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Binderless solid fuel pellets from waste of pulp and paper industry

Jalouphone Xayyasene[1], Vilasuk Thongsiya[1], Thipphaphone Phengmeangkhune[1], Andrew J. Hunt[2] and Yuvarat Ngernyen[3*]

[1] Department of Chemical Engineering, Faculty of Engineering, National University of Laos, Vientiane, Lao PDR

[2] Materials Chemistry Research Center, Department of Chemistry and Center of Excellence for Innovation in Chemistry, Faculty of Science, Khon Kaen University, Khon Kaen, 40002, Thailand

[3] Biomass&Bioenergy Research Laboratory, Department of Chemical Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen, 40002, Thailand

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Abstract

This research studied the preparation of solid fuel pellets from wood dust waste of the pulp and paper industry. Pelletization by a hydraulic press at 20 to 50 bar was utilized to produce fuel pellets with diameter of 1 or 1.5 cm and height of 1.25 cm. The properties of fuel pellet including calorific value (heating value), pellet density, bulk density, moisture and ash content were characterized. These results demonstrated that the minimum pressure required to produce binderless pellets with a 1 cm diameter was 30 bar and this increased to 40 bar for pellets of a 1.5 cm diameter. The heating value of the resulting fuel pellets was between 15,401–16,388 kJ/kg, which is significantly higher than the unpelletized raw material (14,986 kJ/kg). Density of the fuel pellets was between 0.51–0.69 g/cm^3 and the bulk density was 0.30–0.40 g/cm^3. Densification of raw material through pelletization increased the bulk density of sample, thus reducing transportation and storage costs. In addition, the uniform size and shape made pelleted fuels easier to handle and reduced hazards associated with dust. Such processes are ideal for creating new opportunities for the development of solid fuels from paper wastes and could provide an opportunity for power generation within the pulping mill.

Keywords :Wood: Biorefinery: Saw dust: Fuel: Bio-based: Bulk density

*contact: nyuvarat@kku.ac.th, 081-2889649

1. Introduction

Pulp and paper production is a major industry in Thailand. The manufacture process generates several types of solid wastes including wood bark, wood saw dust, fly ash, lime mud and effluent sludge. Wood bark and dust can be used as solid fuel in boilers. However, use of these materials in their unprocessed form can cause inconsistent rates of heating and due to the non-regular shape and low bulk density of the dust make, it difficult to efficiently transport this by-product. Therefore, the densification of raw material into a pellet form (size less than 30 mm) may resolve these issues, and also increase the calorific value of the fuel. The densification of material included pelleting and briquetting can be achieved with and without binder. The most commonly binders include molasses, starch and lignin. Pellets are a popular densified fuel product and offer a number of potential advantages over the raw unprocessed feedstock [1]. Agricultural and forest wastes such as oil palm solid wastes [2], wheat straw [3, 4], sorghum stalk [4], corn stover [4], big bluestem [4], Norway spruce [3], European beech [3] and wood sawdust [1] have been compressed into pellets in order to develop solid fuels with improved properties.

Therefore, this work aims to compress the wood dust from the pulp and paper industry in Thailand to produce a solid pelletized fuel without use of a binding agent, thereby reducing cost for the process. The physical, chemical and thermal properties of pellets are characterized and compare with standards. The effect of pelletizing pressure on the calorific value of pellets was to determine. Thus enabling the selection of optimum pressure required to prepare pellets with the highest heating value. The production of higher energy density pellets would reduce transportation and storage costs, in addition the standardized size of pellets enables automatic feeding into boiler, which are key goals of this research. The use of biomass energy not only reduces the consumption of coal but also may increase the value of the pulp and paper manufacturing process.

2. Experimental

2.1 Preparation of raw material

Wood dust (Figure 1) was received from chipper step of Pulp and Paper Company in Khon Kaen.

Figure 1 Wood dust from pulp and paper industry.

Firstly, the material was sun dried until the weight constant (approximately 3 h), then hammer milled and sieved to powder form with mesh no. 20 or particle size of 850 μm.

2.2 Pelletization of raw material

The press blocks as shown in Figure 2 with diameter of 1 and 1.5 cm, height of 1.25 cm were filled with the powdered dust sample. The block was then compressed using the hydraulic press (Figure 3) at pressures of 20, 30, 40 or 50 bar. At high compressing pressure, the block was fill up with additional powdered sample to keep the length of sample constant at 1.25 cm. A total of 25 pellets were produced simultaneously for each set of conditions under investigation condition.

