Effectiveness of die hole on wood pellet density quality improvement

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Abstract. The characteristics of wood pellets determine the quality of the formation process determines the characteristics produced. One of the process variables was the hole in the die. The aim of the study was to increase the density value of wood pellets by modifying the hole with a slope angle of 45°. The method of this study started from modifying the hole by making taper shapes on the hole of the surface, raw material preparation, mixing, printing, drying, and analysis stages. Whereas the variation in the administration of tapioca adhesive was carried out differently starting from 10%, 15% and 20% tapioca adhesive. The results showed that the modification of the die shape in this case the die hole from a straight shape to a tapered shape and enlarged at the end of the hole greatly influenced the characteristics of wood pellets, especially in the resulting density value. The characteristics of wood pellets produced in this study that water content ranged from 10.49% - 7.13%, the heating value ranged from 17077 - 17291 J/g and the density ranged from 0.82 g/cm³ - 0.86 g/cm³.

1. Introduction
The lower middle class community currently faced with problems of energy needs, especially among the community and households. So far, the energy used by the community comes from petroleum, gas, whose prices are increasing and sometimes hard to find, rare supplies at expensive prices. For this reason, it is necessary to use sawn powder to become wood pellets as fuel. Wood pellet is a form of biomass energy and was first produced in Sweden in 1980 made from raw wood powder which is a waste of wood industry [1]. In several countries such as Germany, Canada and Austria, wood waste wood has been used as boiler fuel in industrial and small and medium scale space heaters during the winter.

Wood pellets are compacted wood particles used as fuel [2]. Pellets are the result of compressing biomass which has a greater pressure than briquettes [3]. Wood pellets have been widely used in several regions in Indonesia, in some places wood pellets are increasingly popular with the high cost of primary energy sources and demands for climate change mitigation. The most important variables in wood pellet production are the types of biomass (species, moisture content, and sent biomass forms), plants and equipment prices, energy costs and labour structures. Wood pellet production is quite beneficial for producers and retailers/distributors, including small and medium scale production.
Bio pellet is one form of solid fuel based on industrial waste with a size smaller than briquettes. Bio pellets have better density and uniformity than bio brickets. Wood pellets produced from various biomass materials, such as sawdust waste from sawmills and veneer waste powders from plywood mills. There are several aspects that need to be considered as considerations in the use of biomass, namely in addition to aspects of the availability of biomass and the biomass supply chain are aspects of caloric value and the content of the biomass (water content, ash content, flying substances, chlorine elements). By knowing the content possessed by a particular biomass, it can be determined that the thermal conversion pathway (direct combustion, pyrolysis, gasification, or fermentation) is most suitable for this type of biomass [4]. The advantage of this bio pellet is it can increase the caloric value produced by the combustion process. In addition, the size and uniformity of bio pellets can also facilitate the process of transfer (transportation) from one place to another.

A binder is needed in making pellets because the presence of adhesives causes the material to be glued and pressed so that it can become pellet. The addition of adhesives also aims to increase the bond between particles, provide a uniform colour and also provide a fragrant smell. Tapioca is a material that is often used as an adhesive in the manufacture of wood pellets because it is easily available and the price is relatively cheap, but tapioca has the property of absorbing water from the air, high adhesive levels can also reduce the quality of wood pellets due to smoke. The type of adhesive and powder size did not significantly affect the water content, ash content, fly substance content and bound carbon as well as the interaction of these two factors, but had a very significant effect on the caloric value and interaction of the two factors [5].

Indra [6] has examined the percentage of adhesives to the characteristics of wood pellets from the remainder of sawn wood. The adhesive is used the tapioca with a percentage of 10, 15 and 20%. From the results of the study, it can be concluded; the type of adhesive and powder size did not have a significant effect on the value of water content as well as the interaction of the two factors, but it had a very significant effect on the caloric value and interaction between the two. The wood pellet characteristics produced in this study were water content ranging from 9.85% - 8.91%. The caloric value ranged from 17058 J/g (4074 cal/g) - 17555 J/g (4192 Cal/g). Then the higher the caloric value, the better the quality of the pellets.

According Effendi A [7], the treatment of wood powder types, powder particle size and compression showed a significant effect on wood pellets. Water content of wood pellets from flower wood, *acacia* wood and tarap wood with particle sizes of 15 mesh, 25 mesh and 35 mesh and heating temperatures of 60°C and 110°C ranged from 9.98% - 4.38%. Utilization of wood waste from the wood processing industry as raw material for wood pellets is categorized as environmentally friendly fuel because of its low emissions/carbon neutral. The use of wood pellets has a small risk of availability, because the raw material consists of sawn wood waste [7]. The longer the drying process, the lower the thermal efficiency produced. The thermal efficiency obtained in the rotary dryer is 16.41%, 12.26%, and 9.70% for each drying time. After the drying process using this rotary dryer, the decrease in moisture content of the raw material is greater, this is due to the large amount of water that is evaporated on wood powder. The initial moisture content of wood powder by 23% dropped significantly after the drying process occurred and these results have met the quality standards of wood briquettes.

