Optimization of Composition, Temperature and Time on Production of Particle Board Made from Pine Bark and EFB

A Saad¹, A Kasim², Gunawarman³, Santosa²

¹ Departement of Agricultural Engineering-Mechanical Engineering Andalas University, Padang Institute of Technology, Padang
² Department of Agricultural Engineering, Faculty of Agricultural Technology, Andalas University, Padang
³ Mechanical Engineering-Andalas University, Padang 25166- Indonesia

Abstract. The study is aimed to find out the feasibility on the Empty Fruit Bunches (EFB) and the Merkusii Pine Bark as a raw material for particle board production. The research carried with varied composition, times and temperature, testing according to the standards of SNI-3-2105-2006 and JIS A 5908-2003. The fiber length of the Empty Fruit Bunches is 0.1-20 mm and particle size of the pine bark passes sieve 40 mesh. The experiment result shows that density, moisture content and MOR meet SNI and JIS but MOE does not meet the standard. The optimal condition is obtained on the composition 70/30 and 75/25.

Keywords - EFB, pine bark, composition, press time, press temperature, properties

1. Introduction

Be aware of adhesives from Urea Formaldehyde (UF), Phenol Formaldehyde (PF), Melamine Formaldehyde (MF), Resorcinol Formaldehyde (RF) and Cresol Formaldehyde (CF) that are not environmentally friendly and unhealthy, on the other hand the lack friendly fiber and decreased wood products has prompted the producers to look for alternative sources of fibers containing cellulose for decades [1][2]. This technology product is known as binder less particleboard, and has developed since the mid1980s until now [3]. Particle boards without synthetic and environmentally friendly adhesives have been developed, a number of particle board studies have been carried out with different materials namely corn biomass [1], biomass pineapple [2] Palm tree trunk [3], rice straws [4], Neolamarckia wood (Neolamarckia cadamba) [5], date palm branches [6], coir pith [7] particles of young and old oil palm trunks[8], Jatropha curcas [9], acacia wood [10], Palm Oil Trunk and gambir (Uncaria gambir Roxb.) [11], durian skin fibers [12], Mahogany wood particle [13], Chitosan [14], corn biomass [15], bamboo [16].

Interested in the development of eco-friendly organic adhesive, then the pine bark is used as an adhesive in the manufacture of organic composite particle board made from EFB. The chemical composition of the EFB is 57.17% cellulose, lignin, 5.68% hemiselulose 31.89%, holoselulose 62.87%[17]. On the other hand, pine tree merkusii flourishing on the island of Sumatra (Aceh, West Sumatra, Riau, Jambi and South Sumatra). Pine wood is treated to use in buildings (interior and unique) and its skin produces waste. Pine bark that has elements of tannin-containing compound complex of
polyphenols \((\text{Cl}_2\text{HgN}_2\cdot\text{H}_2\text{O})\), yield point temperature 101.6°C. EFB and pine bark is organic waste and is not maximum used.

The particle board which is made of EFB and pine merkusii bark is aimed to produce eco-friendly particle board. It should meet the standards, optimizing function the empty palm bunches and pine bark waste. This will reduce the use of formaldehyde adhesives and costs. The manufacture of particle boards is also an effort to meet the needs of the board, whose production is reduced every year. In this study, the physical properties test (density, moisture contents) and mechanical properties test (modulus of rupture, modulus of elasticity and internal bonding)

2. Material and Method

2.1. Prepare of palm oil fiber

EFB is taken from PT. AMP PLANTATION in Agam Regency, West Sumatra which is 110 km from the city of Padang. The EFB itself was still mixed with soil and sand, so it needed to be cleaned. Cleaning was done by soaking in clean water containing 1-2% NaOH for 1 hour at a temperature of 105 °C [21]. Then it was soaked in flowing clean water for one hour. The next step, drying it until the moisture content was 10-20%. The drying step was held with the sun radiating 400-770 watts. Furthermore, EFB fiber was cut with cutting machine and filtered. The size of the filter was 16 mesh, meanwhile the length of the fiber after filtering was 0.1-2.0 cm. At last, the fiber was dried until the moisture content was 5-6%.

