

Effect of Particle Pre-treatment on Physical and Mechanical Properties of Particleboard Made from Oil Palm Trunk

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Abstract. Oil palm trunk can be used as raw material for particleboard. On the other hand, oil palm trunk contains many extractive substances, which can disturb the adhesion of particleboard. The objective of this research was to the effect of particle-pretreatment on particleboard properties made from oil palm trunk. The particle had been pre-treated with cold water (24, 48, and 72 hours) and hot water (1, 2 and 3 hours). The particles were dried to 3% in the oven. Board were made with size 30 (length) x 30 (width) x 1 cm (thick) with density target of 0.7 g/cm³. Particleboard was made bonded urea formaldehyde with pressing temperature of 130⁰C and pressure of 25 kg/cm² for 10 minutes. Control (particleboard without pre-treatment) was also produced. The board properties were tested in accordance with SNI 03-2105-2006. The results showed that particle pre-treatment improved physical and mechanical properties of particleboard. Pre-treatment (immersion in cold and hot water) decreased the moisture content (MC) and thickness swelling (TS) and increased modulus of rupture (MOR), modulus of elasticity (MOE) and Internal Bond (IB) value. The value of density, MC, MOR and IB fulfilled the SNI 03-2105-2006 standard, while the all MOE and TS value have not fulfilled the standard. The best pre-treatment condition was particle immersion into hot water for 2 hours.

1. Introduction

The trend of natural forests in supplying timber for industry has decreased in the last decade. To overcome the problem, an alternative material to substitute wood is necessary. One of the non-timber materials that contain lignocellulose and the amount of biomass is oil palm trunk (OPT). Based on study [1], oil palm plantations can produce OPT of about 183 m³/hectare during replanting and continue to increase in the next replanting period. For each hectare, the oil palm plantation can produce 50.1 m³ of sawn timber from the outer part of OPT, which is generally only one-third of OPT [2].

The utilization of OPT has weakness properties such as high density variations. The OPT density of 40 years old tree was 0.23-0.74 g/cm³ [3], while OPT density of 25 years old tree was 0.14-0.60 g/cm³ [4]. In addition, OPT has high moisture content and high shrinkage. Therefore, the improvement of OPT quality by compressing inner part of OPT [5] and compregnating phenol formaldehyde into the OPT [6] are indispensable. The results of the Technical Feasibility Study and Economical Study revealed that the OPT was suitable to substitute wood for Biocomposite Industry. It is recommended that OPT was suitable for particleboard [7]



Biocomposite technology is a suitable technology of utilizing all materials containing wood and or other lignocellulosic materials, such as OPT. Biocomposites are panels made of wood or other small lignocellulosic material and then rearranged into new products such as particleboard, fiberboard, strandboard, structural composite wood, mineral plank, and composite plastic board [8].

The OPT contains extractive substances. The extractive content of OPT after being dissolved in cold water, hot water, alcohol-benzene and 1% NaOH were 11.2-17.82%; 12.51-18.22%; 9.90-10.84%; and 27.64-32.26%, respectively [9]. The extractive content is increasing from the bark to the center and from the bottom to height of trunk [10]. Wood extractive can effect on the adhesive consumption and its rate of maturation [11], wood wettability and adhesive spread to particles [12]. The presence of extractives in the OPT can disturb the adhesion during the compression of particleboard.

Based on the above information, it is necessary to carry out the study of pre-treatment techniques on OPT particle. The objective of this study was to analyze the particle pre-treatment on physical and mechanical properties of OPT particleboard.

2. Materials and Method

2.1. Material

The material used in this study was OPT from University of North Sumatera. The OPT was converted into 30 mesh particles. The other material was urea formaldehyde (UA-140) from Palmolite Adhesive Industry, Probolinggo with resin content of 63%.