Figure 2 Block for palletization.

2.3 Characterization of solid fuel pellet

Pellet density was determined by measuring the diameter (D) and length (L) of pellet with a digital verneir, in combination with determining the mass of the pellet (m). Characterization was carried out on all 25 pellets to determine the average value. Pellet density was calculated following Equation (1)

$$\text{Pellet density} = \frac{m}{\frac{\pi}{4} D^2 L} \qquad (1)$$

It was noted that pellet density of each sample did not significantly differ and therefore the standard deviation for the fuel pellets was very low and thus is not reported in this article.

Figure 3 Hydraulic press.

Bulk density, which is an important parameter for transportation, as determined by fill the pellet into the box with size of 10×10×10 cm or the volume of 1,000 cm^3. All pellets in the box were weighted and the density was calculated from Equation (2)

$$\text{Bulk density} = \frac{\text{total mass of pellet}}{1{,}000 \text{ cm}^3} \qquad (2)$$

The bulk density of each pelletization condition was carried out three times to determine the average value.

Heating value of raw material and solid fuel pellets were characterized by bomb calorimetry (GALLENKAMP). For each pelletization condition, 3 samples were selected from 25 pellets with a density that was close together. The reported heating value in this article is average value.

Finally, moisture and ash content of pellets were determined following the standard method, EN14774-1:2009 Solid biofuels-Methods for determination of moisture content – Oven dry and EN14775-1:2009 Solid biofuels-Methods for determination of ash content, respectively. A typical procedure for the determination of moisture content is as follows: Place the sample in the crucible and heat at 105 °C for 24 h in a Memmert Incubator Oven, INB200. The sample was removed from the oven and allowed to cool in a desiccator. The moisture content as determined from the difference in sample weight before and after heating. Ash content was determined by placing the sample in crucible (capacity 30 ml) and then heating in a muffle furnace at 550 °C for 1 h. The ash content calculated by dividing the mass of the remaining sample after heating by original weight. Both moisture and ash content were conducted three times to determine the average value.

3. Results and discussion

3.1 Properties of raw material

Properties of powdered wood dust are presented in Table 1. The heating value of wood dust is 14,986 kJ/kg. The moisture and ash contents of raw material are 12.98 wt% and 7.46 wt%, respectively. When compare with other biomass that have been used as raw material for production of fuel pellets, wood dust had calorific values that were higher than rice straw and rice husk, but lower than camphor wood and rubber wood [5]. The moisture content of wood dust is consistent with other biomasses. Wood dust also had lower ash content compared to straw and rice husk. Ash is an inorganic component that remains as a residue after combustion of organic matter, therefore having lower ash content is preferable for a solid fuel, as it can reduce waste and slag formation in the boiler. Heating values of biomass pellets were also affected by the ash content. The higher ashes content of the raw material, the lower calorific value, because ash does not generate energy.

3.2 Effect of compressing pressure on the physical appearance of solid fuel pellets

Figure 4 shows that at low pressures of compression, no pellets could be produced from wood dust without binder. This is true for 1 cm diameter at 20 bar and 1.5 cm diameter at 20 and 30 bar. The properties of fuel pellets were characterized only for stable pellet.

Table 1 Properties of wood dust compared with other researches

Sample	Heating value (kJ/kg)	Moisture (wt%)	Ash (wt%)
Wood dust	14,986	12.98	7.46
Rice straw [5]	13,184	11.98	17.42
Rice husk [5]	13,435	7.78	21.84
Camphor wood [5]	16,786	10.85	4.29
Rubber wood [5]	16,807	15.52	1.21

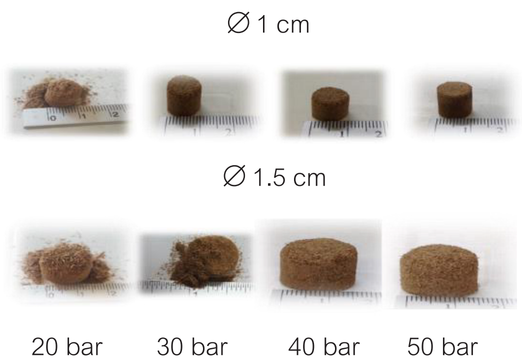

Figure 4 Physical appearance of fuel pellet at different compressing pressure.