2.2. Prepare of fine bark particle

Merkusii pine bark was obtained from the pine plantations of Tanah Datar district, Batu Sangkar, 120 km from the city of Padang. The pine bark was separated from the wood then dried until the water content was 5-6%. Pine bark was cut to a length of 5 mm and smoothed with ball milling and then filtered the particles which passed 40 mesh sieve.

2.3. Particle Board

The dimension of the particles board was l x b x t: 30x30x1.1 cm. The composition of EFB and pine bark were 90/10; 85/15; 80/20; 75/25 and 70/30. The working temperature was 150°C; 160°C; 170°C; 180°C and 190°C. The press time was 10, 15, 20, 25 and 30 minutes. The samples were created into 12 pieces. Target density was 1.0 g.cm⁻³. After mixing the adhesive evenly fibers, it was put in molds measuring 30 x 30 x 8 cm. The mold then was closed and cold compressed for 5 minutes. The plate itself was made of 5 mm thick steel plate. After mixing EFB with pine bark, cold pressing was done at 28°C for 5 minutes followed by hot pressing, then the panel was cooled in a plywood box for 7 days, with temperature was around 28°C. Standard particle board reference, namely JIS 5908-2003 and SNI 03-2105-2006[18]

2.4. Density

The test specimen density of size lxbxt: 10x10x1.1 cm. Density particle board was determined by dividing the weight \((W)\) and volume \((V)\) of a specimen as shown below:

\[ \rho = \frac{W}{V} \text{ g.cm}^{-3} \]  

2.5. Moisture Contents

All of the specimens with a dimension of 10 cm × 10 cm × 1.1 cm were measured by using a weighing balance and recorded as \(M_1\). The samples were dried in the oven at 105°C for 24 hour and reweighed (\(M_2\)). The moisture content(\(\varphi\)) was calculated using formula shown below:

\[ \varphi = \frac{(M_1-M_2)}{M_2} \times 100\% \]
2.6. MOE and MOR
The specimen dimension for examination MOE and MOR was 25 x 4 x 1.1 cm. The three-point bending test method was applied with a computer control system namely Universal Testing Machine (UTM) with a type of UH 300 kN. The bending test referred to ASTM D1037. The data was analysis using version 10 of the design expert programs.

\[ MOE = \frac{F_{pl}S}{4wt}y_1 \]  
\[ MOR = \frac{3F_{pl}S}{2wt^2} \]

2.7. Internal Bonding (IB)
IB is calculated using equation:

\[ IB = \frac{\Delta F}{A} \]

Where W: Weight of the specimens (gram), \( V \): Volume (cm\(^3\)), \( M_1 \) and \( M_2 \): weight of the initial and final weight (gram), \( \Delta F \): pressure difference, the end and the begining(N), L: distance buffers (cm), w: width of the specimens (cm), t: thickness of the specimens, \( y_1 \): Deflection (cm), F: Pull style (N), A: cross-sectional area (cm\(^2\))

3. Result and discussion

3.1. Density and moisture contents
The particle board of EFB and pine bark which has finished the hot press process is then cooled for 7 days at room temperature. This is to lower the temperature on the surface and in the middle part of the particle board which must be equal to room temperature. Density test and moisture content were taken from all particle board compositions, sample sizes and methods referring to SNI 03-2105-2006. The results are as shown in Figures 1 and 2, that the particle board density in the composition of EFB and pine bark 70/30 is 0.72-0.78 g.cm\(^{-3}\) at all hot press temperatures, it meets the standards of SNI 03-2105-2006 for medium density, medium density value 0.4-0.9 g.cm\(^{-3}\) [18], the same is true for compositions 75/25; 80/20; 85/15 and 90/10.
Table 1. The particle board quality for medium density

| Properties                  | Units       | Value       |
|-----------------------------|-------------|-------------|
| Moisture contents (φ)       | %           | ≤ 14        |
| Density (ρ)                 | g cm⁻³      | 0.4-0.9     |
| Modulus of Rupture (MOR)    | MPa         | ≥ 8.04      |
| Modulus of Elasticity (MOE) | MPa         | ≥ 2001      |
| Internal Bonding (IB)       | MPa         | ≥ 0.147     |

