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Research Article

The Moisture Content of Sawdust Fuel Pellets at Different Drying Periods

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Abstract

The development of pellet fuel from biomass has a great opportunity because Indonesia is an agricultural country. Utilizing this biomass can increase economic value, minimize waste generated, and reduce emissions released into the environment. In this study, the pellet fuel was made from sawdust obtained from the Semarang wood sawmill industry. The raw materials are mixed with adhesive, water and then formed using a pellet machine. The high water content in the pellets that have just come out of the pelletizing (27%) process requires drying treatment. The aim of this work was to find out the effect of drying time on the moisture content of the pellet fuel to meet existing standards. The variation of drying time used is 10, 15 and 20 minutes at 100° C. The results showed that the moisture content of the pellet was 22% (10 min), 19% (15 min) and 17% (20 min). The water content in the pellets will decrease 4% on average along with the drying time. However, the water content was still slightly higher than the specified standard (8-13%). Based on model predictions, the necessary drying time is 30-35 min. Ash content obtained from this study is 0.7%. The drying time can affect the density of the resulting pellet product. Accordingly, further studies are needed to determine the drying optimum temperature.

Keywords: Pellet; biomass; fuel; moisture content; drying

1. Introduction

The use of conventional energy sources, such as oil, coal and natural gas, as energy sources for development, has led a number of economic, environmental, social and political effects worldwide (Harun et al., 2019). Indonesia's energy consumption continues to be dominated by fossil fuels, especially oil and coal. Moreover as domestic consumption, these fossil energy product are continuously exported (Sohni et al., 2018). The continued use of fossil fuels may lead to more energy crises (Liu et al., 2014). As a non-renewable resources, fossil energy scarcity would be encountered if it unwell manage. Additionally, if significant new energy sources are not discovered in the near future by 2046, Indonesia faces a lack of energy. The Indonesian Government should have a clear interest in using new and renewable energy, not only in reducing the use of fossil fuels, but also in realizing clean energy or environmental friendly energy. It is necessary to transition from fossil energy to alternative energy, one of which is the use of biodiesel, biomass, biopellets, biogas and biobriquettes (Wahyono et al., 2021). In addition, the world is reorienting policies and investments to generate clean energy based on renewable resources such as biomass (Pua et al., 2020).

The compiler component of biomass consists of Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), and Sulphur (S). Compound composition usually Carbon in 44-51%, Hydrogen about 5.5-6.7%, Oxygen in 41-50%, Nitrogen about 0.12-0.6%, and small amount of Sulphur in 0.2%. (Harun et al., 2019; Tamunaidu and Saka, 2011). The advantages from biomass as energy resources could be explained to reduce greenhouse effect due togas limitation production and small amount of carbon dioxide directly absorb by the plant so that it could reduce carbon dioxide accumulation in the atmosphere, water and soil protection, organic waste limitation, and air pollution reduction. However, because of the low-density value limits of biomass, high humidity content in the manufacturing plant, and non-comparable sizes and shapes, it is difficult to use biomass effectively. To overcome this, pellet fuels were used to increase the density of the biomass.

Fuel pellets are the most popular densified product for fuel proposes (Poddar et al., 2014). Pellets are solid fuels made from biomass, and they are converted to cylindrical densities smaller than briquettes, with lengths of about 6-25 mm and diameters of 10-12 mm. Pellets can be burned immediately, which reduces the effectiveness of burning pellets (Muhammad Yerizam et al., 2021). The usefulness of biomass compared to others is able to converse with heat, electricity and also transportation (Kusumaningrum and Munawar, 2014). Wood pellets are considered high-quality biomass materials used for many industrial and residential applications, including combustion and gasification (Chau et al., 2009, 2009; Erlich and Fransson, 2011; Song et al., 2012; Verma et al., 2012, 2011). Nevertheless, the pellets can produce high-calorie (heat) energy and are environmentally friendly, so they can be used in households and small to medium-sized industries, small and medium-sized power plants. The formed pellets can be used for various purposes, such as electricity generation, domestic and commercial heating, cooking, etc. Currently, pellet fuel is widely used as a large-scale boiler in retail and home heating applications (Anwar et al., 2018). In terms of renewable behavior, some industries also consider pellet fuel to be a replacement for coal.

