C of temperature, followed by 24 hours of allowing standing in room temperature. Afterward, the characterizations of the coal briquettes were done by performing density and compressive strength, while the others physical properties such as specific heat, combustion, and purity properties were also tested. The physical properties showed that coal briquettes are flammable and high ignition characteristics. The stability and speed of combustion to fire have continuous and fixed combustion indicated by the presence of solid ashes. The samples suggested that the M_1 samples provided fragile ashes with mass loss accounted for 56.33%, and it has the highest specific heat values accounted for 246.66 Kcal/Kg. Meanwhile, the lowest specific heat value was 162.26 Kcal/Kg which was M4 samples with mass loss for 34.53%.

1   Introduction

Coal briquettes are solid fuels composed by charcoal added by additive and adhesive materials [1-3]. The briquettes are considered as an alternative source in replacing the main energy resources to replace the fossil fuels. The amounts of petroleum and charcoal are originated from solid and liquid carbon substances [4-7].

The main objective of fabricating the coal briquettes is to provide solid fuels from charcoal with better composition, so that this material is operable and applicable to be utilized compared to the use of charcoal in direct combustion [8]. To obtain good coal briquettes which have low percentage of sulfur and ashes, a good adhesive material accelerates the combustion point as

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well as absorbing the hazard emissions and substances [9-10]. There are several reasons about the use of charcoal to be planned as a potential substitution for petroleum due to the affordability, while the thermal characteristics suggest high and continuous specific heat value. Subsequently, the combustion process occurs without noise, non-soot fractions, vast sources, and the amounts of residual combustion are not scattered. One of the optimum types of charcoal are carbonized coals which are categorized as a super material. This type of coal has been carbonized before being mixed into a briquette, so that this coal produces less odor, and smoke. However, to produce these coal briquettes, the cost of production is relatively high due to the process of uncommon carbonization. On the other hand, a coal briquette which is produced with common carbonization has unstable substances, so that the characteristics are lower compared to those from uncommon carbonization because of the presence certain matters. Therefore, the use of common-carbonized coal briquettes are commonly used small-scale industries [8]. To produce feasible coal briquettes as proper fuels, the charcoal requires to be composed with additives, such as ignition materials (rice husks), adhesives (starch powder), and bonded materials (clay) [11-14].

The selection of rice husks is based on the carbonic composition which can be easily combusted, while the starch powder has adhesive properties with 47% of selenium oxide, 39% of aluminum oxide, and 14% of water [15-17]. Density is the mass ratio to volume of a matter. The briquettes density characteristic is determined by the following equations:

$$\rho = \frac{m}{v} \tag{1}$$

where m is mass (g), v is volume (cm^3) and ρ is density (gram/cm^3).

The compressive strength characteristic is the maximum value of samples resistance to the impact given to the samples, calculated mathematically by the following equations:

$$P = \frac{F}{A} \tag{2}$$

where F is force (lbm), A is surface area of the briquettes (cm^2) and P is pressure (lbm/cm^2).

In fabrication a briquette, this material is expected to be ignited feasibly. Subsequently, the additives affects the ignition times, which in this case is rice husks ashes. To investigate the residual materials formed after combustion, the test is conducted. The missing of clay is expected to result constant residual combustion of briquettes. In testing the residual ashes, mass loss calculation was determined by observing the pores formed on the ashes from the briquettes combustions. The following equation illustrates mass loss [4].

$$M_H = \frac{\Delta m}{m_0} x 100\% \; or \; M_H \frac{(m_0 - m_t)}{m_0} x \; 100\% \tag{3}$$

where m_0 is initial mass, m_t is final mass and M_H is loss mass (%).

2   Materials and Methods

The tools used in this study are digital analytical balance, oven, spatula, hydraulic pumps, beaker glasses, porcelain bowl, and 100 meshes of sieve, calipers, thermometer, and UTM. The materials are the amounts of charcoal and rice husks powders, ceramic clays, and starch as adhesive materials.

The preparation of materials is begun by fining the charcoals which were filtered by 100 mesh of sieve. Then, the samples were dried within $85^{o}C$ for 24 hours to remove the water content, while at the same time the amounts of rice husks were prepared as well as the charcoals did. Meanwhile, the amounts of starch powders were mixed with 20 ml of water, and these amounts were heated in constant stirring to form adhesive materials. Finally all the materials prepared were mixed and stirred constantly to reach homogeneous state, and this mixed material was placed on the hydraulic press to be pressed in 3100 KPa for 20 units of briquettes.

3   Result and Discussion

3.1   Density

The density property of the charcoal was determined by the equation 1. The following Table 1 illustrates the density of the samples prepared.

