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Passion fruit hulls particleboard: the effect of urea formaldehyde level on physical and mechanical properties

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Abstract. The purpose of this research was to explore the suitability of Passion Fruit Hulls (PFH) as a raw material particleboard with variants of urea formaldehyde adhesive content (UF). In this research, PFH particles filtered by sieve in size of 10 mesh to throw dust particles. Furthermore, the particles dried until reaches of 5% moisture content. Levels of UF adhesive was using comprise of 10%, 12% and 14%. Hot pressing conducted at 120°C temperature for 10 minutes at a pressure of 30 kg/cm^2. The results showed that in moisture content for 10% adhesive level, almost all the parameters such as thickness swelling, modulus of elasticity (MOE) and modulus of rupture (MOR) that produced did not fulfiled the standard. The 14% adhesive level produced of the best of PFH particleboard.

1. Introduction

Passion fruit hulls (PFH) are by product from syrup industries. In North Sumatra, the passion fruit hulls existence is abundant. It contains crude protein and lignin approximately 7.32 and 31.79% respectively [1]. Furthermore, PFH also contains lignocellulosic materials so it can be utilized as the raw material of particleboard. Recently, the data about properties of PFH's particleboard is not available.

The research about non-woods particleboard had been dominated by materials of bamboo, sugarcane bagasse, palm oil, banana fibre, rice hulls, etc. The research used the sorghum bagasse and jatropha fruit hulls had been reported in the previous research [2-3]. The results showed that these materials potentially could be developed for particleboard materials. The focused study in this research was to analyse the effect of adhesive level on particleboard properties. According to [4-6] that adhesive level is one of the parameters was affecting of quality particleboard.

2. Materials and Methods

2.1. Materials

PFH waste from syrup industries in Berastagi-North Sumatra Indonesia, urea formaldehyde (UF) from PT. Palmolite Adhesive Industry (PT. PAI) Probolinggo, East Java Indonesia.

2.2. Methodss

2.2.1. Materials preparation. PFH converted into a particle in size of 10 mesh. Furthermore, it dried in an oven at 103°C up to reach of 5% moisture content. The amount of UF adhesive prepared 10, 12, and

14% based on oven dry weight of the particle. Board density and thickness targets were set of 0.8 g/cm^3 and 1 cm respectively.

2.2.2. Board producing. PFH and UF mixed in a rotary blender. After that, it was placed into mat former in size of 25 by 25 cm^2. Furthermore, the mat was pressed using the hot pressing machine at 120^{o}C temperature, 30kg/cm^2 pressure, and for 10 minutes. The next step, board conditioned at room temperature for seven days before testing.

2.2.3. Board cutting. After conditioning, board cutting refers to standard [7]. The parameter for evaluating included of physical (density, moisture content-MC, water absorption-WA, and thickness swelling-TS) and mechanical (modulus of rupture-MoR, modulus of elasticity-MoE, and internal bond-IB).

2.2.4. Water absorption (WA) rate of particle. The determination of WA rate of the particle was conducted by the weighting of 50 g PFH for initial weight (W0). Furthermore, it was immersed in water for one minute and weight after that (W1). This immersing continued every one minute until the saturated condition. The WA rate was calculated using the formula below:

$$V = \frac{W1 - W0}{t}$$

Note: V is WA rate (g/minute), W0 is Initial weight (g), W1 is Weight after immersing (g), and t is Time (minute).

3. Results and Discussions

3.1. Physical Properties

The board density value in this research did not fulfiled the density target of 0.8 g/cm^3. This is due to the lose particles during the compression process as stated by Buffalino et al. [8]. The particle density values had met the standards required in standard ranging from 0.4 to 0.9 g/cm^3 [7].

Table 1. Physical properties parameters

Adhesive Level (%)	Physical properties					
	Density (g/cm^3)	MC (%)	TS-2H (%)	TS-24H (%)	WA-2H (%)	WA-24H (%)
10	0.83	14.70	60.99	83.69	118.64	168.34
12	0.75	12.73	37.04	60.99	76.38	107.91
14	0.78	13.58	37.83	61.10	90.90	107.99

Note: H (Hours)

Parameters of moisture content showed that the higher level of UF adhesive resulted in the decrease of moisture content particleboard. The high value of moisture content obtained in this study because the PFH's particle had hydrophilic properties where the particle can quickly absorb water in the environment.

