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Research Article

The physical properties of sawdust briquette and the thermal performance of biomass briquette stove

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Abstract - The purpose of this research was to study the use of a biomass briquette stove instead of a Liquid Petroleum Gas (LPG) cooking stove. In this research, the biomass briquettes were made from sawdust with waste paper as a binder, and their physical properties were tested. Then, the biomass briquette stove was constructed and tested for its thermal efficiency. From the experiments, it was found that the thermal efficiency of the biomass briquette stove was 31.3 %. Furthermore, the biomass briquette stove and LPG cooking stove were compared for a cost analysis. From the comparison, the fuel cost per energy output of the sawdust briquette was significantly lower than that of LPG. This showed that the stove was a good alternative to save energy and money.

Keywords: Biomass, briquette, sawdust, stove

1. Introduction

A biomass briquette is a kind of solid fuel that is made from many organic materials, depending upon the kinds of plants in the area, such as the fiber and the shells of palm nuts in Malaysia (Husian *et al*., 2002), banana stems and coffee husks in Nepal (Pandey *et al*, 2013), and rice husk and sawdust in Thailand (Chaiklangmuang *et al*., 2008), etc. In this research, sawdust was chosen as the biomass material because there is a lot of sawdust residue from furniture mills in Thailand. It was produced by cutting, sawing, and sanding. The kinds of wood mainly used in Thailand are Teak, Redwood, and Selangan batu. The lower heating value (LHV) of sawdust was found to be 19.5 MJ/kg (Miskam, *et al*., 2009) which was relatively high compared with 13.6 and 14.9 MJ/kg for rice straw and banana leaves (Saikia *et al*., 2013), respectively. This showed that sawdust was a good alternative as an energy resource. Therefore, this research was conducted to study the wet briquetting of sawdust combined with waste paper as a binder. The physical properties of the sawdust briquettes, including moisture content, density, and shatter index, were tested and reported. Moreover, a biomass briquette stove was constructed and investigated to determine its thermal efficiency and the cost of fuel.

2. Methodology

2.1 Raw material preparation and briquetting process

The sawdust was collected from a furniture mill in Nakhon Pathom Province, Thailand. It was mixed with water and waste paper as a binder in the ratios of 5, 10, and 15% by weight as shown in Figure 1. The sawdust was densified in to briquettes with an outer diameter of 11.43 cm and an inner diameter of 3.81 cm under a pressure of 3 MPa by a hydraulic press were collected and sealed to protect against moisture.

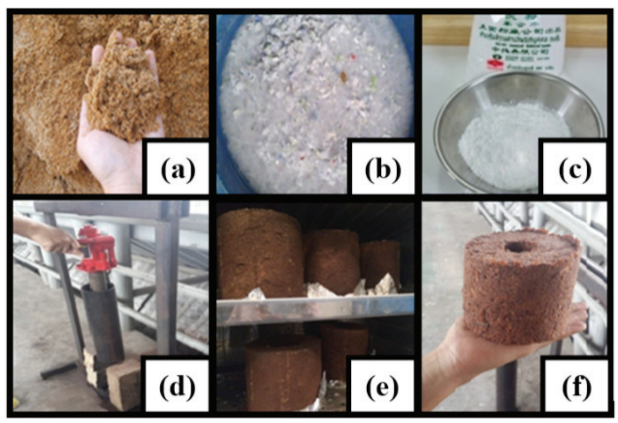

Figure 1. Raw material preparation and briquetting process.

2.2 Physical properties of briquette testing

The physical properties of briquettes, which included moisture content, density and shatter index, were tested as in the following.

2.2.1 Moisture content of briquettes. The moisture content of the briquettes was determined using ASTM D3173. The empty crucible was heated at a temperature of 105 °C for 30 min. Then, the crucible was cooled in a desiccator for 15 min. After that, a 1 g sample was put into the crucible and heated at 105 °C for 20 min. The moisture

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content of the sample could be calculated as follows:

$$M,\% = \frac{W_1 - W_2}{W_1} \times 100. \quad (1)$$

Where, M was the moisture content, W_1 was the weight of the sample used (1 g), and W_2 was the weight of the sample after heating (g).

2.2.2 Density of briquettes. The density of the briquettes was determined by the ratio of the mass to volume of dried briquettes. It could be calculated by:

$$\rho = \frac{m}{\pi h (r_o^2 - r_i^2)}. \quad (2)$$

Where, m was the mass of the briquette after heating (kg) and h, r_o, and r_i were the height, outer radius, and inner radius of the briquette, respectively (m).