2.2 Methods

2.2.1. Preparation of materials

Pre-treatment of OPT particle was carried out by soaking in cold water (24, 48, and 72 hours) and hot water (1, 2 and 3 hours). The code of pre-treatment for soaking 24, 48 dan 72 hours and dipping into hot water for 1, 2 and 3 hours were CW-24, CW-48, CW-72, HW-1, HW-2, HW-3, respectively. Then, the OPT particle was dried inside an oven until reaching a moisture content around 3%. Soaking technique in cold water referred to pre-treatment study of Sentang wood [13] as well as soaking technique in hot water [13-15]

2.2.2. Particleboard manufacturing

After pre-treatment of particle in cold and hot waters, the OPT particle was dried inside an oven with temperature of 90 °C for 24 hours to reach a moisture content about 3%. Then, the OPT particle was mixed with UF adhesive with concentration of 10% and placed in a forming box of 30 cm x 30 cm size. The board thickness was 1 cm and made with target density of 0.7 g/cm³. Furthermore, the OPT particle was pressed using hot press at the temperature of 130°C and pressure of 25 kg/cm² for 10 minutes, and then conditioning for 2 weeks. The next step was to cut the particleboard for several test referring to SNI standard for evaluating the physical properties such as density, moisture content, thickness swelling, mechanical properties including modulus of elasticity and modulus of rupture [16].

2.2.3. Physical and mechanical test

The measurement of physical properties was density (ρ) and moisture content (MC) with a sample size of 10 x 10 x 1 cm, thickness swelling (TS) with a sample size of 5 x 5 x 1 cm. Meanwhile, the mechanical properties measured were Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) with a sample size of 5 cm x 20 cm x 1 cm, and internal bond with a sample size of 5 cm x 5 cm x 1 cm. The experiment was conducted in triplicate. The results were then compared with the SNI [16].

2.3. Data Analysis

The data of physical (density, moisture content and thickness swelling) and mechanical properties (MOE and MOR) were compared with SNI standard particleboard type 8 [16] as shown at **Table 1**.

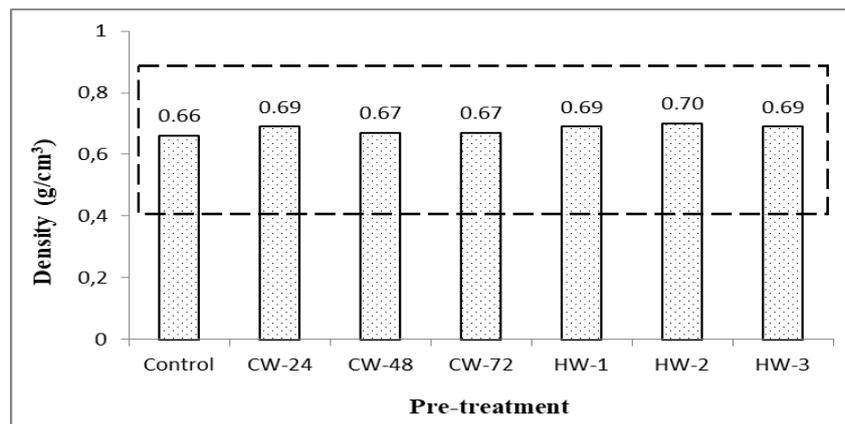
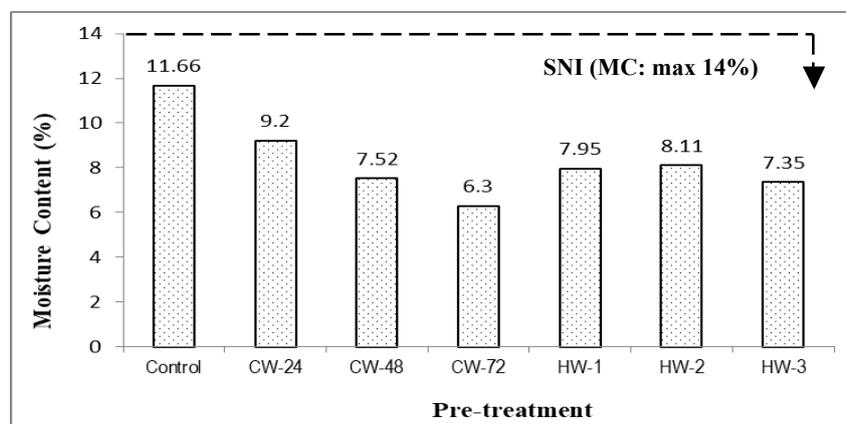
Table 1. The SNI 03-2105-2006

Properties	Standard
Density	0.4-0.9
Moisture Content	Max 14
Thickness Swelling	Max 12
MOR	$\geq 82 \text{ kg/cm}^2$
MOE	$\geq 20400 \text{ kg/cm}^2$
Internal Bond	$\geq 1,5 \text{ kg/cm}^2$

3. Results and Discussion

3.1. Physical properties

The physical properties in this study were density, MC and TS. The density, MC and TS of particleboard with several pretreatment were shown in **Figure 1, 2 and 3**, respectively. Based on **Figure 1**, the density of pre-treatment types of particle board ranged from 0.66-0.70 g/cm^3 . The final density of the particleboard is influenced by several factors such as wood type (wood density), the level of pressing pressure, the amount of wood particles in layer, the adhesive content and other additives [17].

