Solid Fuel Pellets from Pig manure

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Abstract

This research aims to prepare biomass and char pellet from pig manure for using as solid fuels. The powdered raw material was compressed by rotary screw to get two size of 0.8 cm diameter biomass pellet with 1 cm length and 2 cm length, by using starch as binder. The biomass pellets had bulk densities of 0.64 g/cm^3 for small size and 0.59 g/ cm^3 for large size, which lower than the original material (0.98 g/ cm^3). Then the samples were pyrolyzed in fixed-bed reactor at temperature 300–500°C for 1 hr. The results showed that biomass pellet of both size had higher heating value (13,029 and 13,279 kJ/kg) than original raw material (12,495 kJ/kg). Increasing of pyrolysis temperature decreased char yield from 62.7 wt% to 46.9 wt% for small size and 58.3 wt% to 42.6 wt% for large size. The bulk densities of char were lower than the sample without pyrolyzed, i.e. 0.41 – 0.44 g/ cm^3 for small size and 0.38 – 0.39 g/ cm^3 for large size. The heating value of char (15,129 – 17,562 kJ/kg) also had higher value than the sample which no pyrolyzed. Therefore, pig manure can be used as alternative solid fuel with high heating.

Keywords : solid fuel, pellet, pyrolysis, heating value, pig manure

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Introduction

Due to the limitation, non-renewable and high cost of conventional fuel such as petroleum or natural gas, the alternative energy from biomass which availability, renewable, and low cost will be future alternative source. Biomass is organic material derived from agricultural by-products, wood waste, forest or animal waste. The densification by compression of biomass will increase its heating value and easy to control when using as solid fuel because it has the same size. There are two form of solid fuel after compress: pellet (less than 30 millimeters) and briquette (more than 30 millimeters).

The process to convert biomass into higher energy divides into three methods: chemical, bio-chemical and thermal processes. The thermal process also consists of three methods: pyrolysis, gasification and liquidfaction. Pyrolysis is thermal decomposition of material in the absence of oxygen by using middle range of temperature (300 – 800°C). The products from pyrolysis are solid or char, liquid or bio-oil and gas or bio-gas. This research aims to study solid fuel from pig manure by compress into pellet form. Then pyrolyze the obtained pellet to higher heating value solid fuel or char.

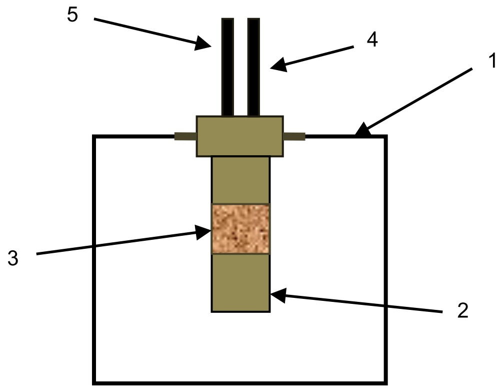
Materials and Methods

2.1 Material and pelletization

Pig manure was received from Faculty of Agricultural, Khon Kaen University. First, the sample was air dried for three days to remove moisture. Then the dried sample was ground and sieved to particle size of 200 micrometers. The sample was compressed in rotary screw (Figure 1 (a)) at 900 rpm by using starch as binder with the ratio of 40 wt%. The compressed sample had cylindrical form with diameter of 0.8 cm and then cut the sample into two lengths: 1 cm and 2 cm.

2.2 Pyrolysis

The biomass pellets about 50 g were pyrolyzed in fixed-bed reactor which heated by high temperature furnace at heating rate of 30°C/min under N_2 flow of 200 cm^3/min. The studied pyrolysis temperatures were 300, 400 and 500°C for 1 hr. The solid product or char was collected and weighted. The exhaust gas was condensed by water at room temperature. The condensable product was collected and weighted, then designed as liquid product. The non-condensable product was purged and labeled as gas product. The amount of gas product was determined by subtract the mass before pyrolysis (50 g) with solid and liquid products. Figure 1 (b) shows experimental set-up for pyrolysis of biomass pellet.



(a) (b)

Figure 1 (a) rotary screw for compress of biomass and (b) experimental set-up for pyrolysis with 1: high temperature furnace, 2: fixed-bed reactor, 3: biomass pellet,4: N_2 gas into the reactor and 5: gas that exits the reactor to condense with water.

2.3 Characterization

The thermal decomposition and proximate analysis (fixed carbon, volatile matter, ash and moisture) of samples were analyzed by Thermogravimetric analyzer (TGA). The sample was heated from room temperature to 700°C at heating rate of 10°C/min under N_2 flow of 100 cm^3/min and then switch to O_2.