The advantage of pellets is that they are environmentally friendly energy because they use organic waste in the production process and emit less than wood. Usually, pellets are composed of five basic categories of food waste, by-products, industrial waste, agricultural residues, wood and energy crops. Various uses of biomass were studied for pellet fuel production (Bilal et al., 2017; Demirbas, 2009; García et al., 2017; Gil et al., 2010; Ishii and Furuichi, 2014; Selvarajoo et al., 2021; Senneca, 2007; Serrano et al., 2011; Shen et al., 2009; Tauro et al., 2018).

The selection of pellets as fuel is always based on their quality. The quality of pellet fuel depends on the chemical composition of the material, such as water content, ash weight, and mineral composition (Chandrasekaran et al., 2012). Moisture content is an important factor that affects the strength and processing speed of the production of pellets. Furthermore, moisture content is one of the most important factors affecting the efficiency, stability and complete combustion of solid biofuels. High-calorie pellets contain low ash and moisture, and are mechanically durable (Proskurina et al., 2019). High moisture content in wood pellets can have a negative impact on the performance of pellets, reduce net energy output during combustion and produce significant pollutants in the atmosphere (Liu et al., 2014). Therefore, the purpose of this study was to investigate the best drying time to meet the quality parameters of the pellets (such as moisture content and ash content). Moreover, the analysis was carried out by qualitative observation of images from digital microscopes such as pellet density.

2. Material and Methods

The material used for these experiments was sawdust waste obtained from the wood sawmill industry in Semarang, Indonesia. Sawdust is a waste product collected after various processes of sanding, cutting, drilling or grinding wood using saws or other tools. The type of sawdust used in this study came from *Dipterocarpus* wood cutting residue. Additionally, the moisture content of the raw materials used for the manufacture of pellets was approximately 25%. To produce pelleted fuel, sawdust was mixed with 10% by weight of tapioca starch as a binder and 10% by weight of water.

In the commercial pelletization process, sawdust is forced through the dies by rollers to make the pellets of cylindrical shape. Due to the compression and friction between the particles and the wall, the sawdust temperature rises to 70–100°C, softening the lignin components and becoming a natural binding agent (Peng et al., 2015). Once exiting the pelletizer, pellets are cooled down, causing the pellets to harden and retain the shape (Nielsen et al., 2009). In general, the bulk density of biomass increased from 40– 200 kg m^{-3} to 600–800 kg m^{-3}, while the volumetric energy density of biomass increased by 4–10 times.

In this study, the pellets were manufactured using a rotating pelletizing machine (Figure 1). When the sawdust is placed in the pelleting tower, the sawdust lignin is heated to 120 to 130°C. These pellets are formed by pressing them through the pellet machine and the cutter cuts them to the right length. In order to increase the strength and longevity of the pellets, a binder may be needed during the pelletization process. Pellets that have just left the pelletizer chamber are at very high temperatures, so they must first be cooled to ambient temperature before they are packaged and stored in the next step. Thus, to reduce the temperature, natural cooling or cooling technology is needed.

Figure 1. Pellet manufacturing process

Moisture content was established using the standard CEN TS14774. After being cooled, the pellet samples were placed on trays to be dried in the oven. The oven capacity used is 53 L (Memmert UN 55, Germany). In the experiments, three variations were set for drying times, namely 10, 15, 20 minutes and 100°C. After drying, all samples were analyzed by moisture analyzers. (Shimadzu MOC63u, Japan). The water content was measured with 5 different samples replications. To determine the significance of the drying time effect, statistical analysis was performed with ANOVA using Microsoft Excel 2019, and significance level (α) alpha was set at 0.05.

Ash content was tested as pen CEN TS 14775. A mass of pellet was ground to under 1 mm size and placed in a crucible. The sample is heated from 0 to 250°C in 5°C per minute steps and kept at this temperature for 1h. It is then heated to 550°C at the same rate and allowed to stand at 550°C for 2 h. The final mass is recorded and the following used to calculate the as content percentage:

$$\text{Ash content (\%)} = ((m_1-m_2)/m_2) \times 100$$

Where m_1 is the initial mass (g) and m_2 is the final mass after combustion (g).

For observation with a digital microscope the sample was cross-sectioned. Then observations were made at various magnifications.