**Figure 1.** Density value of particleboard**Figure 2.** Moisture content value of particleboard

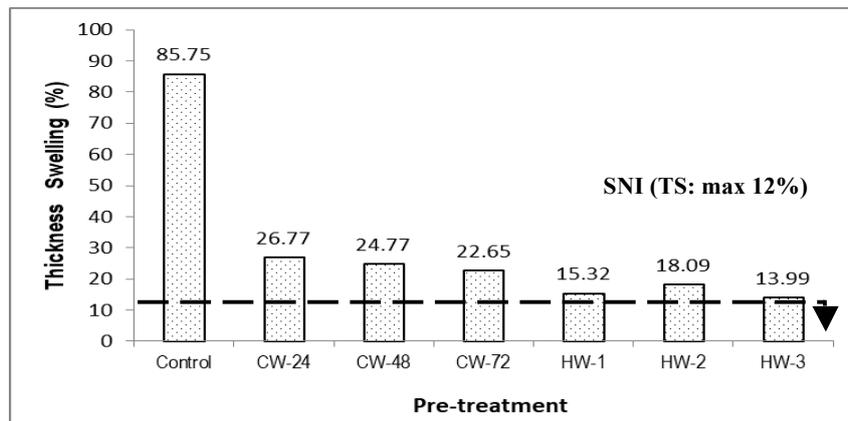


Figure 3. Thickness swelling value of particleboard

Figure 1 showed that the pre-treatment did not cause changes in particleboard density. In manufacturing particleboard, high density is not the main target but how to produce panel wood with low density and the properties fulfil the standard requirements [18]. The particleboards produced in this study are categorized into medium density boards. Medium density particleboard has a density between 0.59-0.80 g/cm³. Based on the SNI standards, the density particleboard between 0.4 - 0.9 g/cm³, and all density of particleboards have fulfilled standard [16].

The MC of pre-treatment type of particleboard ranged from 6.30-11.66 %. **Figure 2** showed that MC value of particleboard tends to decrease. Pre-treatment particle by soaking in cold and hot waters was essentially to remove the presence of extractive substances. This pre-treatment will decrease the extractive content in the wood (tannins, gums, sugars and pigments). The correlation extractive content with glue bond strength was poor. The increase of extractive content can reduce glue bond strength. Also, the higher extractive content had a significantly greater degree of adhesive failure and made the lower mechanical strength [19].

The particle pre-treatment will increase the adhesive ability to penetrate the cell wall and resulting in a good bonding process. Therefore, water vapour accessibility can be reduced [20]. Dissolution of extractive substances can increase the bonding performance of wood particles with their binder. In addition, the effect in hot pressing process using temperature of 130 °C for 10 min leads to the decrease in the hydrophilic properties of the lignocellulose materials. It will result low MC and TS. Based on SNI standard, the maximum MC is 14 % [16]. All MC of pre-treatment fulfils the SNI standard.

Figure 3 shows the TS of particleboards ranged from 15.32 to 85.75 %. The pre-treatment caused a decrease of TS of the particleboard. Particle immersion with cold water (24, 48, and 72 hours) and hot water (1, 2, and 3 hours) decreased the extractive content. The same result was obtained that the immersion of *Jatropha* particle using cold and hot water can removed some extractive component and caused the TS value to decrease compared untreated [13]. The extractive component has influence in decreasing hygroscopic, wood permeability and also increasing wood durability. Although its few number, extractive influential in wettability of wood, affect of pH, consumption, and penetration of glue [21]. The extractive components can be dissolved by immersing in hot water and cold water [18]. The dilution of extractive substances can increase the connectivity between wood particles with the binder. The adhesive ability to penetrate into the wood takes place well, whereby the presence of free hydroxyl groups on wood is filled by the adhesive. Consequently, the hygroscopic nature of the board can be minimized [20].

