Characteristics of wood pellet from sawdust pelletized with the hand meat grinder

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Abstract. Sawdust of three wood species, Merbau (Intsia sp.), Matoa (Pometia sp.), and Binuang (Octomeles sumatrana), are manufactured into wood pellet using hand meat grinder as pelletizer and tapioca flour and sago pulp residue used for binding agents. Sawdust and sago pulp residue were homogenized with a hammermill to obtain 60 mesh powder sizes. Concentrations of binding agents ranging from 30 - 70% based on volume/weight were employed. Hot clean water was used for mixing wood powder and the binding agents by hands. Variables of wood pellets examined are diameter and length (cm), moisture content (%), density (g/cm³), ash and volatile content (%), fixed carbon (%), and caloric value (cal./g) according to SNI 8021: 2014. The results indicate that the wood dimension for a diameter of 0.45 cm and a length of 3.78 cm on average are matched the standard. Wood pellets have an average of moisture content 16.87%, higher than the standard of 12%. Means for density and ash content are 0.8 g/cm³ and 1.54% respectively, corresponding to the standard. An average for caloric values of 4064 cal./g is exceeded the minimum value of 4000 cal./g. However, other characteristics for the volatile matter of 74% and fixed carbon of 7.19% are below the minimum recommended value that needs to be improved for the next manufacturing.

1. Introduction

Green energy derived from biomass is divided into three different forms namely, biofuels, biodiesel, and densified biomass or wood fuel. The later green energy could be in charcoal, briquette, and wood, where they are manufactured from renewable resources of lignocellulosic material from agricultural and forest biomass [1]. The potential renewable resources of biomass in Indonesia are very abundant both in volume, and diversity and this green energy could be alternative energy that could be a future solution in substituting fossil fuels and overcoming the energy deficit in Indonesia [2].

The wood pellets are manufactured from homogenous sizes of lignocellulosic biomass from sawdust or other wood wastes pelletized with or without binding agents [1]. Wood pellets have emerged as a very successful renewable fuel source for energy production, due mainly to their many beneficial characteristics, including high density and calorific value, low moisture contents, and relative convenience of transportation and storage.

Technical characteristics or qualities of wood pellets are determined by their moisture content (MC), caloric value, amount of solidness, mechanical durability, particle density, ash content, and ash melting point [3]. Mechanical wood pellets degradation, solidness, and mechanical durability, during transport and handling, are becoming important issues worldwide[4]. The wood pellets are used for generating energy both for domestic and industrial use for heat and electricity production [5]. It has been reported
that for residential use of the prime class wood pellets have 6 ± 1 mm diameter and 3.15–40 mm length for EU standards, and 5.84–7.25 mm diameter and 3.81 ± 0.0381 mm length for U.S. Standards [1],[3].

Binding agents used in manufacturing wood pellets are varying, ranging from natural-based material such as potato flour or starch and corn starch [3], lignin with activation at 150°C [2]. Generally, wood pellets are manufactured using natural binding agents of existed lignin, lignocellulosic material (sawdust from wood or non-wood sources) have to be heated at high temperatures above 150°C for lignin activation [6]. When the low temperature is employed for the pelletizing process, binding agents such as tapioca flour, sago starch, and others are needed.

Woodworking activities to produce furniture, chair, tables, and other wooden products in Manokwari town are produced byproducts of sawdust, slabs, and wood woold in enormous quantity and mostly are dumped or burns as waste without further utilized or processed [7]. This practice could have severe impacts on the local environment and community, such as producing hazardous emissions to the atmosphere [5],[8], green-house gasses [9]. Processing this residual biomass to green energy of wood pellets is an alternative utilization to eliminate polluting impact on the environment and community. Therefore, this research is designed for manufacturing wood pellets from the sawdust of residual waste from woodworking activities in Manokwari town using two binding agents and to evaluate the characteristics of wood pellets produced according to Indonesia National Standard (SNI) 8021: 2014.

