Characteristics of wood pellet from 5 years old JPP teak (Tectona grandis L.f.)

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Abstract. The use of renewable energy sources made from wood biomass processed in the form of wood pellets is needed to anticipate the decreasing of fossil energy (petroleum and coal). The wood biomass utilization is not only environmentally friendly and more sustainable, but also can reduce greenhouse gas emissions and environmental pollution, especially when used as power source for electricity generator. Compared to other countries, Indonesia has the potential as a major producer because it’s vast amount of forest and biodiversity that can be used as source of raw materials for wood pellets. With 2.44 million hectares forest area (including 1.22 million hectares of Teak plantation), Perum Perhutani has opportunity to develop energy wood. Large potential source is JPP (Jati Plus Perhutani) Teak wood harvested from first thinning (5 years old) and partly from second thinning (10 years old) which still inadequate for sawn timber. The aim of this study was to determine the characteristics of wood pellet from 5 years old JPP teak (Tectona grandis L.f.) as energy sources. Characteristics of wood pellet including the value of water content, calorific value, fly ash, ash content, density and sulfur content compared to the SNI 8021: 2014 quality standard. This research used CRD (Complete Random Design). The treatments on wood pellet making were of three different temperatures (175° C, 200° C and 225° C) applied at 2 timings (3 and 5 minutes). Samples of 5 years old JPP teak wood were obtained from KPH Cepu. The characteristics of JPP Teak wood pellets tested at the Laboratory of Timber Chemicals, Energy and NTFPs at the Forest Products Research and Development Center Bogor. Characteristics of JPP Teak wood pellets compared to national quality standards (SNI 8021: 2014) were water content (0.78 to 2.64%; max 10%), calorific value (4,399 to 4,585 Kcal/Kg; min 4,000 Kcal/Kg), density (0.63 to 0.92 gr/cm³; min 0.8 gr/cm³), fly ash level (77.68 to 79.01%; max 80%), carbon content (17.16 up to 18.16%, min 14%), ash content (3.63 to 4.56%; max 1.2%) and sulfur content (0.01 to 0.02%; max 0.05%). The higher pressing temperature and time, tend to decreasing water content, sulfur content and fly ash content and increasing density and carbon content. The conclusion of this study was that 5-year-old JPP Teak wood can be used as raw material for making Wood Pellets which can meet national quality standards (SNI 8021: 2014) except for the ash content.
1. Introduction
In order to reduce greenhouse gas emissions and other environmental pollution, the use of energy sources in the world nowadays, especially for electricity generation, has shifted from fossil energy (petroleum and coal) to renewable energy sources, including wood pellets. The main producer of wood pellets in the world is the United States while for the ASEAN region is Vietnam. In ASEAN, Indonesia's potential is not inferior to Vietnam. Indonesia excels in a wider number of plantations and agriculture than Vietnam. In addition, compared to other competitors, Indonesia has biodiversity of plants which can be used as sources of unique wood pellet raw material [6].

The use of renewable energy sources made from wood biomass processed in the form of wood pellets is needed to anticipate the depletion of fossil energy (petroleum and coal). The use of wood biomass is not only environmentally friendly and sustainable, but also can reduce greenhouse gas emissions and environmental pollution, especially as a power source for electricity generation. Wood pellets can be used as a reliable fuel because they contain high caloric values and may reduce usage of fossil fuel which is more expensive and keep decreasing in Indonesia.

Wood pellets are used as coal substitute materials in power plant, heater, biomass stoves, and dryer in laundry services. Coal importing countries (South Korea, Japan, China and India) are slowly shifted to wood pellets because of their good quality, environmentally friendly and renewable. In 2013, Europe lacked 7 million tons from 19 million tons of wood pellets. Canada lacked 1 million tons from 4 million tons of wood pellets. Asia (Japan and South Korea) lacked less than 1 million tons and will be the biggest importer of wood pellets in the coming decade. World wood pellet production in 2015 was approached 28 million tons. While the marketing of global wood pellets for electricity and heat power plant continues to grow around 14.1% per year. In 2020, the demand for wood pellets is estimated to increase up to 80 million tons. Therefore, several countries, such as South Korea, Japan, Europe, the United States and Canada were seeking to supply raw materials from tropical countries, such as Indonesia [2].