The value of thickness swelling with UF adhesive is still extremely high. This is due to UF adhesive was for interior purposes and this adhesive was not water resistant. The weakness of UF adhesives is that they were not resistant to moisture or high humidity causing this adhesive not suitable for exterior usage. The thickness swelling of particleboard is influenced by the quality of bonding and

the adhesive properties [22]. The UF adhesive bond is not as strong as the isocyanate adhesive bond. This is because the particleboard that uses UF adhesives absorbs more water and significantly affects the value of its higher thickness swelling [23]. The absence of paraffin in the manufacture of particleboards is also one of the factors of high TS. The reduction of TS can be conducted through the addition of paraffin/wax or other hydrophobic material during the manufacture of the board [24].

The sample still absorbs water when it is immersed in water; this is due to the presence of free and bonded water. The free water lies in the cell cavity, the intercellular space and the gap on the adhesive bond within the wood. The bound water is present in the cell wall and may also be present in the adhesive-wood tissue [25]. Based on SNI standard, the maximum TS is 12% [16]. All TS of pre-treatment did not fulfilled SNI 03-2105-2006.

3.2. Mechanical properties

3.2.1. Modulus of elasticity (MOE), modulus of rupture (MOR) and internal bond (IB)

The MOE, MOR and IB value with several pretreatment were shown in Figure 4, 5 and 6.

