Optimization of Refuse Derived Fuel (RDF) of solid waste in palm starch home industry through the variations of binder materials

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Abstract. A lot of energy consumption and the abundance of waste stimulate various alternative energy from biomass. One of the biomasses that has not been widely used is palm starch waste. Palm's starch home industry in Indonesia produced solid waste that could be converted to synthesis gas through the gasification process. Production of palm starch increases in 2019, gives rise to accumulation waste, causes various diseases, and damages the environment, requiring specific handling. This study investigated the effect of binder material of RDF on palm starch waste. The variations of binder materials used tapioca, rice flour, and mangosteen peel. RDF of palm starch waste with variations of mangosteen peel binder produces the highest calorific value than starch and rice flour, 4009.62 cal/gr. However, RDF with tapioca flour binder has the highest volatile content, so that it can ignite and burn better than rice flour and mangosteen peel binder.

1. Introduction
The noodle home industry in Bendo Village, Klaten City, Jawa Tengah Province, Indonesia, produces an average of 50 tons/day of waste. The processing waste consists of liquid and solid waste from the filtering process of tree trunks. The waste causes odor, groundwater pollution, and aesthetics to the environment. Thus, this waste requires a handler not to disturb the environment and noodles' production process. On the other hand, the home industry waste can be processed into biomass as renewable energy. Several studies related to the processing of waste into energy have been carried out, such as [1][2][3][4][5].

The utilization of biomass into energy can be optimized by converting it into Refuse Derived Fuel (RDF). RDF is an alternative fuel produced from various kinds of waste. RDF has advantages in storage and transportation, high calorific value, and low pollution [6]. One of the factors that affect the quality of RDF is binder material. The addition of binder material to the manufacture of RDF is an important factor [7]. RDF's type of binder material affects the density and pressure resistance, calorific value, ash content, and moisture content. Good binder material has a high binding power so that the RDF will not be easily destroyed during the shipping and storage process. Also, a suitable binder material affects the combustion process's biomass to increase its effectiveness in combustion.
In previous research conducted by [3], the binder material composition used to manufacture RDF palm starch waste was using tapioca flour. These studies indicate that the best ratio composition between palm starch waste and binder (tapioca flour) is 7: 3. RDF, with this comparison, can produce a heating value of 3733.04 cal/ gr. In this study, the focus is on the development of RDF with several variations of binder material types such as tapioca flour, rice flour, and mangosteen peel. The goal is to obtain the type of binder material suitable for RDF palm starch waste.

2. Research Method
The method used in this research is the experimental method. The activities carried out in this study included preparing variations in the composition of palm starch waste (Fig. 1) and tapioca flour (Fig. 2a) of rice flour (Fig. 2b) and mangosteen peel (Fig. 3b). This variation of binder material is the independent variable in this study. The mangosteen peel adhesive is pre-treated by smoothing it using a smoothing machine. This study used a 7: 3 ratio of palm waste and binder material. The RDF made using a press machine with a pressure of 0.5 MPa. Primary data obtained directly from measurements during testing in the laboratory. Measurements were made to obtain data such as heating value, ash content, moisture content, volatile content, and carbon content.

Figure 1. Palm starch waste

![Figure 1. Palm starch waste](image1)

![Figure 2. Variation of palm waste RDF binder](image2)

3. Result and Discussion
RDF was made using a press machine with a pressure of 0.5 MPa. Then RDF is carried out by a drying process for five days to reduce the moisture content. The form of RDF made from palm starch waste can be seen in Figure 3. Visually the three RDFs have the same shape. To find out the difference, RDF is tested. RDF testing aims to determine RDF's calorific value and proximate content, namely the ash content, moisture content, volatile content, and fixed carbon content. The test tools used are the bomb calorimeter, furnace, and oven.
3.1 Effect of RDF binder on the drying process

Drying data were obtained by measuring RDF weight using a scale. Before weighing, RDF is dried in the sun for 4 hours/day, from 10 am – 2 pm. The measurement data can be seen in Figure 4. Figure 4 shows measuring the RDF weight from drying in the sun for five days in 4 hours each drying. Based on the measurement results, it can be analyzed that the efficiency of RDF drying is three days in 4 hours duration. After three days of heavy drying, RDF will be boarding. After the conditions are dry, RDF is carried out by the absorption test. The density test is carried out to determine the density level of the RDF. Measurements are made using the formula (1).

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Density = \frac{mass\ of\ biomass\ sample\ (gr)}{volume\ of\ biomasa\ (cm^3)} \quad \text{…….} \quad (1)
\]

Density is a significant physical property in designing logistics systems for biomass handling. Biomass, which has a high density, will make biomass not easily destroyed during the storage and shipping process. The results of RDF biomass density measurement can be seen in Fig. 5. Based on Fig. 5, comparing the RDF density value of palm starch waste with different binder material types can be analyzed. The measurement results show that RDF with tapioca flour binder has a density value of 0.1145 gr/cm\(^3\), RDF with rice flour binder has a density value of 0.1031 gr/cm\(^3\), and RDF with mangosteen peel binder has a density value of 0.0727 gr/cm\(^3\). Based on the measurement results, it can be analyzed that RDF with tapioca flour and rice flour binder has a higher density level than RDF with mangosteen peel adhesive. This results in RDF with mangosteen peel adhesive tends to have a physically brittle texture compared to RDF with other binders. The difference in density value is because each type of binder can bind different materials.
3.2 Effect of binder on the moisture content of RDF