Table 1. Density samples

Samples	Mass (g)	Clay density (g/cm^3)	Charcoal density (g/cm^3)
M_1	40	1.16	1.79
M_2	60	1.41	1.57
M_3	100	1.57	1.41
M_4	120	1.79	1.16

According to Table 1, the line graphs that have relationship between the densities and charcoal mass are displayed by the following Figure 1a and 1b.
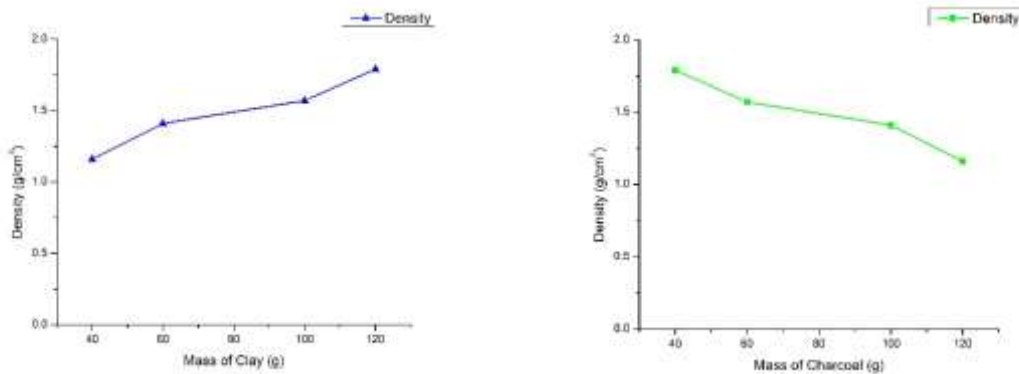

Figure 1. The line graph of density and mass of (a) Clay and (b) Charcoal

From the Figure 1a, it can be seen that the density value tends to increase as well as the inclining clay mass. This showed the amounts of clay are more solid than the charcoal. The linearity equations in the line graph suggested that the clay briquettes already had 0.8 gr/cm^3 before being added by the others additive materials.

The charcoal mass of the briquettes composition also affects the density samples as it is displayed by Figure 1b. From the figure 1b above, the increase of charcoal composed within the samples provided lower density value, as well as it is vice versa. This is affected because of the drying process time inside the heater, so that the material compositions stressed due to the presence of charcoal within the charcoal briquettes.

3.2   Compressive Strength

To obtain a good quality of compressive strength of briquettes, the pressing molding step done by hydraulic pumps must be conducted in constant pressure, i.e. 3100 KPa. The compressive strength is calculated by the equation 2, and the results could be observed by the following Table 2 below:

Table 2. Compressive strength of every sample

Samples	Clay mass (g)	Charcoal mass (g)	Compressive Strength (g/cm^2)
M_1	40	120	56.10
M_2	60	100	64.65
M_3	100	60	72.82
M_4	120	40	86.65

From the Table 2, the line graph could be set up by forming the relationship between mass and compressive strength (Figure 2a, and Figure 2b).
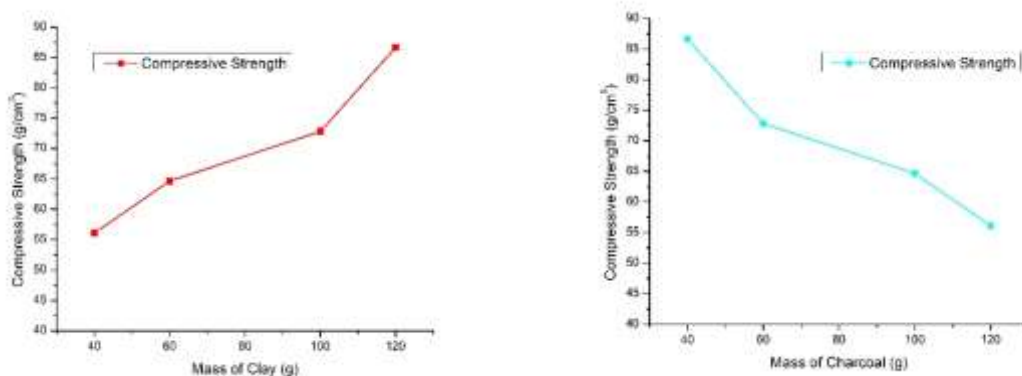

Figure 2. The relationship of compressive strength and mass of (a) Clay and (b) Charcoal

Based on Figure 2a, the relationship of clay mass and compressive strength is directly proportional. This is based on the clay physical characteristic which was more solid when being heated [18]. On the other hand, the compressive strength values are inversely proportional to the charcoal mass. The increase of charcoal mass contained within the mixing composition of briquettes reduced the compressive strength (Figure 2b). Due to the charcoal is vulnerable to be fragile when being pressed, the charcoal contained in briquettes experienced expansion properties when it is dried within $85^{\circ}C$ of temperature. From the Figure 2b, it obviously seen the decrease of compressive strength from sample M_4 to M_3 significantly due to the composition of charcoal is low compared to the M_1 and M_2.

