Emission Factor of Single Pellet Cake Seed Jatropha Curcas in a Fix Bed Reactor

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The objective of this study is to evaluate the emission factor of oil cake seed Jatropha curcas that was formed into pellets with three parameters: pyrolisis, densification and air flow rate. The effect of pyrolisis was investigated using four samples of pellet: non-pyrolysis pellet, 90 minutes pyrolysis pellet, 120 minutes pyrolysis pellet, 150 minutes pyrolysis pellet. The effect of densification was provided by three samples: 11 mm, 13 mm, and 16 mm diameter. Furthermore, the parameter of air flow rate was varied from 0.1 m/s to 0.4 m/s. The results show that the lowest emission factor occurs in the non-pyrolysis pellet containing 14.3 gram carbon monoxide per kilogram pellet. Meanwhile the best densification was obtained by 13-mm diameter pellet containing 14.8 gram carbon monoxide. Air flow rate of 2.0 m/s was the suitable air flow rate to achieve lowest emission factor.

Keywords: *emission factor, pellet, pyrolysis, Jatropha curcas waste, solid fuels, combustion*

Introduction

In the last decades, the development of Jatropha curcas plants has been increasing in trend significantly. Several countries like Asia and Africa as well as South America and Indonesia (Hambali, 2007), Thailand (Kritana et al., 2010), India (Shah et al., 2005), and Nicaragua (Foidl et al., 1996) develop biodiesel from its seed. Studies on a conversion of the plants into biodiesel have been conducted by researchers (Openshaw, 2000; Shah et al., 2005; Giibitz et al., 1999; Banerji et al., 1985; K. Pramanik, 2003). Jatropha curcas waste, such as cake seed, sludge and shell have greatly potential to be converted into a solid fuel (Kumar et al., 2003; Kumar and Namasivayam, 2009; Vyas and Singh, 2007; and Sricharoenchaikul et al.) Lopex et al. (1997) converted its material into biogas through anaerobic digester process (Lopex et al., 1997).

As reported by authors (Openshaw et al., 2000; Banerji et al., 1985), the content of cake seeds of Jatropha curcas achieved 61% to 67% per unit weight. Meanwhile the content of Jatropha curcas oil (JCO) was around 33 to 39%. This means that there is a high possibility to extract Jatropha curcas waste to energy both from shell and cake seed.

Combustion is a chemical process to convert solid waste into heat energy. The process includes drying, devolatilization, and char combustion (Borman and Ragland, 1998). In the devolatilization process, CO emission rises to the peak level and gradually decreases until char combustion reactions stop. The products of biomass combustion consists of carbon dioxide (CO_2), water, ash, sulfur oxide (SO_2), carbon monoxide (CO), unburned hydrocarbon particles, nitrogen oxide (NO_2), smoke and soot (Ndiema CKW et al., 1998). This paper reports the CO emitted from single pellet combustion in a locally fix bed reactor. The parameters analyzed in these experiments are dimension, pyrolysis and air flow rate. The carbon monoxide released in combustion process is the objective of this research. The best pellet material relating with CO released is the lowest emission factor.

Material and Method

In this experiment, cake seed Jatropha curcas waste was used. It was collected from a local bio-diesel factory. The cake seed sample used was in heterogeneous shapes and sizes. This waste still contained residual oil because not all oils can be released by mechanic pressure machine system in factory. The residual oil trapped inside of cake seeds caused agglutination and it caused randomized particles. The residual oil inside of this cake seed also influenced the heating value.

This study has three variables: pyrolysis, densification and air flow rate. The effect of pyrolysis was categorized into different holding times. This means that the samples entered into the pyrolysis reactor and were held within for a few minutes. The samples were divided into four: non-pyrolysis, 90 minutes pyrolysis (90 minutes holding time), 120 minutes pyrolysis, 150 minutes pyrolysis pellet. The effect of densification was divided into three pellets: 11 mm, 13 mm, and 16 mm diameter. The effect of airflow rate has provided four air flow rates: 0.1 m/s, 0.2 m/s, 0.3 m/s, and 0.4 m/s.

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Pyrolysis

Pyrolysis is a chemical decomposition process with heat energy in absence of oxygen (O_2). The temperature of pyrolysis is around 300- 800°C and releases substances such as carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), hydrogen (H_2) steam (H_2O), and carbon (C). The objective of the pyrolysis process is to increase the ignition property, reduce smoke, and increase the heating value (Vest, 2003).

Figure 1. Pyrolisis reactor.