2. Material and Method

2.1. Sawdust and binding agent

Sawdust from three wood species was used, Merbau (Intsia sp.), Matoa (Pometia sp.), and Binuang (Octomeles sumatrana) representing the high, medium, and low density of wood species. Sawdust was collected from local woodworking workshops and laboratories of forest products, the faculty of the forestry university of Papua. A single container of recycled rice container, approximately 20 kg, was used to collect sawdust for each wood species and dried on the laid mattress on the floor at the shading room for two consecutive weeks. Sawdust was randomly homogenized its thickness to maximize the air-dried process. Sawdust was homogenized into wood powder using a hammer mill to obtain 60 mesh sizes using siever 60 mesh. The homogenized wood powder was further dried to reduce moisture content (MC) at around 15% in the shading circulation room temperatures.

Two binding agents, namely tapioca flour and residual waste of sago pulp, were used. Tapioca flour was purchased from the local market. Residual waste of sago pulp was collected from the laboratory of agricultural products technology, the University of Papua. Sago pulp was homogenized with the hammer mill to obtain 100 mesh size of sago pulp powder and dried to reach approximately 25% MC.

2.2. Research variables.

Research variables consist of diameter and length (mm), moisture content (MC %), density (g/cm³), ash content (%), volatile content (%), fixed carbon (%), and caloric value (cal./g). All variables are measured according to Indonesian National Standard (SNI) 8021:2014.

2.3. Research procedures.

The tapioca flour binding has concentration for 30, 40, and 50 % of the total sawdust powder (v/w %) for Merbau, Matoa, and Binuang. At the same time, sago pulp residue has a concentration from 60, 70, 100% to wood sawdust of Merbau and Binuang. Volumetric mixing wood sawdust with binding agents is 200 g to fulfill the full capacity of the hand meat grinder as pelletizer. The designed-binding agent was diluted in hot water at the aluminum pan, and sawdust powder was poured into the aluminum pan, mixed and homogenized gently with hand, as illustrated in Figure 1a. The mixtures were pelletized using the hand meat grinder that has been installed permanently on the table to produce wood pellets (Figure 1b). Wood pellets were taken and dried on the paper and then cut into the designed length, as illustrated in Figure 1c-d.
Figure 1 Manufacturing wood pellets from sawdust with a binding agent of tapioca flour pelletized with a hand meat grinder, a) mixing wood powder and a binding agent, b) pelletizing stage, c) wood pellets produced, d) final length of wood pellet

3. Results and Discussion

3.1. Results

An average for physical and thermal properties of wood pellets made from sawdust of three wood species using two binding agent systems are summarized in Table 1.

Table 1 An average for wood pellets characteristics manufactured from three wood species using two binding agents

| Binding system | Wood species/ concentration (V/W) | Diameter (cm) | Length (cm) | Moisture content (%) | Density (g/cm³) | Volatile matter (%) | Ash content (%) | Fixed carbon (%) | Caloric value (cal/g) |
|----------------|----------------------------------|---------------|-------------|----------------------|-----------------|---------------------|----------------|-----------------|---------------------|
| Tapioca flour  | Merbau 30                         | 0.47          | 3.94        | 18.36                | 0.67            | 79.52               | 1.37            | 0.93            | 4039                |
|                | 40                                | 0.46          | 4.04        | 18.63                | 0.80            | 78.86               | 1.27            | 1.24            | 4012                |
|                | 50                                | 0.48          | 4.01        | 18.22                | 0.66            | 77.26               | 1.36            | 3.20            | 3986                |
| Matoa          | Merbau 30                         | 0.46          | 4.03        | 17.58                | 0.65            | 81.86               | 0.82            | -0.04           | 4090                |
|                | 40                                | 0.45          | 4.03        | 18.59                | 0.72            | 79.47               | 0.85            | 1.09            | 4179                |
|                | 50                                | 0.45          | 4.01        | 18.35                | 0.64            | 81.97               | 0.83            | -1.16           | 4024                |
| Binuang        | Merbau 60                         | -             | -           | -                    | -               | -                   | -              | -               | -                   |
|                | 70                                | 0.44          | 3.13        | 15.03                | 0.71            | 80.65               | 1.2             | 1.2             | 3863                |
| Sago pulp      | Merbau 50                         | 0.41          | 3.16        | 15.22                | 0.76            | 80.05               | 1.5             | 3.18            | 8320                |
|                | 70                                | 0.44          | 3.23        | 16.87                | 1.06            | 61.70               | 1.5             | 19.99           | 3621                |
|                | 100                               | -             | -           | -                    | -               | -                   | -              | -               | -                   |
|                | 60                                | 0.46          | 3.20        | 15.67                | 0.86            | 73.94               | 1.9             | 8.46            | 3667                |
|                | 70                                | 0.45          | 2.20        | 18.12                | 1.09            | 66.40               | 2.4             | 13.02           | 3593                |
|                | 100                               | 0.45          | 3.25        | 14.3                 | 0.76            | 72.62               | 1.9             | 11.20           | 3377                |
| SNI 8021:2014  | 4 – 10 mm                        | 5 x length    | Max. 12%    | Min. 0.8 g/cm³       | Max. 80%        | Max. 1.5%           | Min. 14%        | Min. 4000 cal/g  | -                   |