2.2.3 Shatter index of briquettes. The ASTM D3038 method was used to determine the shatter index. In a drop shatter test, briquettes were dropped three times from a height of 1.8 m on to a concrete floor. The pieces of the briquettes were screened, and the pieces bigger than 20 mm were weighed. The shatter index could be calculated as follows:

$$R,\% = W_f / W_i \times 100. \quad (3)$$

Where, R was the shatter index, W_f was the final weight of the briquette pieces bigger than 20 mm (kg), and W_i was the initial weight of the briquette before dropping (kg).

2.3 Biomass briquette stove and Water Boiling Test (WBT) procedure

A rocket stove (Bryden *et al*., 2005) was constructed and tested as shown. The stove was made from a round steel pipe with a diameter of 11.43 cm. The height of the stove was 45 cm and the length of the pipe for inserting the biomass briquette was 20 cm. The Water Boiling Test version 3.0 (Bailis *et al*., 2007) was used to determine the thermal efficiency of stove, which could be calculated by:

$$\eta,\% = \frac{c_w m_w (T_{eb} - T_{env}) + m_{ev} h_w}{m_f LHV_f} \times 100. \quad (4)$$

Where η was the thermal efficiency of the stove, c_w was the specific heat of water (4.19 kJ/kgK), m_w was the mass of the water (1 kg), $T_{eb} - T_{env}$ was the temperature difference between the boiling temperature and the initial temperature of the water (°C), m_{ev} was the mass of evaporated water (kg), h_w was the specific enthalpy of vaporization (2,257 kJ/kg), m_f was the mass of fuel (1 kg), and LHV_f was the lower heating value of the fuel (19.5 MJ/kg).

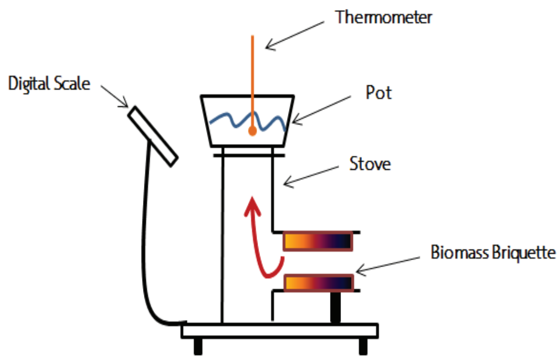

Figure 2. Biomass briquette stove and Water Boiling Test.

2.4 Cost saving analysis

A cost saving analysis of the biomass briquette stove was analyzed by a comparison with when using an LPG cooking stove. The percentage of the cost saving was determined by:

$$CS,\% = \frac{C_{LPG} - C_{BB}}{C_{LPG}} \times 100. \quad (5)$$

Where, CS was the percentage of the cost saving and C_{LPG} and C_{BB} were the fuel costs of the LPG and the biomass briquette per energy output (Baht/MJ), respectively, which could be calculated by:

$$C_{LPG} = \frac{P_{LPG}}{\eta_{LPG} LHV_{LPG}}, \text{ and} \quad (6)$$

$$C_{BB} = \frac{P_{BB}}{\eta_{BB} LHV_{BB}}. \quad (7)$$

Where, P_{LPG} and P_{BB} were the prices per mass unit of the LPG and the biomass briquette (Baht/kg), η_{LPG} and η_{BB} were the thermal efficiencies of the LPG and the biomass briquette stoves, and LHV_{LPG} and LHV_{BB} were the lower heating values of the LPG and the biomass (MJ/kg), respectively.

3. Result and discussion

3.1 Physical properties of sawdust briquettes

3.1.1 Moisture content of sawdust briquettes. Figure 3 shows the moisture content of the sawdust briquettes. Paper was used as the binder with ratios of 5, 10, and 15% by weight. From the testing, it was found that the ratios of paper did not have an effect on the moisture content of the sawdust briquettes. The average moisture content was 3.4 %. However, it should be note that this value was the moisture content of the sawdust briquettes after the drying process in the oven. Therefore, if briquettes were not sealed, the moisture content may be higher than this value.