In this experiment, Temperature of pyrolysis was maintained at 400^{o}C. The holding time then has varied between 90 and 150 minutes to observe the emission effect.

Heating Value and Proximate Analyses

For determining the moisture, volatile matters, and fixed carbon content, the ASTM method was applied in proximate analysis as shown in Table 1. Furthermore, heating value analysis is conducted using a bomb calorimeter with ASTM 2015 method.

Tabel 1 provides a proximate analysis and heating value of cake seed Jatropha curcas with parameter of pyrolysis. It can be observed that increasing a holding time in pyrolysis process increases the content of fixed carbon. It also will decrease the percentage of volatile matter. The logic explanation of this reason is because the long of holding time releases more volatile matter while short of holding time releases uncomplete volatile in particles. The most important aspect of this phenomena is how the holding time generates a better heating value. It can be summarized that increasing the holding time increases the heating value.

Densification

Figure 2 provides the difference of three physical characteristic of densified pellet. A local press machine is used to densify this process. The pressure applied to this process is 750 kg/cm^2. Pellet is made from a mixture of cake seed Jatropha curcas and a small quantity of binder. The weight of raw materials used was 1.5 g with variation diameters of pellet: 11, 13 and 16 mm. The result of pellet is shown in Fig. 2, as well as the variation of pellet lengths: 15, 8, 6.5 mm.

Figure 2. Pellets diameter.

Table 1. The result of proximate and heating value analyses.

Proximate analysis of cake seed				
Analysis	Non-Pyrolysis	Pyrolisis-90	Pyrolisis-120	Pyrolisis-150
Moisture (%)	17.79	10.68	7.99	9.28
Volatile (%)	50.21	44.95	44.09	40.52
Ash (%)	4.55	7.25	6.70	7.70
Fixed carbon (%)	27.45	37.13	41.23	42.50
Heating value				
HHV (cal/gram)	4,055	4,901	5,040	5,342

Emission Factor

An emission factor is used to measure the emissions' substance which is released by material activity. Table 2 provides the emission factors of carbon monoxide (CO), which is released during the combustion process from biomass feedstock.

The emission factors presented above use varying feedstock and stove. The lowest emission factor is achieved by cow dung cake using two-put mud stove while the highest emission factors is achieved by charcoal fuels using angethi stove up to 280 g/kg.

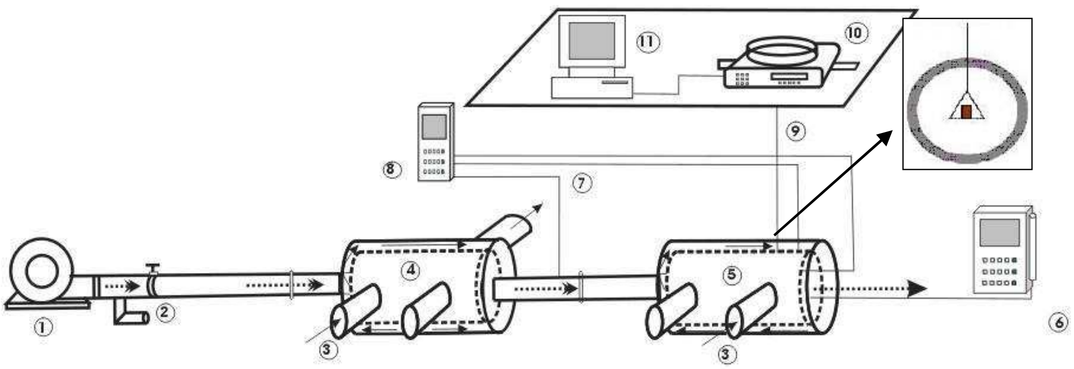
Combustion Apparatus

The schematic of the combustion apparatus is shown in Fig. 3, which consists 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 mass balance (10) to analyze the mass reduction from a single pellet. Pellet cup is connected to the mass balance and controls the mass of pellet for each second. Then, the data is stored to the computer automatically. Digital thermocouples (7, 8) measure gas temperature while the gas analyzer (6) measures CO emission. The Weighing unit used for this research is AND from A&D while gas analyzer used Dwyer series 1207. The unit quickly measures and calculates CO emission with high accuracy (±20 ppm < 400 ppm, ±5% > 400 ppm).

Initially, the combustion chamber (5) is heated by gas fuel in gas heater chamber (3). Air flow is regulated using the controller valves (2). The digital thermocouple reader provides the temperature information from combustion chamber. Inside of its combustion chamber, pellet cup is prepared which is connected to electronic mass balance (10). After the steady temperature achieved, pellet enters into combustion chamber. It is located in a cup. The combustion process is started and the mass of pellet reduces. This information appears in computer (7).

