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Technical Short Paper

EXPERIMENTAL STUDY ON COMBUSTION OF BIOBRIQUETTES *Jatropha curcas* SOLID WASTE

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ABSTRACT

This paper described conversion *of Jatropha curcas* waste into solid fuel through densification. The *J. curcas* waste contains 61-67% cake seed per unit weight. The densification makes a cake seed easy to collect, ship, store and use. The cake seed is useful as a solid fuel. Initially, the waste was examined with proximate and heating value analyses which were used to identify moisture, volatile matter and ash contain. Next, the fixed bed reactor was adopted as the process of the combustion characteristic identification. The results showed that the increasing surface area per mass reduced the reaction time. Meanwhile, the increasing diameter of the cake seed pellet would result in decreasing combustion gas temperature. The diameter of the pellet did not influence CO emission significantly. The highest CO emission was found at the air flow veloocity of 0.1 m s^{-1} and temperature of 222 °C.

INTRODUCTION

Nowadays the amount of energy consumption has reached 400 EJ per year. The higher level of energy consumption, particularly the fossil energy, leads to the increase of related energy cost. This, in turn, has triggered the problems faced by imported countries. As a key component, energy becomes very important for economic development. If the energy price increases, the industrial production cost will increase. Moreover, the energy issues are converted from the decreasing of fossil energy reserve. This year represents the peak of the fossil energy production, which means the production of energy will decrease in the future. To solve the problem, it is important to diversify the energy, particularly renewable energy. The use of fossil energy leads to environmental issues in terms of greenhouse gas which adds to the global warming effect. The complex problems mentioned above challenge the establishment of renewable energy in the next decades.

Biomass is one of the most important renewable energy resources in the world. In recent decades, the utilization of biomass has dramatically increased. There were many reasons. First, biomass is a renewable resource, because of the availability of biomass is unlimited, and its regenerative process runs well. Second, the extraction of biomass energy can be carried out more flexibly. The biomass can be burned directly without high technology. It also can be conversed into

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Fig. 1. *Jatropha curcas* fruit.

gas or liquid [1]. Biomass energy is more environment-friendly compared with the fossil fuel. The emission of CO_2 released from biomass into atmosphere is absorbed through a photosynthesis process. It is called the carbon neutral. If this is the case, the excessive accumulation of carbon dioxide in atmosphere will not occur.

Several countries, such as Indonesia, have begun to increase the development of *Jatropha curcas* (Fig. 1) as an energy plant to reduce the dependence on the fossil fuel. As reported by the National Indonesian Biofuel team [2], Indonesia will provide the areas of 1.5 million ha for *J. curcas* plant in 2010. Then, in 2015 the area will reach 3 million ha. The cultivation of *J. curcas* as a plant for energy in Indonesia was supported by the fact that the *J. curcas* is a plant that can grow in marginal soils. It does not compete with other food plants.

Several other countries also developed *J. curcas*, like Mexico, Thailand [3], Nicaragua [4], and India [5]. Most studies focused on the conversion from *J. curcas* into biodiesel [5-8], while several literatures reported about *Jatropha* solid waste such as cake seeds (seed husk), sludge, shells like activated carbon [9], seed husk open core gasification [10], the fixed bed pyrolisis of physical nut waste [11], and *J. curcas* part for energy [12]. The cake seeds of *J. curcas* were the waste resulted from the development of crude *Jatropha* oil into a solid fuel. As reported by many authors [3,7,11], the content of cake seeds of *J. curcas* reached 61-67% per unit weight. The potential makes the cake seeds the domestic cooking fuel or the energy for biodiesel industry. The objective of this work was to determine combustion characteristics from cake seed *J. curcas* briquettes. Moreover, pyrolysis and densification were studied.

METHODS AND MATERIALS

Cake seeds were collected from the local biodiesel factory. Originally, the form of cake seeds was heterogeneous as the result of press machine destruction. Sieve was used to establish homogeneity of cake seeds with mesh size 30-40. Next, the proximate and heating value analyses of cake seeds were performed (Table 1).

Table 1. Proximate and heating value analyses

Proximate analysis	
Moisture (%)	1.43
Volatile (%)	66.6
Ash (%)	4.6
Fixed carbon (%)	27.5
Heating value	
Higher heating value (MJ kg^{-1})	17.2

The cake seeds powder was mixed with starch binder for pellet making. The binder ratio was 70% water and 30% cassava starch. While the ratio of binder with cake seeds powder was 10% binder and 90% cake seed powder per unit weight. It meant that the binder role might be ignored because the ratio was very small. The mixing was performed in the homogeneous material and a pellet was formed through the densification process

1. Palletizing Process

A local press machine was used for the densification with the applied pressure of 1.55 MPa. Pellet was made from *Jatropha curcas* waste of 1.5 g. The diameter varied from 11 to 16 mm with the briquette length of 6.5 to 15 mm (Fig. 2).

The schematic of the combustion apparatus is shown in Fig. 3. It consisted of an air fan (1); a valve (2) to control the air flow rate; a gas heater (3); a preheat chamber (4) to provide the desirable temperature in the fixed bed combustion chamber (5); a computer (9) and weight balance (10) to analyze the mass reduction from a single pellet. Pellet cup was connected to the weight balance and the mass of a single pellet was measured every minute. Then, the data would be sent to the computer. Digital thermocouples (7, 8) measured gas temperature while the gas analyzer (6) measured CO emission.

Fig. 2. Pellet diameter.