The advantages of biomass utilization are renewable, environmentally friendly, reducing greenhouse gas emissions and acidic gases [1]. Whilst the disadvantages are high water content, non-uniform shape and size, low density which can increased the cost of storage, handling and transportation, besides susceptible to destructive microbes [5]. To improve the quality as energy sources, biomass formed into products such as: briquettes, carbon pellets and or wood pellets. The mixture of 75% elephant grass (Penisetum purpureum) charcoal and 25% nyamplung (Calophyllum inophyllum L.) shell charcoal can improve the physical properties of carbon pellets with an average water content of 3.35%, fly ash level 26.19%, ash content 13.59%, carbon content 60.21%, density of 0.68 kg/cm², compressive strength of 5.91 kg/cm² and caloric value of 6,080 cal/g [7].

Compared to other countries, Indonesia has the potential as a major wood pellets producer because its vast amount of forest and biodiversity as a source of raw materials for wood pellets. Perum Perhutani as forest government’s company was given the task of managing forests on Java Island with 2.44 million hectares of forest area, including 1.22 million hectares of teak (Tectona grandis L.) plantations which is very potential to develop energy wood. JPP Teak (Jati Plus Perhutani) used mainly for woodworking, but the harvest from the first thinning of 5 years old plantation which not yet qualified for woodworking has the potential to be used as energy wood. Harvest from the first thinning (5 years old) and some harvest from the second thinning (10 years old) were quite large as raw material for wood pellets.

In this study, wood pellets were made using 5 years old JPP Teak wood. Wood pellet molding machines worked through torrefaction process which can regulate specific temperature treatment while timing treatment used the stopwatch. Production of wood pellets was expected to improve the quality of JPP teak wood biomass as energy sources. This study aimed to determine the characteristics of wood biomass and wood pellets from 5 years old JPP Teak.
2. Materials and Methods

2.1. Materials
5 years old JPP Teak were obtained from KPH Cepu, Central Java. Research equipment were machetes, saws, wood cutting machines, ovens, containers, stirrers, 40 mesh sieves, stopwatches, wood crusher and pellet molding machines.

2.2. Methods

2.2.1. Material preparation
JPP Teak wood raw materials were cut into 5 cm long pieces, thinly sliced into chips and dried in oven at 100°C for 24 hours. The wood from the oven then grounded into powder and sieved until it passed the 40 mesh sieve.

2.2.2. Making of wood pellets
Wood pellets were made using pure JPP Teak wood powder. To determine the molding optimal temperature, a preliminary research was carried out using temperatures of 125°C, 150°C and 175°C. Analyzed parameters were the value of water content, fly ash level, ash content, carbon content, density and calorific value compared to the National Standard (SNI 8021: 2014). This study used CRD trial design with 3 temperature treatments (175°C, 200°C and 225°C) and 2 time treatments (3 and 5 minutes).

3. Results and Discussion

3.1. Preliminary research
Preliminary research was conducted to determine the effect of molding temperature on the physical properties of the wood pellets. The results showed that the use of temperatures of 125°C and 150°C for 3 and 5 minutes were not optimal. The wood pellets produced were not compact and break easily. The use of temperature of 150°C and 180°C for 15 minutes caused carbon pellets made from elephant grass burned (100%, 75%, 50% and 25%), while 100% nyamplung shell carbon were not burned [7]. This may caused by the low density of elephant grass raw material then become flammable in temperatures above 120°C. Wood pellets look compact and not destroyed starting at a temperature of 175°C for 3 minutes. Thus the treatment for making of JPP Teak wood pellets used the temperature started at 175°C and the time started at 3 minutes.

Table 1. Characteristics of 5 years old JPP teak wood

| No. | Characteristics          | 5 Years old JPP teak | SNI WP 8021-2014 | Reference                |
|-----|--------------------------|----------------------|------------------|--------------------------|
| 1   | Calorific value (Kcal/kg)| 4,062.0              | Min. 4.000       | IKM 04 (BOM Kalorimetri) |
| 2   | Density (g/cm³)          | 0.9                  | Min. 0.8         | SNI 06-3730-1995         |
| 3   | Water content (%)        | 19.3                 | Max. 12          | SNI 06-3730-1995         |
| 4   | Ash content (%)          | 2.5                  | Max. 1.2         | SNI 06-3730-1995         |
| 5   | Fly ash level (%)        | 80.3                 | Max. 80          | SNI 06-3730-1995         |

