Briquette production from rice husk by using screw compaction

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Abstract. Most of the agricultural residues have low density resulting in increasing the cost of storage and transportation. With the reduced volume by the compacting process, density and other properties are increased while the storage and transportation space and cost can be reduced. The effects of screw characteristics on the briquette qualities were measured. The process condition for producing fuel briquettes with screw extruders can be used as renewable energy in the industry. Rice husk was collected and its moisture content was reduced around 8-12%. A screw used as feeding and compacting with a length of 45 centimeters and 19 degrees of screw tip angle. The mold temperatures were around 300-400 degrees Celsius. Three lengths of the screw were tested. While the briquette properties were analyzed, such as density durability, an expansion length, heating value, and moisture content of fuel briquettes after the compression process. The experimental results showed that the suitable compression condition for agricultural materials was in the range of 45.9 cm screw length and mold temperature in the range of 330-360 degrees Celsius. The briquettes had a durability of 98.67%, a density of 0.846 g/cm³, expansion ratio of 1.1853 %, the heat value of 3813 cal / g, moisture content after compression of 1.9% w.b. and capacity of 112.8 kg/hr. Increasing the screw length improved the performance of compression, continuous working, and briquette fuel quality. Reducing the screw length required a higher mold temperature, leading to the failure of continuous working, defective machines due to extra burden and deteriorating quality of fuel briquettes.

Keywords: Compression, Biomass fuel, Agricultural residue

1. Introduction

Thailand has fertile areas and most of population are farmers. As rice is the main staple of Thai food, rice has been grown a lot for domestic consumption and exportation. Moreover Thailand is in the world’s top ranking for rice exportation. After harvesting, paddy rice is delivered to a mill to be transformed to be milled rice. During the transformation process, there is a residue of paddy rice called rice husk which is waste product. The accumulation of rice husk causes air pollution, contamination and other problem issues. The solution is to turn waste to be renewable energy which can be used as fuel for household cooking, as well as this helps reduce global warming caused by the use of fuel oil or LPG as well [1-3].
The process of increasing in density can help reduce the transportation cost, management and storage as this process shape the packaging smaller, resulting in being compactable and convenient to use [4]. There are basically 3 methods to increase density, namely, High and medium pressure compaction with a heating device and low pressure compaction with a binder [5]. For a popular process for increasing in density in developed countries is screw extrusion process by heating at the end of the extruder. This extruder is friendly users as it is not complicated and is easy to use [6], and high efficiency which can produce briquette up to 200 kg/hr [7]. There are many approaches applied to improve the quality of briquette such as mixing a different ratio of biomass or adding carbon powder to all ratio of mixers[8, 9]. The density of the sample depends on the temperature and humidity of the test material. The higher the temperature, the higher the density of the compressed fuel [10]. The study of biomass components has ability for studying the chemical composition of biomass with adhesion ability after heating with the concentration at various levels that affect the quality of the briquette [11]. The study of the biomass size quality of briquette showed that mixing biomass in different sizes can help decrease the energy for compression and help increase the density of briquette as well [12]. The shape of screw, compression die and friction coefficient for material affecting the suitable pressure for compressing briquette can help the machine work effectively [13-15]. Density can be increased by increasing the pressure while the density decreases with increasing the physical size and moisture [16].

From the article that has been studied from the above research, there has not been any study on screw wear testing. This research aims to study the compression process of briquette by testing the deterioration of screw with control the temperature at the mold and then properties tests were applied to the products, namely, durability, density, expansion, heat value, and moisture content used in order to select the suitable screw for biomass briquette process.

2. Materials and methods

2.1. Materials
In this study, the rice husk from the mill in Chiang Mai was used as material for testing and then its moisture content was reduced to be 8-10 %w.b.[5].

2.2. Briquette preparation
The briquette producing machine is screw extruder type, Main components of machine are an electric motor with a capacity of 25 horsepower, 380 volt electric power, 970 revolutions per minute, and three 380 volt electric heating coils. In the experiment, screws with 3 different lengths were used to emulate the deterioration. The temperature during testing was about 300-330, 330-360 and 360-390 °C

2.3. Analysis of physicochemical properties
Density of briquette was calculated by the weight ratio per volume of briquette. The briquette compressed density was measured immediately from the die while relaxed density was measured after 30, 60, 1440, and 10,080 min[17]. Weight of briquette was recorded by digital scales. The diameter and height values could be measured by using a Vernier caliper. Percentage of expansion (%) was calculated using the equation below [18].