Moisture content data were obtained by laboratory testing using standard ASTM D-3173 procedures. The moisture content affects the initial ignition of the flame. Moisture content analysis was needed to determine the water content in RDF. The moisture content will affect the calorific value of the fuel. The higher the moisture content, the lower the calorific value. Moisture content also affects the initial ignition during the combustion process. High moisture content will make the initial ignition process difficult during combustion. The following results of the analysis of moisture content are shown in Figure 6. The analysis of the effect of using binders on RDF of palm waste can affect the moisture content. The highest moisture content was found in RDF with tapioca flour binder (10.25%). RDF with mangosteen peel binder has a moisture content of 9.66%. Meanwhile, the lowest moisture content was found in RDF with rice flour binder (8.73%). Based on these data, it can be seen that RDF with tapioca flour binder has a higher moisture content than RDF with rice flour and mangosteen peel binder. The condition is because tapioca flour can bind water to be humid.

3.3 Effect of binder on the calorific value of RDF

The calorific value will be released when the fuel is burned. Its calorific value can determine the supreme quality of fuel. Calorific value measurements were carried out using a bomb calorimeter. The data of measurement results are shown in Figure 7. Figure 7 shows that the RDF of palm starch waste with variations of mangosteen peel binder produces the highest calorific value, 4009.62 cal/g. RDF of palm starch waste with rice flour binder produces a calorific value of 3853.70 cal/gr, while RDF with tapioca...
flour binder produces the lowest calorific value (3733.04 cal/gr). Based on the results, it can be analyzed that variations in the type of binder affect the RDF palm starch waste’s calorific value. The content of RDF's calorific value with the lowest variety of tapioca flour binder is because it can bind water, causing RDF to have the highest water content. The high-water content causes low calorific value.

3.4 Effect of binder on the volatile content of RDF

Volatile content was measured using standard procedures ASTM D-897-88. Volatile is used to determine the amount of volatile content of each RDF sample. The volatile content affects the burnability of the sample. If the volatile content is high, the fuel is easy to ignite. The results of the analysis of the volatile content are shown in Figure 8. The analysis results in Figure 8 show that the use of binders on RDF of palm starch waste affects the volatile content. The highest content was found in RDF with tapioca flour binder (64.51%). RDF with rice flour binder has a volatile content of 63.02%. In comparison, RDF with mangosteen peel binder contained the lowest volatile content (60.36%). These results can be concluded that RDF with tapioca flour binder has the highest volatile content to ignite and burn better than rice flour and mangosteen peel binder.

3.5 Effect of binder on ash content of RDF

Ash content was obtained by laboratory testing using standard ASTM D-830-87 procedures. The ash content is used to determine the amount of unburned content of each RDF sample. Thus, the ash content plays an essential role in determining the quality of the fuel. The results of the analysis of the ash content are shown in Figure 9. These results indicate that the use of a binder on RDF of palm waste affects the ash content. The highest ash content was found in RDF with mangosteen peel binder (4.99%). RDF with rice flour binder has an ash content of 4.19%. Meanwhile, RDF with tapioca flour binder has the lowest
ash content (4.00%). Therefore, it can be seen that RDF with mangosteen peel binders has a higher non-combustible substance content than RDF with binders of rice flour and tapioca flour.

3.6 Effect of binder on the carbon content of RDF

Carbon content data was obtained by reducing its impurity content, such as moisture content, volatile content, and ash content. The higher the carbon content of a fuel, the better the combustion process. The results of the analysis of carbon content are shown in Figure 10. The data in Figure 10 states that adhesive use in RDF palm waste can affect the carbon content. The highest carbon content is found in RDF with mangosteen peel binder (24.99%). RDF with rice flour binder has a bound carbon content of 24.07%.

In comparison, the lowest carbon content was found in RDF with tapioca flour binder (21.24%). Based on the data analysis, it can be seen that RDF with mangosteen peel binder has the highest bound carbon content. High carbon content will increase the calorific value of the fuel.

4. Conclusion

This study focuses on developing RDF of palm starch waste with several variations of binder types such as starch, rice flour, and mangosteen peel. Based on the results of the research and data analysis conducted, it can be concluded as follows:

a. The three types of binders used to make RDF of palm starch waste (rice flour, starch, and mangosteen peel) have similarities in the average drying time of 3 days in 4 hours.

b. RDF of palm starch waste with mangosteen peel binder produces the highest calorific value than tapioca flour and rice flour binder.

c. RDF of palm starch waste with tapioca flour binder produces the highest water content than binders from rice flour and mangosteen peel.

d. RDF of palm starch waste with binder variations of starch produces the highest volatile content than binders from rice flour and mangosteen peel.

e. RDF of palm starch waste with various mangosteen peel binders produces the highest ash content compared to binders from starch and rice flour.

f. RDF of palm starch waste with various mangosteen peel binders produces the highest carbon content compared to binders from starch, rice flour.

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