This research is considered important because one of the densities of wood pellets is strongly influenced by the shape or construction of the die hole. Several previous studies have not discussed the results of research relating to the influence of passages on the characteristics of wood pellets. Based on this, it is necessary to examine the construction of the shape of the passages in wood pellet moulds, so that wood pellets can be obtained with maximum density. From this research, we will find new things in increasing density of wood pellets from sawn wood waste. The new findings are the shape of the die hole from wood pellet die.

Biomass in the form of pellets can be used directly as solid fuel. The advantages of wood pellets as a fuel include high density, easy storage, and handling. But the problem that is often faced in the process of forming wood pellets. This is the characteristic of wood pellets, especially the density...
value. Based on the description above, the research is about how to utilize industrial wood waste to increase wood density and increase the density of the value of wood pellets produced. The objective of this study is to increase the value of wood pellets by modifying the die holes with a slope angle of 45°.

2. Methodology

2.1. Materials

The tools and materials are used countersink and drilling machine (as tools and materials for modification of die hole), wood pellet die machines, moisture content test kits, sieves, scales. Whereas the material is used arbitrary wood sawdust (81 mesh), tapioca flour (as adhesive), and hot water.

2.2. Modification of die hole

Design the die hole plan that will be modified as shown in Figure 1. Drilling to expand all pass holes in the wood pellet machine with a predetermine suitability of 45° tilt angles with a depth of about 2 mm.

![Figure 1. Design modification of die hole](image)

2.3. Production Process of Wood Pellets

In preparation of raw material, any wood sawdust waste will be used as raw material for wood pellets with a mesh filter 81. The filtered powder would be dried in direct sunlight so that the water content was the same. Wood pellet raw material with mesh 80. Making wood pellets was done with wood pellet machine. Mixing was carried out with the same parameters in each percentage of the adhesive ie: 1 kg of wood sawdust with 10%, 15%, and 20% tapioca adhesive treatment and 1 litre of hot water. Tapioca flour given hot water will turn into glue, and then mixed with wood sawdust.

This wood pellet was printed by using a wood pellet machine, where the roller with a pressure of 60 kg/m2 rotates to grind the raw material in the die, then the pellet that came out of the die hole will be cut by a knife, so the size is the same. The process of printing wood pellets takes about 1 minute 30 seconds for once the grinding process is evenly distributed. Drying of the finished pellets was dried in direct sunlight, so that the water content in the pellet was reduced and the pellets become denser because the binding agent has dried.

This stage involves analysing the effect of modification on the pass hole on the characteristics of wood pellets made from sawn wood. The analysis was carried out when the die hole were modified using an electric drill using Countersink which made taper on the upper hole with a slope angle of 45°. This stage also tests the characteristics of each pellet which has been glued by the adhesive; the tests to be carried out include water content and heating value. Result is compared with the standard Indonesian wood pellets with reference to SNI [8]. Indonesian national standards require wood pellet characteristics (density, moisture content, ash content, carbon-related content, volatile substances and calorific value) as in SNI 8021: 2014 [8]. The percentage comparison of wood pellet making was varied by treating the adhesive or tapioca flour differently. The use of adhesive was varied: 10%, 15%, and 20% to the weight of the wood.
Table 1. Requirements for wood pellet according to SNI 8021: 2014

| Parameter                        | Unit   | Requirements |
|----------------------------------|--------|--------------|
| Density                          | g/cm³  | ≥ 0.8        |
| Water Content                    | %      | ≤ 12         |
| Ash Content                      | %      | ≤ 1.5        |
| Volatile substances / parts missing | %     | ≤ 80         |
| Carbon content                   | %      | ≥ 14         |
| Calorific Value                  | Cal/g  | ≥ 4000       |

3. Results and Discussion

To find out the effectiveness of the die hole modification, was used as a comparison. He took the results of [6] because all the variables of the wood pellet formation process were the same except for the shape of the pass hole in the die.

