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Effect of Isocyanate Resin Level on Properties of Passion Fruit Hulls (PFH) Particleboard

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Abstract. The main problem of particleboard is had low dimensional stability. The using of exterior adhesive type will help to improve that problem. The objective of this research was to evaluate of isocyanate level on physical and mechanical properties of passion fruit hulls particleboard. Passion fruit hull particles (PFH) were dried up to 5% moisture content. Particleboard made in size of 25 by 25 cm^2 with density and thickness were 0.80 g/cm^3 and 1 cm respectively. Isocyanate resin at various level (7,5,9,and 11%) used for manufacturing of board. After blending of particle and resin, materials were placed into the mold in size of 25 by 25 cm^2. Furthermore, elements were pressed using a hot pressing machine with the temperature, time, and pressure of 160^{o}C, 6 minutes and 30 kg/cm^2 respectively. Conditioning process was applied for 7days in room temperature. The results showed that the increasing of resin level resulted in improvement of some parameters such as moisture content, thickness swelling, modulus of elasticity, modulus of rupture, and internal bond. Isocyanate resin level of 11% produced the best properties of PFH particleboard.

1. Introduction

Passion fruit plant (*Passiflora edulis* Sims *F.edulis* Deg) is one of the famous plants in North Sumatra. It dispersed in Karo regency and North Tapanuli Regency, North Sumatra Province. Passion fruit was extracted as raw materials in syrup manufacturing. A byproduct of syrup manufacturing was passion fruit hulls (PFH) waste. According to [1], PFH has lignin content and coarse fiber of 31.79 and 38.89% respectively. It is potentially as raw materials of particleboard.

The previous research was conducted by [2] PFH particleboard bonded with urea formaldehyde resin resulted in low dimensional stability. The adhesive has important role in particleboard manufacturing. Isocyanate is one of exterior adhesive had advantages such as free formaldehyde emission and its better adhesive bond compared to another exterior resin. As stated by [3] isocyanate has more tolerance to the higher moisture content of particle, had lower temperature and faster time in hot pressing, and had higher dimensional stability. Focused of this research was to the analysis of isocyanate adhesive levels on physical and mechanical properties of particleboard made from PFH.

2. Material and Method

Passion fruit hulls were collected from the syrup industry “PT. Dewi Markisa” in Berastagi, North Sumatra, Indonesia. The isocyanate resin used for the binder in this research.

2.1. Materials preparation

Drying of the particle was conducted in two steps. The first step, fresh passion fruit hulls was dried up to air-dry condition to reduce moisture content before oven drying. The second step, the particle was oven dried up to 5% moisture content. After drying, PFH was mill to get particle size of 10 mesh.

2.2. Determining of pH and Extractive Content

The determination of pH conducted refers to [4]. The determining of extractive content in hot and cold water's solution refers to [5].

2.3. Board manufacturing

Particle and isocyanate adhesive blended using rotary blending machine. The adhesive levels in this research were set on 5, 7, 9, and 11%. After that, particle was placed into the mold in a size of 25 cm by 25 cm. Furthermore, sheet pressed using a hot pressing machine was setting at 160^{o}C temperature for 6 minutes and pressure of 30 kg/cm^{2} to get the density target of 0.8 g/cm^{3}. Conditioning process was applied on boards for 7 days in room temperature.

2.4. Board cutting and testings

Cutting and testing of board refer to [6]. The testing parameter included density, moisture content, water absorption, and thickness swelling for physical properties. While of mechanical properties included of the internal bond, modulus of elasticity, and modulus of rupture.

3. Results and discussion

3.1. pH value and extractive content of PFH particle

The aim of determination pH is to determine the acidity of mango fruit and to know how the effect of pH with freshness indicator of mango fruit.

Table 1. Data of pH value and extractive content of PFH particle

Material	Parameter		
	pH	Extractive content in cold water (%)	Extractive content in hot water (%)
Passion Fruit Hulls	5.9	33.66	37.16

According to Table 1, the extractive content of PFH was quite high. High extractive substances of lignocellulose material can interfere with the gluing process of particleboard. As stated by [7] extractive effects on adhesive consumption and curing rate, and result in blowing during the hot pressing process. As reported by [8] extractives give the effect of wood wettability, and adhesives spread. Most extractives have hydrophobic characters. The acidity of materials greatly determined of adhesive performance. Some adhesives types are very sensitive to the acidity of lignocellulose materials. The isocyanate adhesives have a reasonably good tolerance to acidic conditions, but very acidic particles condition can cause the board's internal bond strength to below. As reported by [9] the internal bond of flake board made from Kapur wood with a pH of less than 4 were lower than that of Hemlock, Red lauan, and Douglas fir. Furthermore, According to [10] that wood pH has a strong influence on gelatinization time at lower catalyst concentrations. This effect will decrease when the catalyst concentration used is increased. According to [11] polymerization rate of the adhesive depending on raw material (wood and adhesive) used, this will directly affect on temperature and time of pressing in the manufacture of particleboard.