SNI 8021:2014 4 – 10 mm length Max. 12% Min. 0.8 g/cm³ Max. 80% Max. 1.5% Min. 14% Min. 4000 cal/g
Table 1 highlights that the physical and thermal properties of wood pellets made from sawdust of three wood species using two binding agent systems pelletized using the hand meat grinders are varied. Each characteristic of wood pellets examined is narrated in detail in the following paragraphs.

3.1.1. Binding agent. Two binding agents used for manufacturing wood pellets resulted in different responses for each species of wood. Table 1 shows that tapioca flours with a concentration of 30% are failed for the binding agent of Binuang sawdust powder, but the higher concentrations (40 and 50%, respectively) succeeded. It was examined that a low concentration of binding agents could not penetrate or mix well with the lighter wood species or low density. Sago pulp as residual waste obtained from sago extraction starch processing was also reported failed for the binding agents for wood pellets made from Merbau sawdust powder, mainly for 60 and 100% concentration, However, another concentration was successful in producing wood pellets.

3.1.2. Wood pellet dimensions. An average of wood pellet dimensions resulted from different treatments exceeds the SNI standard of 0.4 cm in diameter, where an average of 0.45 cm in diameter was obtained. It is also applied for wood pellet’s length, where an average, the length of wood pellets produced from different treatments exceeds the minimum length of 1.2 cm. Table 1 also highlights that tapioca flour binding agents produce wood pellet with an average length of 3.78 cm compared to those were produced from sago pulp residue agents of 2.97 cm on average.

3.1.3. Moisture contents and density. As been summarized in Table 1, it is highlighted that the average moisture content (MC) wood pellets produced in this experiment exceeds the SNI 8021:2004. The averages of MC recorded are 17.50% and 16.24% for tapioca flours, and sago pulp residue binding agents respectively, higher than the MC recommended for 12%. The wood pellet binding with tapioca flour made from higher wood density tends to have higher MC than that are lighter density, such as Merbau 18.40%, Matoa 18.17%, and Binuang 15.15%.

The density of wood pellets from three wood species binding with tapioca flour produced using hand meat grinder pelletized overall are lower than the minimum density required. It is summarized that an average density of wood pellet binding with tapioca flour from three wood species was 0.70 g/cm³. On the other hand, two wood species binding with sago pulp has an average of 0.94 g/cm³, higher than 0.8 g/cm³ as the minimum density.

3.1.4. Volatile matter, ash content, and fixed carbon. An average for volatile matters recorded from wood pellets produced from sawdust of three wood species using tapioca flour as a binding agent was 79.95%. Nevertheless, it is lower than those recorded from the wood pellets of two wood species binding with sago pulp residue, which was 68.66%, as shown in Table 1.

Ash content criteria for wood pellet according to SNI 8021:2014 is maximum of 1.5%. The ash contents of wood pellets using a binding agent tapioca flour from three wood species have an average of 1.15%, but for those are made from two wood species binding agent sago pulp having an average of 1.93%, higher than the value recommended.