The heating value of samples determined by using bomb calorimeter (Gallenkamp Autobomb). The true density of the pellet determined by measured the length (L) and diameter ($2r$) and weighted the sample (m). Then the true density calculated from equation $m/\pi r^2 L$. The bulk density determined by filling the samples in the box with the size of 10 ×10 ×10 cm^3 (V = 1,000 cm^3) before weighting the sample (m_T). The bulk density equal to m_T/V.

Results and Discussion

Results of this studied divided into four parts: (1) properties of pig manure (2) properties of pig manure pellet (3) effect of pyrolysis temperature on product yield and (4) properties of char pellet from pyrolysis.

3.1 Properties of pig manure

The analysis of properties of pig manure consist of thermal decomposition, proximate analysis, heating value and bulk density. Figure 3 shows the thermal decomposition of pig manure. It was found that the weight of sample small decrease at temperature around 100–120°C. This indicated the moisture content of the sample. The large weight decreasing of the sample started at 200°C until 500°C which occurred the devolatilization. Therefore, the optimum temperature for pyrolysis should be done in the range of 200 – 500°C. This thermal decomposition curve can be further indicate the proximate analysis of the sample i.e. fixed carbon content, volatile matter content, ash content and moisture content.

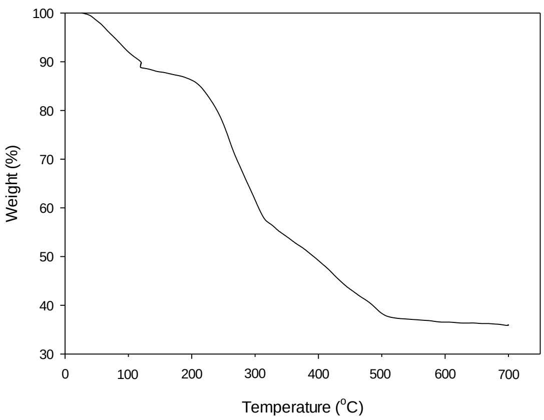


Figure 2 Thermal decomposition of pig manure.

Table 1 shows proximate analysis, heating value and bulk density of pig manure used in this study compare with other biomass. It has been seen that pig manure had fixed carbon (14.3 wt%) higher than eucalyptus bark (9.6 wt%) and corncob (13.7 wt%) and insignificant lower than palm fiber (14.4 wt%) and rice straw (16.0 wt%). The heating value of 12,495 kJ/kg of pig manure also higher than eucalyptus bark (6,811 kJ/kg) and corncob (11,298 kJ/kg) and a bit lower than palm fiber (13,127 kJ/kg) and rice straw (13,450 kJ/kg). This indicate that pig manure suitable for using as solid fuel.

Table 1 Properties of pig manure compare to other biomass

Sample	Proximate analysis (wt%)				Heating value (kJ/kg)	Bulk density (g/cm^3)	Ref.
	Fixed carbon	Volatile matter	Ash	Moisture			
Pig manure	14.3	54.1	20.8	10.8	12,495	0.98	this study
Eucalyptus bark	9.6	28.0	2.4	60.0	6,811	–	Almeida et al., 2010
Corncob	13.7	45.4	0.9	40.0	11,298	–	
Palm fiber	14.4	42.7	4.4	38.5	13,127	–	
Rice straw	16.0	57.0	21.0	6.0	13,450	–	Park J et al., 2014

3.2 Properties of pig manure pellet

Table 2 demonstrates heating value, true density and bulk density for both size of pig manure pellet compare with other biomass pellet. It can be seen that pig manure pellets from both size had higher heating value (13,029 and 13,279 kJ/kg) than original pig manure before compressed (12,495 kJ/kg, Table 1). The pig manure pellets obtained in this study also had heating value insignificant lower than rice straw pellet (13,970 kJ/kg).

The large pellet had higher true density (0.96 g/cm^3) than small pellet (1.28 g/cm^3). For bulk density, the pellets had lower value (0.64 and 0.59 g/cm^3) than original sample (0.98 g/cm^3, Table 1). This was due to the powdered sample can be fully filled in the test box while obstruction can occurred between the samples in the case of pellet form. Therefore, the amount of sample in pellet form that can be filled in the box test then less than powdered form.