3.2. Characteristics of Raw Materials (5 years old JPP Teak Wood)
Characterization of raw materials was needed to determine the effect of the molding process into wood pellets as an energy source. Measurement of the characteristics of raw materials was carried out on raw materials before any treatment such as drying. The calorific value was determined by the value of carbon content, water content, ash content and fly ash level [4]. The calorific value was 4,062 Kcal/kg, qualified to meet the SNI Wood Pellet Standards (Table 1). Another characteristic that meets SNI
standard was the density value of 0.9 gr/cm³. While the water content of 19.3%, ash content of 2.5% and fly ash level of 80.3% were not qualified compared to SNI Wood Pellet standard.

3.3. Characteristics of 5 years old JPP Teak Wood Pellets

Characteristics of the JPP Teak wood pellets compared to SNI Wood Pellet standard (SNI 8021: 2014) were water content (0.78-2.64%; max 10%), calorific value (4,399-4,585 Kcal/kg; min 4,000 Kcal/Kg), density (0.63-0.92 gr/cm³; min 0.8 gr/cm³), fly ash level (77.68-79.01%; max 80%), carbon content (17.16-18.16%; min 14%), ash content (3.63-4.56%; max 1.2%) and sulfur content (0.01-0.02%; max. 0.05%).

| No | Sample codes | Water content (%) | Ash content (%) | Density (gr/cm³) | Sulfur content (%) | Fly ash level (%) | Carbon content (%) | Treatments |
|----|--------------|------------------|----------------|-----------------|-------------------|------------------|-------------------|------------|
| 1  | JPP 5A       | 2.47             | 4.56           | 0.63            | 0.02              | 77.87            | 17.58            | 175°C,3 mnt |
| 2  | JPP 5B       | 2.64             | 3.63           | 0.79            | 0.02              | 78.70            | 17.67            | 175°C,5 mnt |
| 3  | JPP 5C       | 1.61             | 3.83           | 0.79            | 0.02              | 79.01            | 17.16            | 200°C,3 mnt |
| 4  | JPP 5E       | 1.27             | 4.22           | 0.92            | 0.01              | 77.68            | 18.10            | 200°C,5 mnt |
| 5  | JPP 5D       | 0.94             | 3.97           | 0.82            | 0.01              | 77.87            | 18.16            | 225°C,3 mnt |
| 6  | JPP 5F       | 0.78             | 3.93           | 0.74            | 0.01              | 77.88            | 18.19            | 225°C,5 mnt |
|    | **Rerata JPPS** | **4.457**     | **1.62**       | **4.02**        | **0.78**          | **0.02**         | **78.17**        | **17.81**   |

|                | SNI Wood Pellet standard | Standar Korea | Standar Eropa EN SNI WP 8021 - 2014 |
|----------------|--------------------------|---------------|-------------------------------|
|                | ≥4,000                   | ≥4,300        | 3,941≤Q≤4,538                 |
|                | ≤ 12                     | ≤ 10          | ≤ 10                          |
|                | ≤ 1.2                    | ≤ 0.7         | ≤ 3                           |
|                | ≥0.8                     | ≥0.64         | ≥0.6                          |
|                | ≤ 80                     | ≤ 0.05        | ≤ 0.04                         |

Thus wood pellets made from 5 years old JPP Teak wood had water content, calorific value, density, fly ash content, carbon content and sulfur content qualified compared to SNI Wood Pellet standard (SNI 8021: 2014) except for ash content (max 1.2%). The calorific value is influenced by the carbon content. The higher the carbon content, the higher the calorific value. Carbon content is influenced by the number of evaporated non-carbon compounds during densification [3].

4. Conclusions and Recommendation

4.1. Conclusions

The calorific value and density of 5-year-old JPP teak were qualified compared to SNI 8021-2014 standard, while the water content, ash content and fly ash level were not qualified. After being processed into wood pellets, the calorific value, density, water content, sulfur content and fly ash level were qualified compared to SNI standard except for ash content.

4.2. Recommendation

5 years old JPP Teak wood harvested from first thinning can be used as energy wood and has potential as additional income for the company.

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