Fixed carbon for wood pellets produced from three wood species binding with tapioca flour has an average of 1.20%, and it is very low compared to the standard value of 14%. It seems that these values are not a normal average. However, the other wood pellets produced from two wood species binding with sago pulp residue have an average of 13.17%, which closes to a minimum value needed.

3.1.5. Caloric value. Table 1 reported that the caloric values of wood pellets produced in this experiment are varied. The wood pellets manufactured from three wood species binding with tapioca flour agent have an average of caloric value 4564 cal./g, higher than the minimum value of 4000 cal./g. However, wood pellets binding with residual sago pulp has an average caloric value less than the recommended value, where it has an average of 3564 cal./g.
3.2. Discussion

Wood pellets are densified biomass that is used as green energy sources made from lignocellulosic resources of agricultural and forest biomass, where their abundance is enormous[10], including the Indonesian archipelago [2], [6], [11] and these renewable resources could be converted using simple and cheap technology into green energy for domestic and industrial uses [12]. Using hand meat grinders available in the local market, residual waste from woodworking activity could be manufactured into wood pellets with binding agents of tapioca flour and sago pulp residue, even though their characteristics are varied. Visual appearances of wood pellets made from Merbau, Matoa, dan Binuang sawdust powder binding with tapioca flours are illustrated in Figure 2a-c. In contrast, those wood pellets are made from Merbau, Binuang binding with sago pulp residue (Figure 2d-e), and pure sago pulp residue are shown in Figure 2f.

![Figure 2](image)

**Figure 2** Visual appearances of wood pellet from sawdust of three wood species binding with tapioca flours: (a Merbau, b) Matoa, c) Binuang and sago pulp residue: d) Merbau, e) Binuang, f) pure sago pulp residue

Wood pellet dimensions (diameter and length) produced are fulfilled to the Indonesian national standard for wood pellets. However, the moisture content of wood pellets produced from all treatments exceeds the maximum value. It is probably due to shorting drying times, and more drying times are required. Densities of wood pellets recorded on average are close to the minimum value recommend, and it could be improved using different pelletizer or modified hand meat grinders. Other wood pellet characteristics, such as volatile matter, ash content, and fixed carbons, recorded from this experiment, are not consistent with the recommended values. It is probably because of human error during the experiment, mainly the minus value for fixed carbon using the binding agents of tapioca flour (Table 1). However, the other experiment using a binding agent of sago pulp residue improved the fixed carbon values[13]. Caloric values of wood pellets recorded from this experiment are, in general, fulfilling the minimum recommended value, especially the sawdust powder binding with tapioca flour. However, the
sawdust powder binding with sago pulp residue has lower caloric values than the minimum values recommended. It needs further consideration in future manufacturing wood pellets by modified hand meat grinder or employed other pelletizer machines [13], or mold-pelletizing machine with a binder [11].

Wood pellet is manufactured using a pellet machine called pelletizer, where sawdust is heated to a temperature around 150°C to activate lignin substance as a natural binding agent [2,6]. Caloric values of wood pellets produced at a temperature of 150°C from different biomass are 3151 cal./g for rice straw and 4161 cal./g for coconut fibers, respectively [2]. In contrast, the wood pellets from Agathis sawdust mixed with its bark pelletized at 190°C have an average caloric value of 4524 cal./g for a wood powder without bark and 4628 cal./g for wood powder with a bark of [6].

Characteristics of wood pellets made from the waste of woodworking and sago pulp residue could be improved mainly by caloric value by increasing wood pellets density, and caloric values and reducing moisture content. A new machine wood pellet has been employed using similar binding agents (without lignin activation) and the wood pellet characteristics improved, and the improvements have been reported [13].

4. Conclusion
It is concluded that the sawdust of three wood species from the waste’s woodworking with sago pulp residue and tapioca flours as the binding agents are successfully manufactured into wood pellets using the hand meat grinders. Even though the characteristics of wood pellets produced are not passed all variables, the wood pellet dimensions (diameter and length) and density conceded to the Indonesian national standard. Other characteristics can be improved by employing a standard pelletizer or the hand meat grinder with modification. Notably, the caloric values are matched to minimal standard values.

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5. References
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