Table 2 Properties of pig manure pellet compare with other biomass pellet

Sample	Heating value (kJ/kg)	True density (g/cm^3)	Bulk density (g/cm^3)	Ref.
Pellet size 0.8 cm×1 cm	13,029	0.96	0.64	this study
Pellet size 0.8 cm×2 cm	13,279	1.28	0.59	this study
Rice straw pellet	13,970	–	–	Tirinthong et al., 2013

3.3 Effect of pyrolysis temperature on product yield

Figure 3 shows the product yield at various pyrolysis temperatures for pyrolysis time of 1 hr. It was found that the amount of char decreased with increasing pyrolysis temperature for both pellet size. This was due to the second decomposition of char to liquid product (as can be seen that the liquid product decrease with increasing pyrolysis temperature). The aim of this study require solid fuel, therefore, the temperature of 300°C which gave highest amount of char was optimum temperature for pyrolysis

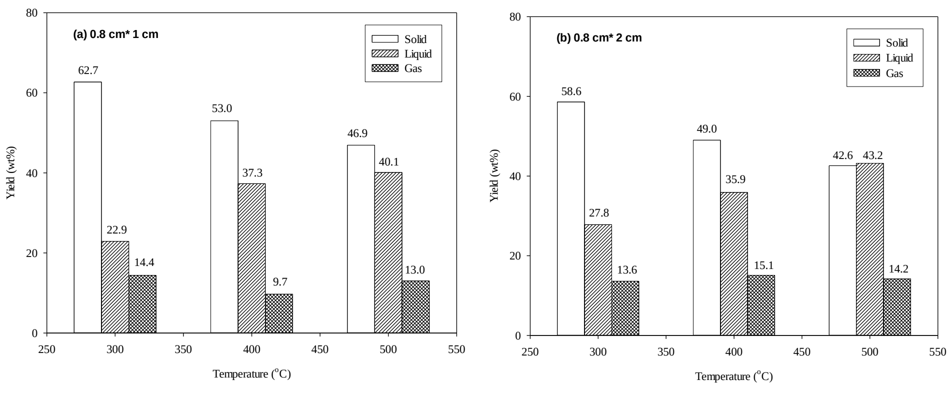


Figure 3 Product yield of pyrolysis process at various temperatures for 1 hr (a) pellet size 0.8 cm×1 cm and (b) pellet size 0.8 cm×2 cm.

3.4 Properties of char pellet from pyrolysis

Table 3 shows the properties that is heating value, true density and bulk density of char from both size of pellets. It was clearly showed that char had higher heating value (15,129 – 17,562 kJ/kg) than the sample with no pyrolyzed (13,029 and 13,279 kJ/kg, Table 2). The true density of char slightly decreased from the sample with no pyrolyzed. This due to the contraction of sample between pyrolysis process. The bulk density of char also decreased from the sample with no pyrolyzed. Because we can fill the char in the box test with equal amount of the sample with no pyrolyzed (the true density of both samples insignificant different) but the weight of char lightly than the sample with no pyrolyzed, therefore the bulk density of char pellet less than the biomass pellet with no pyrolyzed.

After pyrolysis, the sample (char) had higher fixed carbon (49.7 wt%) than the sample with no pyrolyzed (16.1 wt%) as shown in Table 4. Therefore, the char had higher heating value than the sample with no pyrolyzed. It was noted that the content of fixed carbon, volatile matter, ash and moisture of compressed samples did not different from the original sample (Table 1). Table 4 also shows that biomass and char pellet from pig manure obtained in this study had heating value higher than lignite coal, char from palm leaf rib and char from rice straw.

Table 3 Properties of char pellets at various pyrolysis temperatures for pyrolysis time of 1 hr

Temperature (^{o}C)	Pellet size 0.8 cm×1 cm			Pellet size 0.8 cm×2 cm		
	Heating value (kJ/kg)	True density (g/cm^3)	Bulk density (g/cm^3)	Heating value (kJ/kg)	True density (g/cm^3)	Bulk density (g/cm^3)
300	16,044	0.98	0.42	16,433	0.98	0.38
400	17,123	0.88	0.41	17,562	0.77	0.39
500	15,332	0.86	0.43	15,129	0.82	0.39

Conclusion

Results in this study show that pig manure can be used as alternative energy with high heating value of 12,495 kJ/kg. The compression of sample into pellet form can increase heating value 4.3 – 6.3% (13,029 – 13,279 kJ/kg) from the original sample. The pyrolysis process also increase the heating value of obtained char pellets (15,129 –17,562 kJ/kg) about 14.0 – 24.4% from biomass pellets and about 21.1 – 40.6% from the original sample.

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Table 4 Proximate analysis and heating value of biomass and char pellets (size 0.8 cm×1 cm) from pig manure compare with other solid fuel

Sample	Proximate analysis (wt%)				Heating value (kJ/kg)	Ref.
	Fixed carbon	Volatile matter	Ash	Moisture		
Pig manure pellet	16.1	52.4	21.0	10.5	13,029	this study
Pig manure char pellet (300°C)	49.7	22.8	25.4	2.1	16,044	this study
Rice straw char	–	–	–	–	16,500	Park et al., (2014)
Palm leaf rib char	–	–	–	–	11,640	Abnisa et al., (2014)
Lignite coal	–	–	–	–	10,468	Wikipedia (2015)

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