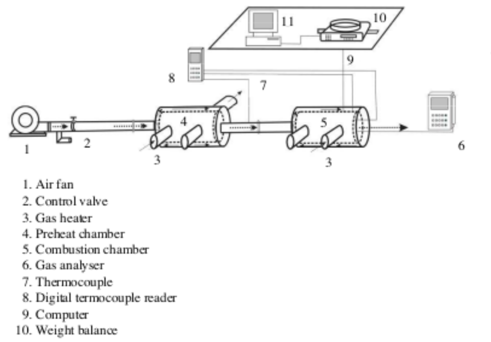

Fig. 3. Combustion equipment scheme.

2. Experimental Procedure

The purpose of the study was to see the effect of pellet diameter and air flow rates on combustion temperature and outlet CO concentration. Initially, the fixed bed combustion was cleaned to remove the old ash. Then, the combustion chamber was heated with temperature of 400 °C and air velocity of 2 m s^{-1}. Next, the cake seed pellet was put inside the cup place in the combustion chamber with the measurements of mass reduction and outlet CO concentration as described above.

RESULTS AND DISCUSSION

1. Influence of Dimension

The reaction time is used to measure the performance of pellet under combustion chamber. Figure 4 shows the reaction time and temperature as a function of pellet diameter. It can be seen that the diameter of 13 mm had the longest reaction time of 28 min. While the reaction time periods for pellets with 11 and 16 mm diameters were 25 and 26 min, respectively. This was caused by the surface area per mass. The pellets with 13 mm diameter had the lowest surface area per mass (395 mm^2 g^{-1}) while the values were 472 and

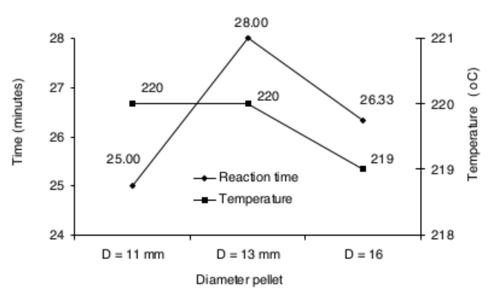

Fig. 4. Reaction time and temperature of pellet under different diameter.

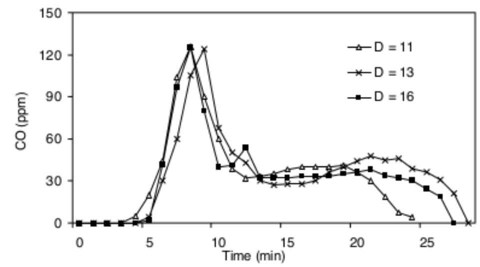

Fig. 5. The emission of CO versus time with different diameters using air flow rate 0.2 m s^{-1}.

469 mm^2 g^{-1} for pellets with 11 and 16 mm diameter, respectively. Meanwhile, the diameter pellet provides no such influence through the temperature of the combustion. As shown in Fig. 5, the 1st 5 min was for drying when the moisture was released. Devolatilization occurs from the first 5 to 8 min with the sharp increase in CO emission. The process released the volatile matters as well as other combustible gases such as H_2, CH_4 and CO.

2. Effect of Air Flow Rates

Figure 6 shows the gas temperature under the different air flow rates. It can be seen that the increasing air flow rate decreased the gas temperature in the combustion chamber. Although higher air flow rates strengthened the heat transfer in the combustion chamber, it carried high energy waste while leaving the combustion chamber. It could be also observed that the increasing of the air flow rates decreased reaction of time (Fig. 6).

Figure 7 shows the effect of air flow velocity on CO emissions. The air flow rates had significant effect on devolatilization process. The highest CO emission occurred at the air flow velocity of 0.1 m s^{-1}, with the lowest CO emission at air flow velocity of 0.2 m s^{-1}. The high CO concentration was caused by the low

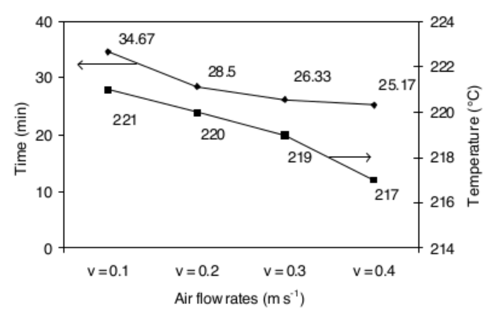

Fig. 6. Reaction time and temperature of pellet under different air flow rates.

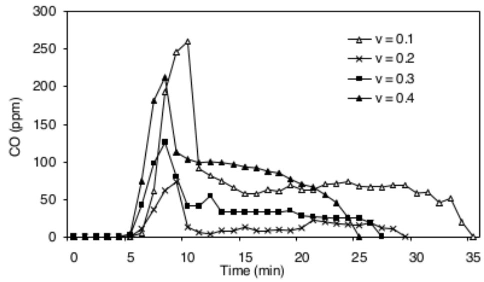

Fig. 7. The emission of CO versus time with different air flow rates using diameter 13 mm.

oxygen supply resulting in the incomplete combustion of pellet material. At higher air flow, further oxidation of CO to CO_2 occurs resulting in lesser CO emission.

CONCLUSIONS

The dimensions of pellet significantly affected the reaction time. Decreasing surface area per mass would increase the reaction time as in the case of 13 mm pellet diameter. No significant influence of the temperature in the combustion chamber with diameters of pellets. The highest CO emission occurred at air flow rate of 0.1 m s^{-1}. This was due to the low air flow rate caused the low oxygen supply. Also at higher air flow rate, further oxidation of CO to CO_2 occurs resulting in lesser CO emission.

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