Table 2. Data of Physical and Mechanical

Parameters	Resin Levels (%)			
	5	**7**	**9**	**11**
Density (g/cm^3)	0.64	0.69	0.63	0.57
Moisture Content (%)	10.35	8.35	7.17	5.98
Thickness Swelling (%)	22.26	18.46	16.88	13.41
Water Absorbtion (%)	62.57	68.58	59.05	51.33
Modulus of Rupture (kg/cm^2)	21.73	27.11	22.29	30.61
Modulus of Elasticity (kg/cm^2)	2189	2809	3862	4077
Internal Bond (kg/cm^2)	2.19	2.27	2.92	4.27

3.2. Density and Moisture Content (MC)

The average density values ranged between 0.57 to 0.69 g/cm^3 (Table 1). The highest and lowest density values were produced by particleboard with 7 and 11% respectively. The density of particleboard in this study did not reach the target of 0.8 g/cm^3. Several non-wood lignocellulose materials like PFH are bulk density, so the chances of springback getting bigger. Similar to the previous research, [2, 12] reported that passion fruit hulls and jatropha fruit hulls particleboard bonded with UF resin resulted in density value below of the target. Overall the density values have a meet standard which requiring board density values ranging from 0.40 to 0.90 g/cm^3 [6].

The average of moisture content value ranged between 5.98 to 10.35% (Table 1). The highest and lowest moisture content was produced by particleboard with 5 and 11% adhesive level respectively. Overall the moisture content of particleboard has a meet standard in which requiring moisture content values are ranging from 5 to 13% [6].

3.3. Thickness Swelling (TS) and Water Absorption (WA)

The thickness swelling value ranged between of 13.41 to 22.26%. Based on Table 2, it can be seen that there is a decrease in thickness swelling value along with the increase of adhesive level. According to [13] increasing the amount of adhesive would increase the bond between particles to resulted in better dimensional stability of particleboard. All boards produced did not meet the standard in which requiring a maximum board thickness of 12% [6]. PFH was porous characteristic, so it requires a higher adhesive content to produce a low thickness swelling value.

The water absorption of particleboard ranges from 51.33 to 68.58%. The lowest and highest values were found at the adhesive content treatment of 11% and 7%, respectively. Water absorption of particleboard produced in this study was quite high. It was due to the character of PFH as a raw material is porous. As reported by [2] water absorption rate of PFH particles are 10 gram per second. It has an impact on board during the conditioning process in which board will easily to absorb of moisture.

3.4. Modulus of Elasticity (MoE) dan Modulus of Rupture (MoR)

The MoE value of particleboard ranged between of 2189.46 to 4077.12 kg/cm^2. The highest and lowest of MoE values were produced by particleboard that use of 11 and 5% adhesive level respectively. Overall, the increase in adhesive content caused an increase of MoE value. As stated by [7] the value of MoE is influenced by level and type of adhesive, bonding strength of adhesive, and size of particles. The low MoE value in this study due to two reasons. First is in homogeneous particle size. According to [14] ideal particles for getting strength and dimensional stability are thin flake particles with uniform thickness and high of slenderness ratios. The second is the low chemical component such as cellulose, hemicellulose, and lignin of passion fruit hulls compared to wood causing this material to have no strength.

MoR value of particleboard ranged from 21.73 to 30.61 kg/cm^2. Similar to MoE value, the highest and lowest of MoR value was produced by particleboard with 11% and 5% adhesive level. Overall the

MoE and MOR value in this study did not meet the standard in which this standard of requiring a minimum MoE and MOR value of 20,000 and 80 kg/cm^2 respectively [6].

3.5 Internal Bond (IB)

The IB value of particleboard ranged from 2.19 to 4.27 kg/cm^2. The highest and lowest IB values were resulted from the board using 11 and 5% respectively. Overall the IB value of particleboard in this research had met JIS A 5908-2003 that requiring a minimum IB value of 1.5 kg/cm^2. As stated by [3] the bond occurs in MDI resin are chemical bonds in which these chemical bonds are stronger and more stable than mechanical bonds. MDI in an isocyanate group (-N = C = O) reacts with hydroxyl groups in wood to form a urethane chain. A combination of factors such as non-polar, aromatic components of MDI is resistant to hydrolysis.

4. Conclusion

Overall, the increase of adhesive content improves the physical and mechanical properties of the particleboard. The density, moisture content, and internal bond value have met standards. However, of thickness swelling, MOE and MOR value did not meet of JIS A 5908 (2003). The adhesive level of 11% produced the best physical and mechanical properties of particleboard in this study.

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