3. Result and Discussion

The moisture content is one of the most important factors that adversely affects the properties of pellets, such as the density of bulk and the mechanical durability of storage and transportation. The results of the analysis of pellets moisture content with changes in drying time are shown in the Table 1. According to the results of the measurement of five pellet samples, the highest moisture value of undry pellets was 29.94%, while the average moisture value was 27.61 %. The results obtained show that after the completion of the pelletization process, the water content of the pellet remains relatively high. This is because the raw material contains more than 20% moisture and is mixed with water before pellets are made. Compared to other kinds of sawdust, moisture content is usually around 20% (Pusparizkita et al., 2022).

Drying time certainly affects the moisture content of the pellet. The moisture content of the 10-minute drying process was about 22%. The highest moisture content of the samples in 10 minutes changed to 25.3%, while the lowest moisture content was 18.45%. For a longer drying time of 15 minutes, pellets produced an average moisture content of 19.37%. Furthermore, the drying time of the longest variation in the study resulted in a moisture content of 15–19% of the pellet. On average, the moisture content of the pellet has decreased to 17% for 20 minutes. During the long drying period, more water evaporated in the pellets (Fig. 2). As the p-value for drying time was less than our significance level (1.13E-6), this factor was statistically significant.

However, efforts to reduce water content are not optimal as water content remains above the specified standards. Stable pellets can be formed with a range of moistures between 8 and 12% (wb) depending on the biomass in question. Above these moistures, problems with mold formation and pellet degradation can occur. Over these moisture levels, problems such as mold formation and pellet degradation can occur (Nielsen et al., 2009). Another factor to consider is that the higher the moisture content, the lower the net calorific value (NCV) of the biofuel pellet presented for combustion.

Table 1. The moisture content of the sawdust pellet at various drying times

Sample	% Moisture content			
	Non drying	Drying 10 min	15 min	20 min
1	29.94	18.45	17.9	15.67
2	29.07	22.08	19.31	17.42
3	28.07	25.3	20.34	17.19
4	26.31	23.7	19.28	19.23
5	24.7	20.71	20	16.3

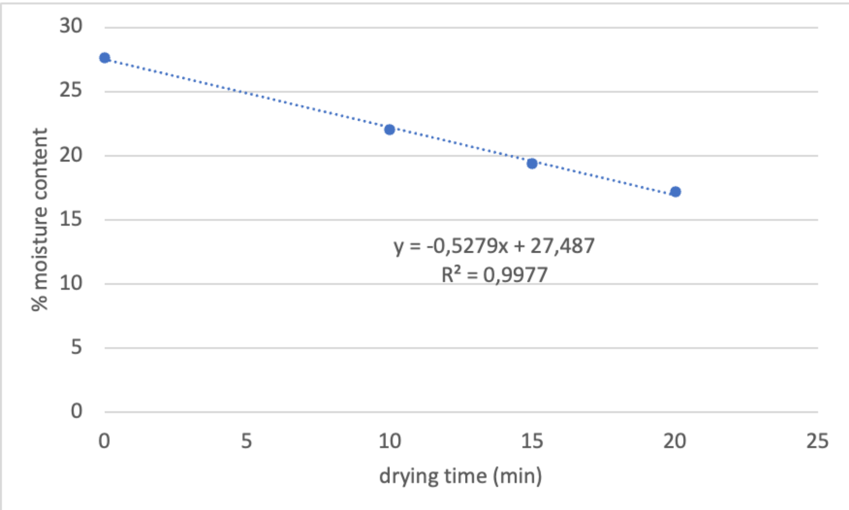

Figure 2. Tendencies of declining moisture content with drying time

In addition to determining the trend towards the effect of drying time on water content, according to Figure 2, the optimal drying time can be predicted to obtain water content as required by standards. One thing is certain, the necessary drying time will exceed 20 minutes. However, by using the simple model equation obtained (as seen on Fig. 2), the optimal drying time at 100°C is 30-35 minutes. The water content to be produced ranges from 10-12%.