\[
\text{%expansion} = \left(\frac{l_f - l_i}{l_i}\right) \times 100
\]

when \(l_f\) = final radius of briquette
\(l_i\) = initial radius of briquette

Durability test according to LVS EN 14774-2: 2010 with a tumbler test at a speed of 21 ± 0.1 rpm for 5 minutes was done. The briquette left on the sieve was calculated for durability by the third equation [19]. The heating value (HV) was measured by a Bomb calorimeter Leco AC (500following the ASTM D240. Moisture content was measured following the ASTM D 3173 – 73
3. Results and discussion

3.1. Effect of screw length
From the experiment on deterioration of screws after use with 3 recording lengths including 45.3, 45.6, and 45.9 cm with die temperature ranges of 300-330, 330-360, and 360-390 °C, using the rice husk as the testing material, it was found that increasing the length of screws helps the machine have a tendency to work better as the change of length caused the different compression power [13] which can be seen from the capacity production from figure 1. And the machine could work continuously with low load. At the same time, decreasing the reduction length of the screw made it have higher load because of increased friction. Inserting the screw with 45.3 cm length. Resulted that the machine could only work at 360-390 °C with an increase in compression difficulty.

![Figure 1. Compression of Briquette production](image)

3.2 Effect of die temperature
Heating the die one by one could help soften the binder within the material and helped briquettes solidify better [20]. In which water is an important aid when water-soluble compounds are present in the feed such as starch, sugar, soda ash, sodium phosphate, potassium salt, and calcium chloride [21]. Increasing the temperature in the die could help decrease the friction while compressing. However, overheating could make the compression pressure deficient. The effect of temperature towards density from figure 2. Illustrated that the density of briquettes would be higher when lowering the temperature. At 300-330 °C, briquettes could have highest density.

![Figure 2. Density of briquette](image)
3.3 Durability
Durability of briquettes was between 91.14% - 98.97% as shown in figure 3. When experimenting on the screw with the same length, as the temperature in die was lowered, durability of briquettes tended to be higher. For deterioration test of the screw by changing the screw length to 45.3, 45.6, and 45.9 cm, respectively, it was found that the difference in the length of the screw at the same temperature caused the difference in density. With the temperature at 360-390 °C, using 45.3, 45.6 and 45.9 cm screws resulted in the densities of 97.65%, 96.14%, and 91.14% respectively. For the highest durability at 98.97%, it could be done by using 45.9 cm screw at the temperature of 300-330 °C.

![Durability of briquette](image)

3.4 Density & Expansion ratio
From the experiment of screw deterioration by shortening the length of the screw, it was found that the resulted densities of briquettes were different. With the 45.3 cm screw, the briquettes could not be compressed when the temperature within the die was lower than 360 °C because the screw with this length will cause the machine to receive very high load and friction. The immediate highest density after the compression was 856.87 kg/m³ using 45.6 cm screw at 300-360 °C and the highest density after measuring every 30, 60, 1,440, and 10,080 minutes was 880.14 kg/m³ using 45.9 cm screw at 300-330 °C for 60 minutes as shown in figure 4. For the expansion ratio by collecting briquette samples at normal environment at temperature, it was found that expansion ratio was unstable because the moisture in the air affected the expansion ratio of briquettes with the range ratio from -2.25% to 1.34%, as seen in figure 5.

3.5 Heat value and moisture
Testing the heat using bomb calorimeter (Leco AC500) according to ASTM D240 standards and test the moisture using hot air oven according to ASTM D 3173-73 standards where the rice husks before the compression have heat and moisture value at 3,440 cal/g and 8.7% w.b. respectively. After that, find the heat and moisture value of the briquettes after compressed using 45.9 cm screw at 300-330 °C and found that heat and moisture value of the briquettes are at 3,813 cal/g and 1.9% w.b. after the compression.
Figure 4. Density of briquette at (a) 300-300 °C, (b) 360-330°C, and (c) 390-360 °C

Figure 5. Briquette expansion ratio axis
4. Conclusion
Screw is the part of the compression machine that will be deteriorated after use. From the experiment on the length of the screw to emulate the deterioration. Even if the screw was deteriorated, the machine is still usable. But will have an impact on the compression process and the wear of machinery parts. However, production capacity will be reduced and the experimental results show the usable temperature was limited as the die required higher temperature, because when the screw was deteriorated, it requires more heat to be able to begin the compression process. The compression wasting more energy and time required for heating. Moreover, other parts of the machine may worn out because the machine receive higher load from deteriorated screw such as the conveyer belt and motor and the resulting briquette did not have any difference in attribute. The other factors such as size and moisture of the material also affects the compression of briquettes as well as their attributes as well. These factors should be studied further.

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