The water absorption of the particleboard produces is still quite high because the UF adhesive had a low resistance to the water so that UF adhesive is more widely used for interior application. According to [9], UF adhesives were resulted from a condensation polymer of formaldehyde with urea, which has hydrolyzable on its hydrogen bond. When the particleboard immersed in the water, it will be easily to penetrate into the particleboard, as a consequence is the high value of water absorption. In addition, other factors that influence WA values are hygroscopic properties of particles. The hygroscopic is the ability of the materials that were easily passed by the water so that the material will be easy to expand after being immersed in the water. The rate of water absorption in the PFH can be seen in Figure 1.

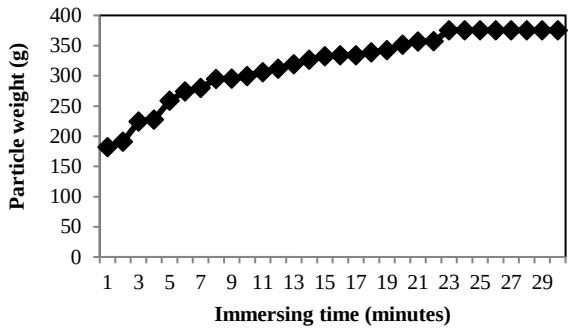

Figure 1. Water absorption rate of particle

Particle absorption rate test is performed by immersed the passion fruit hulls particles with a dry weight of 50 g. The results of the water absorption rate obtained on the PFH particles increase during the 30 minutes immersion until it reaches the water saturation point. After that, the final weight of PFH particles reached of 375.43 g. These results can prove that the PFH particles are porous materials. The rate of water absorption of PFH around 10.84 g/minute shows that PFH has hydrophilic properties. The high thickness swelling produced due to the use of UF adhesive, where the adhesive is used for the interior application. Bulky's property of non-wood materials is another reason that resulted in higher the thickness swelling value. Thickness swelling of the wood panel was influenced by adhesive quantity and distribution, MC of furnish, furnish compatibility, the chemical composition of furnish, etc [10]. The particles are resistant to MC will be able to produce of boards with good dimensional stabilization [11].

Increased of adhesive levels resulted in decrease the thickness swelling of the board. Iskandar and Supriadi [12] stated that the more adhesive resulted in better interparticles of bond in the particleboard produced. In addition, PFH particles have a high enough extractive substance that is equal to 37.16%. It can inhibit in glueing process on the particleboard manufacturing. According to [4], extractive substances affect to the adhesives consumption, the rate of adhesive curing and the durability of particleboard. Based on Standard, the thickness swelling value of PFH's particleboard produced did not meet the standard where the maximum thickness swelling is allowed less than 12% [7].

3.2. Mechanical Properties

The increasing of adhesive level resulted in higher MoE value, it was due to by higher of interparticle bonding that has resulted in improvement of strength to retain of the load. The MoE value did not meet standard, it is probably due to particle size. Small particle size resulted in lower mechanical properties, It is similar founding with [13]. Furthermore, particle geometry in form slenderness ratio is one of the important factors was affecting of modulus of elasticity properties [4-5].

Table 2. Mechanical properties parameters

Adhesive Level (%)	Mechanical properties		
	MoE (kg/cm^2)	MoR (kg/cm^2)	IB (kg/cm^2)
10	6570.13	42.07	1.97
12	4523.30	31.72	2.60
14	7890.13	54.68	3.43

The similar trend with MoE also occurred in MoR value. The higher of adhesive content resulted of better MoR value. The MoR parameter also did not meet JIS A 5908-2003 that require of MoR value minimum of 82 kg/cm^2.

Trend IB value similar with MoE and MoR. It is supported by [12] research who reported that increasing of adhesive content resulted in higher of IB sugarcane bagasse particleboard. The increasing of adhesive level resulted in higher of covered the surface of the particle and its probably to improve the interparticle bond strength.

4. Conclusions

The physical and mechanical properties of particleboard were improved through to the higher of the adhesive level. Almost all parameters in this research did not meet standard execpted for density, moisture content and IB. The 14% adhesive level is the best resin content to produce passion fruit hulls particleboard, however, it is not an optimum condition.

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