Indonesian National Standard (SNI) for Particle Boards, BSN, SNI 03-210-2006, p-15

The experiment of dry based moisture content on the 70/30 compositions in all temperature levels shows the value in 10.2-11.5%. This moisture content value is smaller than the maximum value in the table 1 which is 14%. So the value meets the particle board standard. Moisture content in the composition 75/25; 80/20; 85/15 and 90/10, the value 10-12%

3.2. Modulus of Rupture (MOR)

The important mechanical properties of the particle board are Modulus of Rupture and internal bonding. Experimental data were analyzed using software "expert design version 10". The results of data analysis were displayed in three-dimensional graphs, each composition analyzed the MOR and IB values with hot press temperature variables and hot press time. Figures 3, 4, 5, 6 and 7 each show MOR values for each particle board composition. In the composition of 70/30 the maximum value of MOR is obtained: 8.57 MPa, temperature of hot press 165-175°C and the time of hot press 20-23 minutes. The maximum value of MOR, temperature and time of each composition is shown in Table 2.

Table 2. Maximum MOR value, Temperature and time for each composition

| Composition | Max.MOR (MPa) | Temperature (°C) | Time (minutes) |
|-------------|---------------|------------------|----------------|
| 90/10       | 6.99          | 160-180          | 20-25          |
| 85/15       | 7.22          | 170-180          | 17-25          |
| 80/20       | 7.55          | 160-180          | 15-25          |
| 75/25       | 8.15          | 165-178          | 18-24          |
| 70/30       | 8.57          | 165-175          | 20-23          |

From Table 2, it is known that the optimum MOR that meets SNI 03-2105-2006 is 8.15 and 8.57 MPa, compositions of 75/25 and 70/30, temperature of hot press 165-175°C and time of 18-23 minutes. The MOR value of the composition of 90/10, 85/15 and 80/20 has not met SNI 03-2105-2006
3.3 Internal Bonding (IB)

Using the same analysis method, the internal bonding obtained is shown in figure 8, 9, 10, 11 and 12. The figures illustrate the optimum value of internal bonding with two parameters i.e. time and temperature, different conditions for each composition, time and temperature, shown in table 3. Internal bonding at the optimum conditions of each composition meets SNI 03-2105-2006.
Table 3. Maximum IB value, temperature and time for each composition

| Komposisi | Mak. IB (Mpa) | Temperature (ºC) | Time (minutes) |
|-----------|---------------|------------------|----------------|
| 90/10     | 0.156         | 160-180          | 17-25          |
| 85/15     | 0.17          | 160-180          | 15-25          |
80/20  0.16  160-175  15-25
75/25  0.19  170-175  19-23
70/30  0.19  165-177  15-24

Although the internal bond meets the standard, the highest value is obtained in the compositions of 75/25 and 70/30, the temperature of the hot press is 165-177°C and the hot press time is 15-24 minutes.

4. Conclusion
From the data analysis and discussion of the experiment on particle boards made from Empty Fruits Bunch and pine bark some conclusions can be taken:

1. The pine bark waste and empty fruits bunches can be processed into particle boards without synthetic adhesives, this absolutely can reduce the use of synthetic adhesives using, reduce empty fruits bunches waste and *pine merkusii* skin and meet the needs of local boards and national.

2. The optimum value of the properties of particle board (density, moisture content, MOR and IB) without synthetic adhesives meet SNI 03-2105-2006 and JIS 5908-2003 with Empty Fruits Bunches compositions and *pine merkusii* skins is 70/30 and 75/25.