The effect of density values on wood pellets greatly influences the characteristics of other wood pellets, such as moisture content and calorific value. High density / density values affect the decrease in moisture content caused by the pressure on the modified passages that get different pressures and cause water to come out of wood pellets which results in smaller pellets of wood so that the wood pellets would be difficult to absorb moisture content. The low water content had a positive impact on calorific value. The lower the value of water content, the higher the calorific value. This was caused by wood pellets which were low in water, resulting in tapioca adhesives being able to bind wood powder well and filling empty cavities on wood pellets, thereby reducing water particles on the wood pellets. Research results on average percentage of wood pellet adhesive between 10%, 15% and 20% after testing (between before and after modification of die holes) could be seen in figure 3.

a. Moisture Value (%)

The graph of the test results for the moisture content could be seen in Figure 2. The moisture content in the main material of wood pellets namely sawdust determines the quality of the pellets to be produced. Wood pellets with high water content would have a low calorific value, where a wood pellet with low water content is would have a high calorific value. This was caused by the heat used to evaporate water on wood pellets could be used as heat in combustion.

![Figure 2. Graph of moisture value (%) before and after modification of the die hole](image)

The moisture content of wood pellets was directly related to the calorific value. The more adhesive was given, the lower the water content of the wood pellets, which would increase the heating value of the wood pellets. This was due to the smaller particle size of tapioca adhesives compared to the size of sawn sawdust which is Figure 2 Graph of Moisture Value (%) before and after modification of the
pass hole. Causing tapioca adhesives to bind with wood sawdust where tapioca adhesive fills empty holes in wood pellets which can reduce water particles on wood pellets. After modifying the pass hole, the results of the water content were lower when compared with the results of the water content when prior to the path hole modification. This is due to the modified hole that has advantages in terms of density which affects the water content.

b. Calorific Value (J/g)

In testing this calorific value using the Automatic Bomb Calorimeter - K88890. Figure 3 is the result of testing the calorific value.

![Figure 3. Graph of calorific value (J/g) before and after modifying the die hole](image)

After modifying the pass hole, it was obtained that the calorific value was less than before the modification. This was caused by when testing the calorific value, the wood pellet mass entered into the Bomb Calorimeter was not up to 1 gram, which was where the previous study [6] included a wooden pellet mass reaching 1 gram. This was one of the reasons why the calorific value was different where the results of the heating value before modified pass holes were superior compared to the results of the heating value after modified pass holes.

c. Density Value (g/cm$^3$)

The calculation of density was done by determining the volume on the wood pellet according to the previous research, then weighing the mass. After the mass and volume were obtained, the calculation was carried out using the density formula, mass divided by volume. The density graph could be seen in Figure 4.

![Figure 4. Graph of density value (g/cm$^3$) before and after modifying the die hole](image)
After modification of the pass hole, the density values data were superior when compared to the results of previous studies [6]. The difference lies in the volume of the pass hole that has changed compared to the pass hole before and after modification. The modified passages with a 45 degree slope angle (2 mm depth) get a treatment of reducing the cross section of a large area (modification area) towards a small area (pass hole) so that the pores of the wood pellets got denser and certainly gave a density effect more on the density.

It could be concluded that after modifying the pass hole, it turned out that the characteristics of wood pellets were not the same. Looking at the parameters were measured the value of water content, calorific value and density with the results of the study [6] in which the pass hole in the wood pellet machine has not been modified.

The effect of density values on wood pellets greatly influences the characteristics of other wood pellets, such as moisture content and calorific value. High density values affect the decrease in moisture content caused by the pressure on the modified passages that got different pressures and cause water to come out of wood pellets which resulted in smaller pellets of wood so that the wood pellets would be difficult to absorb moisture content. The low water contents a positive impact on calorific value. The lower the value of water content, the higher the calorific value. This was caused by wood pellets which were low in water, resulting in tapioca adhesives being able to bind wood powder well and filling empty cavities on wood pellets, thereby reducing water particles on the wood pellets.

Wood pellets are compacted wood particles used as fuel. Wood pellets have been widely used in several countries. Wood pellets are increasingly popular with the high cost of primary energy sources and demands for climate change mitigation. Wood pellets produced can be used in industries and households. The use of wood pellets must use a kitchen or a special furnace. Wood pellet production is quite beneficial for producers and retailers/distributors, including for small and medium scale production. The most important variables in wood pellet production are types of biomass (species, moisture content, and biomass forms), plants and equipment prices, energy costs and labour structures.

4. Conclusion
Wood pellets are alternative energy sources that are clean, renewable and available in large quantities. There has been an increase in the density value of wood pellets produced using modified die hole (slope angle 45°). Increasing the density value has the advantage of being easy in storage and transportation. The characteristics of wood pellets produced in this study were that the water content ranged from 10.49% - 7.13%, the heating value ranged from 17077 J/g (4078 cal/g) - 17291 J/g (4129 cal/g) and the density ranged from 0.82 - 0.86 g/cm³.

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