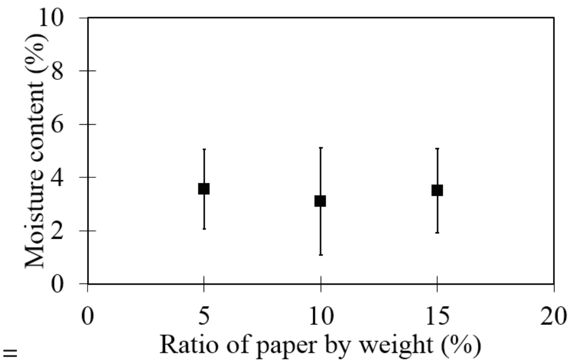

Figure 3. Moisture content of sawdust briquettes.

3.1.2 Density of sawdust briquettes. The density of the briquette is an important parameter. The higher the density of the briquette, the more energy that can be stored or transported for the same density of the sawdust briquettes after drying. From the testing, it was found that the ratios of paper had no effect on the density of the sawdust briquettes. The average value of the density was 337 kg/m^3.

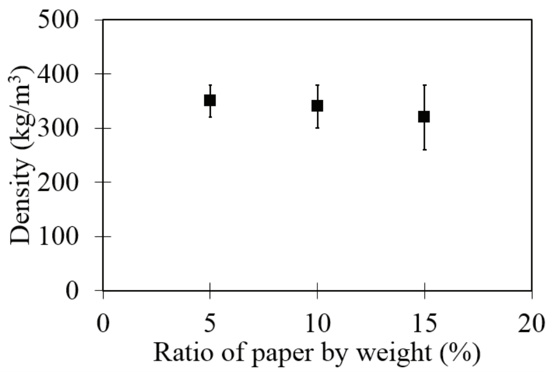

Figure 4. Density of sawdust briquettes.

3.1.3 Shatter index of sawdust briquettes. The durability of the briquettes was determined by using the shattered index. The three combinations of briquettes from sawdust with paper are shown can be seen that the sawdust briquettes with 10% and 15% paper had shatter indexes of 73% and 76%, respectively, while the briquette with 5% paper had a shatter index of 27%. This showed that the optimum ratio of paper as a binder was 10%, because it has good durability and low cost.

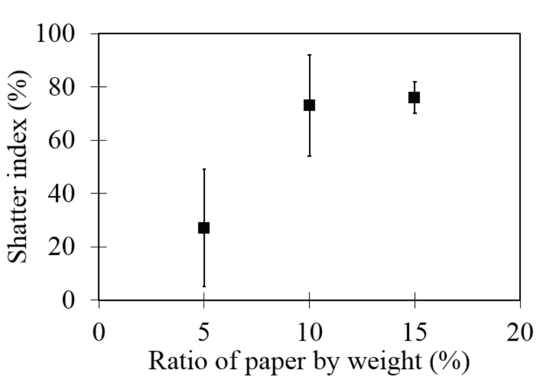

Figure 5. Shatter index of sawdust briquettes.

3.2 Thermal performance of biomass briquette stove

The thermal efficiency of the biomass briquette stove was investigated using the WBT method. The sawdust briquettes with 10% paper were used as the fuel. From the experiment, it was found that the average value of the thermal efficiency of the biomass stove was 31.3%, which was slightly higher than the thermal efficiency of an LPG cooking stove (Jenjit *et al*., 2009).

3.3 Analysis of cost saving

From the cost saving analysis, the fuel costs per energy output of the sawdust briquette and the LPG were compared using equations 5-7. The comparison results are shown in Table 2. It was found that although the LHV of the sawdust briquette was lower than that of the LPG by about two times, the percentage cost saving of using the sawdust briquette instead of the LPG was as high as 79%. This was because of the more expensive price of LPG, and it is expected that LPG price may be increased in the future. Therefore, the biomass fuel should be used for energy cost savings.

Table 2. Comparison data.

Parameters	Biomass briquette stove	LPG cooking stove
Thermal efficiency	31.3%	29.0%
LHV of fuel	19.5 MJ/kg	46.6 MJ/kg
Price of fuel	1.75 Baht/kg	19 Baht/kg
Cost of fuel per energy output	0.29 Baht/MJ	1.40 Baht/MJ

4. Conclusion

In this research, the physical properties of a sawdust briquette with paper as a binder were tested and reported. The optimum ratio of paper was 10 % by weight, which had a moisture content of 3.4 %, density of 337 kg/m^3, and shatter index of 73%. An experiment was conducted to test the thermal performance of a biomass briquette stove and to analyze the fuel cost. It was found that the cost of the sawdust briquette per energy output was only 0.29 Baht/MJ, while that of LPG was 1.40 Baht/MJ. This shows that the saw dust briquette is a good alternative for energy cost savings.

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