Table 2. Emission factor from biomass combustion (Zhang et al., 1999).

Fuel type	Fuel	Stove	E (g/Kg)		Fuel type	Fuel	Stove	E (g/Kg)
Dung	Cow dung cake	Hara	61		Wood	Brush wood	Brick	110
cake	Cow dung cake	Traditional mud	49			Brush wood	Improved brick	170
	Cow dung cake	Two-put mud	30			Brush wood	Metal	160
	Cow dung cake	Two-put ceramic	31			Fuel wood	Brick	42
Crop	Wheat straw	Brick	62			Fuel wood	Improved brick	99
residue	Wheat straw	Improved brick	170			Fuel wood	Metal	74
	Maize stalk	Brick	36			Eucalyptus	Three-rock	49
	Maize stalk	Improved brick	79			Eucalyptus	Metal	54
	Mustard stalk	Traditional mud	66			Eucalyptus	Two-pot mud	89
	Mustard stalk	Metal	56			Eucalyptus	Two-pot ceramic	63
	Mustard stalk	Two-pot mud	94			Acacia	Three-rock	50
	Mustard stalk	Two-pot ceramic	55			Acacia	Traditional mud	48
	Paddy straw	Traditional mud	48			Acacia	Metal	50
	Paddy straw	Two-pot mud	100			Acacia	Two-pot mud	75
	Root fuel	Traditional mud	45			Acacia	Two-pot ceramic	45
	Root fuel	Metal	67					
Root	Root fuel	Two-pot mud	55			Char briquette	Angethi	120
fuel						Charcoal	Angethi	280



1. Air blower
2. Controller valve
3. Gas heater
4. Preheater chamber
5. Combustion chamber
6. Gas analyser
7. Thermocouple
8. Digital termocouple reader
9. Computer
10. Mass balance

Figure 3. Combustion equipment scheme.

Result and Discussion

Effect of Pyrolisis

The emission factor is found by integrating the CO emission along a combustion period. From Fig. 4 it can be seen that increasing the holding time increases the emission factor. Therefore, non-pyrolysis pellet releases lowest emission factor. In this stage, non-pyrolysis pellet shows the best solid fuel. To clarify this result emission facto vs. diameter pellet is shown in Fig. 6.

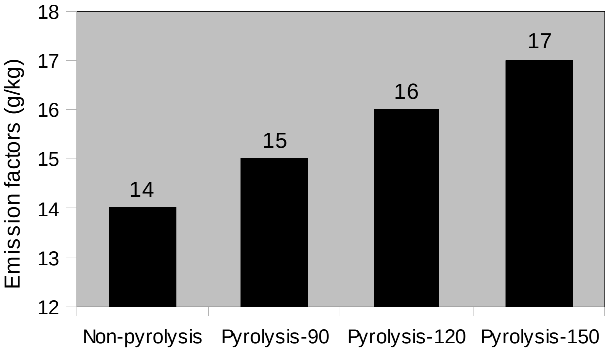


Figure 4. Emission factor vs. pyrolysis.

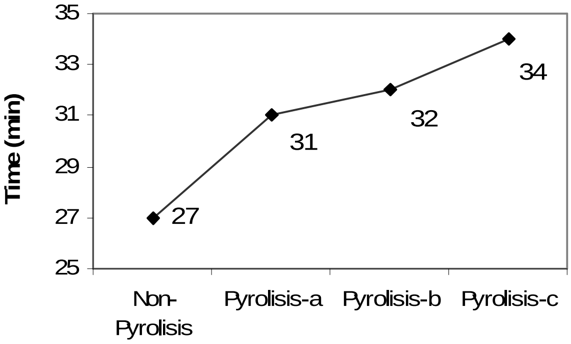


Figure 5. Effect pyrolysis on burning time of pellets.

It is quite complicated that pyrolysis makes high emission for solid fuel. However, it can be understand that the high emission is caused by burning time. Furthermore, this parameter is influenced by the fixed carbon content. The experiments showed that the fixed carbon contents were 27.45, 37.13, 41.23, 42.50% for non-pyrolysis, pyrolysis 90, pyrolysis 120 and pyrolysis, respectively. It can be concluded that increasing the burning time increases the emission, because during the combustion process the material releases its emission.