3.3 Properties of solid fuel pellets

As expected, calorific value (or heating value) of fuel pellets increase after densification as shown in Table 2. The heating value increased from 14,986 kJ/kg to 15,401–16,388 kJ/kg on pelletization of the dust. At the same diameter of pellet, the increasing of compression pressure resulted in samples with marginally elevated heating values. Therefore, the using of low pressure for pelletization of wood dust is suitable due to lower energy of compression [1]. The moisture and ash content did not change after pelletizing.

The density of a wood pellet increases with increasing pressure at the same diameter. This was due to increased packing of sample and greater mass when using high pressure to maintain a consistent length of pellet. Constant volume and greater mass leads to an increase in density.

The pelletization increased the bulk density from 220 kg/m^3 to 300–420 kg/m^3. This was in agreement with the work of Theerarattananoon et al. [4]. It has been found that the bulk density decreases when the pellet diameter increases. Thus meaning, that pellets of smaller diameter can be stored in larger mass than those of larger diameter in the same volume.

At the same diameter, the compressing pressure did not significantly affect the bulk density because all pressures utilized the same pellet size.

Table 3 compares properties of prepared solid fuel pellets with standard of solid biofuel-biomass pellet according to Thai Industrial Standards (TIS). The diameter and length of prepared wood pellets are in the range of standard values. However, bulk density is lower than that of the standard. The moisture content is higher than standard, while ash content is lower than standard. The heating value of wood pellet is also higher than the standard values.

Table 4 demonstrates the properties of solid fuel pellets produced in this study compared to the results of previously published studies. It was found that all properties including heating value, moisture and ash content, pellet and bulk density of wood pellets prepared in this work are in good agreement with fuel pellets produced from oil palm [2], sorghum stalk [4], corn stover [4], wheat straw [4], big bluestem [4], scots pine [6], cedar wood and camphor wood [7].

Table 2 Properties of fuel pellets

Sample	Heating value (kJ/kg)	Moisture (wt%)	Ash (wt%)	Pellet density (g/cm^3)	Bulk density (kg/m^3)
Wood dust	14,986	12.98	7.46	–	220
∅ 1 cm					
30 bar	15,401	12.10	8.97	0.54	360
40 bar	15,612	12.19	8.43	0.58	380
50 bar	15,986	12.48	8.77	0.69	400
∅ 1.5 cm					
40 bar	15,934	12.77	8.74	0.51	300
50 bar	16,388	12.83	8.97	0.59	330

Table 3 Properties of fuel pellets prepared from this study compare with standard of Thailand

Property	Wood dust pellet	Standard	
		Normal grade	High Quality grade
Diameter (cm)	1 and 1.5	0.6–1.2	
Length (cm)	1.25	0.315–4.0	
Bulk density (kg/m^3)	300–400	> 600	
Moisture (wt%)	12.10–12.83	< 10	
Ash (wt%)	8.43–8.97	< 20	< 10
Heating value (kJ/kg)	15,401–16,388	> 14,600	> 16,700

Table 4 Properties of fuel pellets prepared from this study compare with other researches

Sample	Heating value (kJ/kg)	Moisture (wt%)	Ash (wt%)	Pellet density (g/cm^3)	Bulk density (kg/m^3)
Wood dust					
	15,401 – 16,388	12.10–12.83	8.43–8.97	0.51–0.69	300–400
Oil palm: empty fruit bunch, frond, shell, mesocarp [2]					
	12,954 – 19,765	1.5–5.8	4.15–18.03	–	460–970
Sorghum stalk, Corn stover, Wheat straw, Big bluestem [4]					
	–	–	–	0.436–0.852	360–500
Scots pine [6]					
	18,370	–	0.7	–	–
Cedar wood, Camphor wood [7]					
	18,860 – 19,570	–	0.89–1.07	–	–

4. Conclusion

The present study has evaluated the impact of pelletizing pressure on the physical, chemical and thermal properties of fuel pellet production from wood dust. The pelleting process resulted in an increase in heating value from 14,986 kJ/kg to 15,401–16,388 and bulk density from 220 g/cm^3 to 300–400 kg/m^3. The properties of pellets including diameter, length, bulk density, moisture and ash contents and heating value are consistent with standard values for solid fuel pellets based on the Thai Industrial Standards (TIS). Future investigations will focus on the scale-up of the pelletization systems to assess the benefits of the proposed schemes on a commercial scale.

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