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References
[1] M. Baskaran *et al.*, “Properties of binderless particleboard from oil palm trunk with addition of polyhydroxyalkanoates,” *Composites Part B: Engineering*, vol. 43, no. 3, pp. 1109–1116, 2012.
[2] Y. Indrayani, D. Setyawati, T. Yoshimura, and K. Umemura, “Mechanical and Physical Properties Ofmedium Density Fiberboard Produce from Renewable Biomass of Agricultural Fiber,” vol. 3, no. 3, pp. 66–68, 2013.
[3] M. Baskaran, R. Hashim, O. Sulaiman, S. Hiziroglu, M. Sato, and T. Sugimoto, “Optimization of press temperature and time for binderless particleboard manufactured from oil palm trunk biomass at different thickness levels,” *Materials Today Communications*, vol. 3, pp. 87–95, 2015.
[4] X. Li, Z. Cai, J. E. Winandy, and A. H. Basta, “Selected properties of particleboard panels manufactured from rice straws of different geometries,” *Bioresource Technology*, vol. 101, no. 12, pp. 4662–4666, 2010.
[5] H. Lias, J. Kasim, N. Atiqah, N. Johari, I. Lyana, and M. Mokhtar, “Influence of Board Density and Particle Sizes on the Homogenous Particleboard Properties from Kelempanyan(Neolamarckia cadamba),” *International Journal of Latest Research in Science and Technology ISSN*, vol. 3, no. 6, pp. 173–176, 2014.
[6] M. Ghofrani, A. Ashori, and R. Mehrabi, “Mechanical and acoustical properties of particleboards made with date palm branches and vermiculite,” *Polymer Testing*, vol. 60, pp. 153–159, 2017.
[7] E. Ahmed, A. Das, M. Hannan, and M. Shams, “Particleboard from coir pith,” *Bangladesh Journal of Scientific and Industrial Research*, vol. 51, no. 3, p. 239, 2016.
[8] J. Lamaming, R. Hashim, O. Sulaiman, T. Sugimoto, M. Sato, and S. Hiziroglu, “Measurement of some properties of binderless particleboards made from young and old oil palm trunks,” *Measurement: Journal of the International Measurement Confederation*, vol. 47, no. 1. pp.
813–819, 2014.

[9] D. Iswanto, A.H., Febrianto, F., Hadi Y.S., Ruhendi, S., & Hermawan, “Sifat fisik dan mekanis papan partikel dari kulit buah jarak (Jatropha Curcas) diperkuat partikel kayu,” _Jurnal Ilmu dan Teknologi Kayu Tropis_, vol. 10, no. 2, pp. 103–111, 2012.

[10] I. Palle, N. Hori, T. Iwata, and A. Takemura, “Optimization of polyol production via liquefaction from Acacia mangium and analysis of the polyols by traditional methods and two-dimensional correlation spectroscopy,” _Holzforschung_, pp. 1–8, 2018.

[11] A. Kasim and A. Fuadi, “Influence of Temperature and Pressing Time on Particleboard Processing from Palm Oil Trunk (Elaeis guineensis Jacq.) and Gambir (Uncaria gambir Roxb.) Adhesive on Particleboard Properties,” _Wood Science and Technology_, pp. 17–21, 2007.

[12] S. Charoenvai, “Durian Peels Fiber and Recycled HDPE Composites Obtained by Extrusion,” _Energy Procedia_, vol. 56, pp. 539–546, 2014.

[13] R. Widyorin and F. E. Puspitasari, “The influence of treatment extraction and time press on the particle board without adhesive from mahogany sawn powder,” _Biokomposit_, pp. 225–232, 2010.

[14] X. Ji, Y. Dong, R. Yu, W. Du, X. Gu, and M. Guo, “Simple production of medium density fiberboards (MDF) reinforced with chitosan,” _Holzforschung_, vol. 72, no. 4, pp. 275–281, 2018.

[15] T. Wu, X. Wang, and K. Kito, “Effects of pressures on the mechanical properties of corn straw bio-board,” _Engineering in Agriculture, Environment and Food_, vol. 8, no. 3, pp. 123–129, 2015.

[16] R. Liu, M. Liu, S. Hu, and A. Huang, “Comparison of six WPCs made of organo-montmorillonite-modified fibers of four trees, moso bamboo and wheat straw and poly ( lactic acid ) ( PLA ),” _Holzforschung_, pp. 1–10, 2018.

[17] F. Kasim and A. Kasim, “Hydrolysis of Oil Palm Empty Fruit Bunch Fibers to Produce Sugar Hydrolyzate as Raw Material for Bioethanol Production,” _International Journal on Advanced Science, …_, vol. 3, no. 3, pp. 24–27, 2013.

[18] Indonesian National Standard Agency, “Indonesian National Standard (SNI) for Particle Boards,” _BSN_, vol. SNI 03-210, p. 15, 2006.