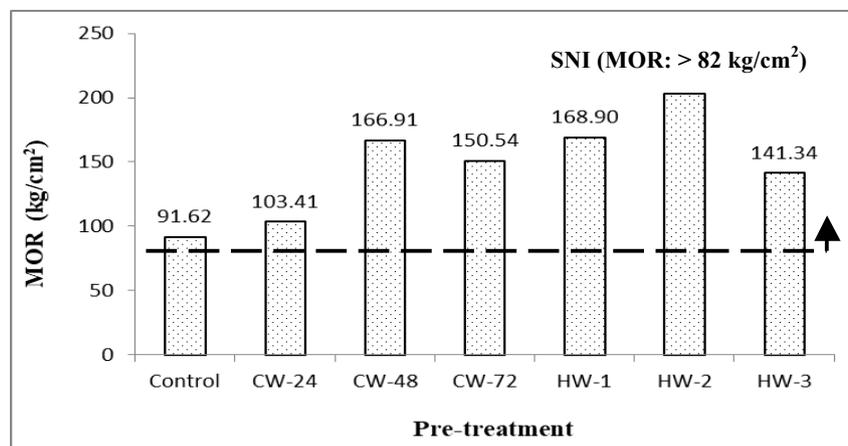


Figure 4. MOR value of particleboard

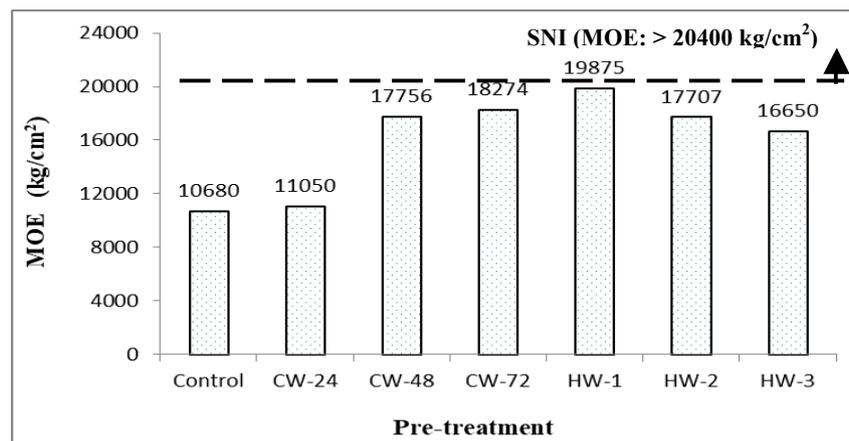


Figure 5. MOE value of particleboard

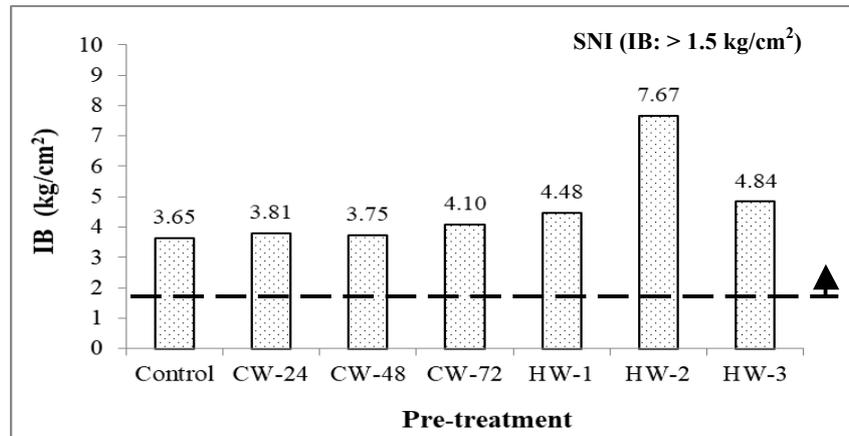


Figure 6. IB value of particleboard

Based on **Figure 4, 5 and 6**, the MOR, MOE, and IB values of the particleboard were ranged from 91.62-203.23 kg/cm², 10680-19875 kg/cm² and 3.65-7.67 kg/cm², respectively. The values of MOR, MOE and IB after pre-treatment tend to increase. The MOR, MOE and IB values of pre-treatment samples were higher than that of control. All of MOR and IB values of particleboard fulfilled the SNI standards. By contrast, MOE values of particleboard with several pre-treatments did not reach the SNI standards [13].

Figure 4 showed that MOR control was 91.62 kg/cm². After pre-treatment of particle using cold water (24, 48, 72 hours) and hot water (1, 2 and 3 hours), the value of MOR tend to increase from 103.41 kg/cm² until 203.23 kg/cm², respectively. The increase of MOR value using pre-treatment was 12.86-121.82%. The highest of MOR value was 203.23 kg/cm² achieved with the hot water immersion for 2 hours.

Figure 5 showed that MOE control was 10680 kg/cm². After pre-treatment of particle by using cold and hot waters, the MOE value tend to increase from 11050 kg/cm² to 19875 kg/cm². It means that the pre-treatment improved the MOE value around 3.46-85.16%. However, the MOE did not fulfilled SNI 03-2105-2006.

Figure 6 showed that IB value was tend to increase from 3.75 kg/cm² to 7.67 kg/cm² compared to control (3.65 kg/cm²). The pre-treatment improved the IB value around 2.7%-110.13%. The highest IB value was 7.67 kg/cm² and achieved with the hot water treatment for 2 hours. The MOR value is influenced by the content and type of adhesive materials used, adhesive strength and fibre length. Factors affecting the MOR value of the panels are wood density, particle geometry, particle orientation, adhesive content, moisture content and hot press process. Meanwhile, the value of MOE is influenced by the content and adhesives types, adhesive strength and fibre length [11]. The pre-treatment by soaking in hot water will reduce alkaline extractives, decrease the pH value and increase the absolute acid buffer capacity of the particles [26].

The extractive substances are not a part of structural wood. The presence of extractives can inhibit penetration of adhesives into particles/strands, and resulting in lower mechanical properties of composite [16]. Soaking the strands in hot water can improve the surface tension of strands, strands adhesion and adhesives [27]. Thus, it can improve the mechanical properties of composite. It was reported that immersing red meranti wood flakes in hot water for 2 hours can improve the strength of OSB [28-29]. Also, immersing Sentang wood flakes in hot water for 2 hours and steam for 1 hour can increase MOR, MOE and IB value [13].

The other research reported that extractives have correlation with the wettability of wood surfaces to form good bonding of adhesives [30]. Wettability can be used as an indication of its gluing properties. One way to measured the wettability was by using cosine-contact angle method. The previous report that OPT have poor wettability or great of OPT contact angle compared Meranti and Sengon wood. The liquid resin did not flow easier and formed a higher contact angle [31].The

improved of gluing properties will affect on particleboard quality. It is necessary to pre-treatment in the form of submersion in hot water or in cold water. It showed that good wettability will improve gluing properties and particleboard quality.

4. Conclusion

Particle pre-treatments by soaking in cold and hot waters decreased MC and TS. Thus, the physical properties of particleboard increase compared to control. All of densities and MC of particleboard fulfil the SNI requirements. However, the TS has not fulfilled SNI requirements. The mechanical properties (MOR, MOE and IB) increase after particle pre-treatments. The MOR, MOE and IB value increase around 18.87-121.82%; 3.46-85.16% and 2.7%-110.13%, respectively. All of MOR and IB values fulfilled the SNI requirement, but the MOE values were not.

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