Effect of Densification

Figure 6 shows the influence of pellet diameter on released emission. In this experiment, air flow used is 0.3 m/s. The combustion chamber was determined at 400°C. It can be observed that pellet with diameter of 11 mm showed the lowest emission. Meanwhile highest emission is obtained by pellet with diameter of 13 mm. This phenomena is caused by surface area parameter which is explained by Fig. 7.

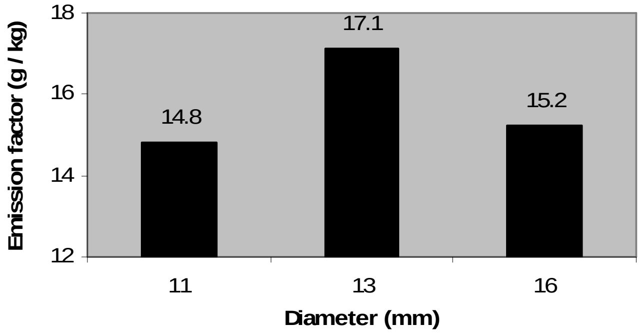


Figure 6. Emission factor vs. diameter pellets.

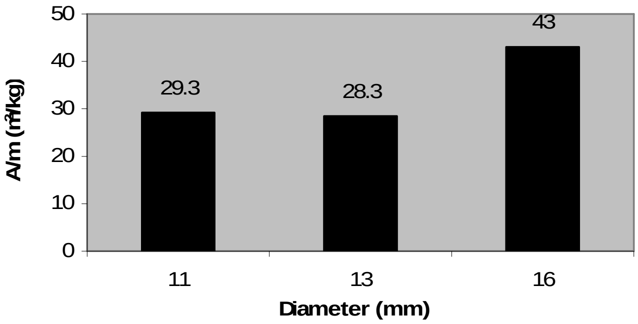


Figure 7. Surface area of pellets.

The surface area per mass (A/m) of pellets determined the emission factor. As we have seen above, a pellet with diameter of 13 mm results the lowest surface area per mass. This is related to the length of combustion process which caused high emission.

Effect of Air Flow Rate

Figure 8 shows the influence of air flow rate on emission factor. In this experiment, the air flow rates varied from 0.1 m/s to 0.4 m/s. Meanwhile the pellet diameter is determined as 13 mm. It is used non-pyrolysis sample. Temperature of combustion chamber is set at 400°C.

The Air flow rate 0.2 m/s has lowest emission at 4.7 g/kg. Meanwhile the highest emission released occurs at 0.4 m/s air flow rate. Air flow rate is related with supply of oxygen. At air flow rate 0.2 m/s, oxygen supply forms a complete combustion. The air flow rates higher than that influence the increasing of emission. It is because the oxygen is unable to react well with fixed carbon (C) and it causes incomplete combustion process which releases more carbon monoxide (CO). This occurrence can be related to the residence time and thrust of air flow rate. The residence time of carbon monoxide (CO) is too short. It causes incomplete combustion. The other causes are the thrust of air flow rate pushing of carbon monoxide (CO) to exit the chamber before it react with oxygen (O_2) to form carbon dioxide (CO_2). Therefore, it only conducts the partial combustion.

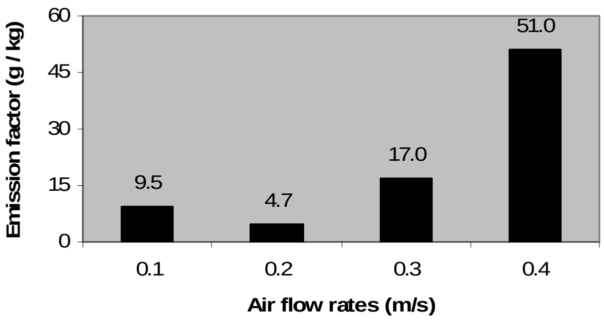


Figure 8. Emission factor vs air flow rates.

Conclusion

Based on experimental results, it can be generally found that cake seed Jatropha curcas is a material waste with potential to develop as solid fuel. This potential must be related to the environment effect. Emission factor is used to measure carbon monoxide (CO) which is released by solid fuel combustion. The results show that the best emission factor from varying the pyrolysis is cake seed non-pyrolysis. It releases 14.3 gram carbon monoxide in a kilogram fuel. In densification effect, the lowest emission factor is achieved by pellet with diameter of 13 mm.

The Air flow rate 0.2 m/s has the lowest emission at 4.7 g/kg. At this rate, oxygen supply forms more complete combustion than other rates. It has been indicated that the residence time and the thrust of air flow rates cause this emission.

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