3.3 Specific heat value

The charcoal and clay masses contained within the mixing composition affects the specific heat value. The heat values of charcoal are calculated by the equation 4 below [18-20]:

$$Q_b = Q_a + Q_g + Q_u = m_a.C_a\Delta T_a + M_g.C_g\Delta T_g + M_u.L_u \qquad (4)$$

where Q_b is Specific heat value of charcoal, Q_a is Water heat (cal), Q_g is Glass heat (cal) and Q_u is latent heat (cal).

The test results are illustrated by the following Table 3.

Table 3. Specific Heat and Charcoal Mass

Samples	Δ Ta (^{0}C)	Δ Tg (^{0}C)	m_a (gram)	Clay mass (gram)	Charcoal mass (gram)	Q (Kcal/kg)
M_1	73	69	19	50	150	246.68
M_2	73.5	70	18.6	100	125	209.38
M_3	73	70.4	18	125	100	176.48
M_4	73	71	17.5	150	50	162.26

From the results of Table 3 above, it can be designed the line graph which shows the relationship of specific heat values (Kcal/kg) to the charcoal (Figure 3a), and the line graph displaying the relationship of specific heat values (Kcal/kg) to clay (Figure 3b).

The Figure 3a shows the specific heat values has declining trends with the charcoal mass of the briquettes composition, and this is caused by the high amounts of carbon elements within the charcoal. This also suggested the carbon is easily to be reacted as long as combustion is occurred. Based on the Figure 3b, the specific heat value is indirectly proportional to mass clay, which is caused by the higher solidity of the clay compared to the charcoal.

3.4 Time ignitions measurement

One of the aims of this research is how to fabricate briquettes that is easily to be ignited. One of the factors that can affect the ignition of briquettes is the ignited additive materials (rice husks

ashes). The time ignition of briquettes samples are $M_1 = 18.40$; $M_2 = 18.70$; $M_3 = 18.20$; $M_4 = 18.0$ in a minute. Actually, the ignition time of M_4 samples is the fastest due to the highest composition of ignited additives.
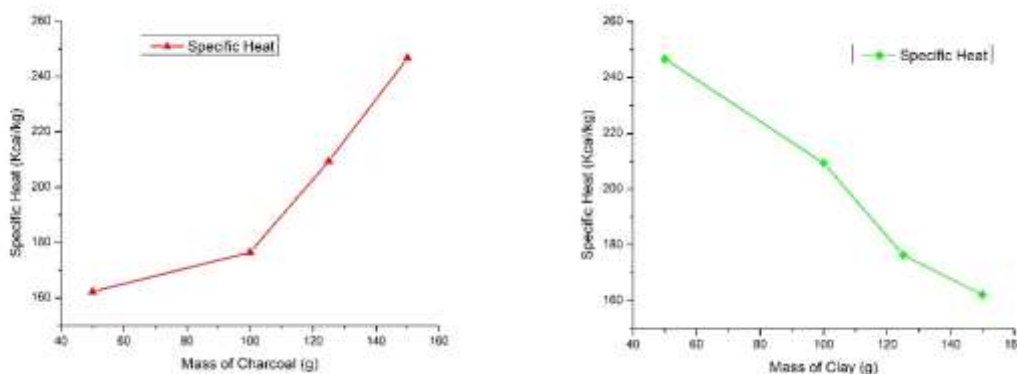

Figure 3. The relationship of specific heat and mass of (a) Charcoal and (b) Clay

3.5   Ashes measurement

To observe the formation of ashes after combustion, the briquettes were tested to determine the ashes, with the mixing of clay. The fabrication aims to produce briquettes with the un-scattered characteristics of ashes after combustion. In the ashes measurements, the amounts of mass loss are calculated by observing the pores formed according to the equations 3. And this implies to the directly proportional to the mass loss of charcoal mass.

4   Conclusions

It can be concluded that the increase of charcoal composition provides higher specific heat, however the mass loss is increasing with fragile residual combustion material. In this study, the sample M_1 has the highest specific heat accounted for 246.68 Kcal/kg. The inclining clay compositions during the fabrication of charcoal briquettes produced lower specific heat values with 18 minutes of ignition time and hard residual combustion materials.

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