The properties of the pellets vary depending on the material. According to Indonesian Standard SNI 8021 2014, the quality parameters of the pellets are: 12% moisture content, 1.5% ash content, 80% volatile matter, 14% fixed carbon, 400 Cal/g of caloric value and density is 0.8 g/cm^3. In general, the ideal moisture content after palletization appears to be 8–13 % (Sgarbossa et al., 2014). Other experimental studies have shown that the optimal humidity content for cellulosic material palletization is 8-12% (Liu and Wyman, 2005). The moisture content of pellets, such as weight density and mechanical durability during storage and transportation, are one of the most important factors affecting the properties of pellets.

Studies have found a positive correlation between the durability of the pellet and the optimal humidity (10%), since water and the temperature, pressure and chemical composition of the raw material act as binding agents to improve the quality of the pellet. They recommended that a good quality product needs to have a water content of 5 to 12 per cent (from the point of view of optimal density and long-term deposit properties).

Table 2. Moisture content and ash content comparation

		Wood	Willow	Mischantus	Wheat Straw	Barley Straw	Rape Straw
Moisture Content (%) (wb)	**Mean**	9.39	13.46	12.17	10.66	10.77	11.39
	Variance	0.061	0.1522	0.9927	0.0217	0.0021	0.0032
Ash Content (%)	**Mean**	0.31	2.22	3.56	6.49	4.05	5.83
	Variance	0.0001	0.0242	0.0323	0.0101	0.0049	0.5823

This study also compares the results of the water content obtained with previous studies (under the same drying conditions for 25 h). The comparison results are shown in Table 2. With a fairly short duration at the same temperature, the resulting pellet moisture content in this study could reach the same average (drying time at 100^{o}C for 30-35 minutes). Even though the water content of the raw materials used was higher than previous studies. All raw materials entered the pelleting process with <18% MC (Carroll and Finnan, 2012).

Ash content of herbaceous biomass tends to be significantly higher than that of wood. Knowledge of ash content is essential for choosing the correct combustion and ash cleaning technologies. For fuels with high ash content underfeed stokers are not suitable due to the risk of ash layer formation, which can lead to irregular air flow, causing incomplete combustion and increased emissions. For these types of fuels, grate, or fluidised bed combustion is more suitable. The results showed that the average ash content of the pellets from sawdust was 0.7%. With the ash content obtained, the pellet products in this study can be categorized as good quality pellets. Compared to the other ash content in table 2, the ash content of the pellets in this study was far below than willow, mischantus, wheat straw, barley straw and rape straw. The type and melting point of ash also has a large effect on combustion. However, this is not considered in this research. Higher ash content leads to higher fly ash emissions. Higher ash contents can be handled in most modern boilers with automated ash removal systems but it results in shorter periods between ash disposal operations (Carroll and Finnan, 2012).

Observations on the surface of the pellets can be seen in Figure 3. Variation of drying temperature in the final product has the potential to increase the density of the pellet product. This can be seen from the absence of cavities on the surface of the pellets. This plasticizes the lignin that binds to the particle of sawdust and facilitates the formation of the pellet. When lignin-rich biomass is compacted under high pressure and temperature, lignin becomes soft exhibiting thermosetting properties. The softened lignin acts as glue (Carroll and Finnan, 2012). A higher density is desirable, as the more compact the material, the less costs associated with storage and transport. Density is one of the crucial properties of a good quality pellet, as low density indicates the pellets easily break during transportation and utilization (Li et al., 2020; Peng et al., 2015).

Figure 3. Digital Microscope observation for pellet with drying time a. 10 minutes, b. 15 minutes and c. 20 minutes (5x magnification)

4. Conclusions

The three variations in the drying time of the pellets produce products with an average water content of approximately 17% to 29%. Pellets with the lowest water content were produced during the longest drying process. However, a large quantity of water-rich pellets does not meet the standards for solid fuel use. According to the model, the best drying time at 100°C is 30 to 35 minutes. Based on the analysis of ash content, the resulting pellet products are of good quality, namely 0.7%. The drying time can influence the density of the resulting pellet product. The longer the drying time, the more potential pellet products are denser. On a large scale, it is also necessary to consider the efficiency of long drying times from the point of view of energy demand. Therefore, for further research, the optimum temperature for pellets from sawdust still needs to be studied. Other alternatives are pre-treatment of raw materials to meet standards such as solid fuel requirements. Moreover, to find out the pellet quality further, some additional analysis needs to be done.

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