Characteristics of Binderless Particleboards Made from Heat-treated Wood Species

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ABSTRACT

Extractives gave a different effect on the properties of binderless particle boards. This research was designed to investigate the characteristics of binderless particleboard from biomass waste of three wood species. To investigate the effect of its extractive, two kinds of particles were used in this research i.e particles with and without boiling pretreatment. Binderless particleboards were made by using hot pressing system at temperature 180^{0}C for 15 minutes. Sengon, jackfruit, and teak particles were used as raw materials. The method used was completely randomized design by two factors, which the first factor was wood species (sengon, jackfruit wood, and teak wood), while the second factor was pretreatment of the raw materials (with and without boiling pretreatment). Boiling pretreatment was done by soaking the particles in hot water with the temperature of 100±2^{0}C for 3 hours. The physic and mechanics properties of those boards were then evaluated based on JIS (Japanese Industrial Standard for Particleboard) A 5908. The results showed that interaction of both factors affected significantly on modulus of rupture. Wood species affected on density and internal bonding of the binderless particleboards. It showed that removing extractives by boiling pretreatment could increase modulus of elasticity of particleboard.

INTRODUCTION

Binderlessboard is well known as composite, which its self-bonding is improved only by activating the chemical components of the board constituents during steam/heat treatment. No synthetic resin is added in the manufacture of the boards, therefore the properties of the composites were significantly affected by the chemical composition of its raw material. Degradation of hemicellulose during steam/heat treatment to produce furan products is believed to play an important role in self-bonding (Shen, 1986). Therefore, binderless boards are usually prepared from non-wood raw materials, which are rich in hemicellulose. Widyorini et al. (2005a) found that partial degradation of the three major chemical components of the kenaf core by mild steam injection treatment increased the bonding performance and dimensional stability of the binderless boards. In addition, cinnamic acid, that ususally found in non-wood materials, was also contributed to the self-bonding mechanism (Widyorini et al., 2005b). So far it was still a few reports on manufacture of binderless board made from wood with good performance, especially by hot-pressing. Angles et al. (1999) found that by thermomechanically pretreatment, binderless panels made from mixture of softwood (spruce and pine) could be produced with good properties. Ando and Sato (2010) produced sugibinderless particleboards by hot-pressing at 200 ^{0}C with relatively high internal bonding, but lower properties in water resistance. In Indonesia, a large amount of woody biomass waste is generated in the manufacturing process of wood industry. Sengon, jackfruit, and teak wood from community forest are now commonly used in wood industry. Therefore, it is desirable to manufacture these boards without using any synthetic resins.

The removal of extractives is usually an important point to produce the good quality of resin-bonded boards. The extractives may not be compatible with the conventional resin binders, and may interfere the bonding properties of the composites. Extractives usually consist of extracted sugars, tannin, flavonoids, waxes, resin- and fatty acids, etc. Considering that no synthetic resin is applied in the binderlessboard, the effect of extractive in self-bonding mechanism is interesting to be investigated. It was still a few paper concerned on the effect of extractive on the self-bonding of binderlessboard. Widyorini et al. (2006) showed that removing extractive could improve bonding properties of bagasse binderlessboards, while it did not affect on properties of kenaf core binderlessboard. It also showed that after removal of ethanol-benzene extractive from bagasse rind, which usually contains silica and waxes, the mechanical properties of its boards were increased significantly. This research was designed to investigate characteristic of binderless particleboards made from sengon, jackfruit, and teak wood particles. The effect of the removal of hot water-extractives on the board properties is also discussed.

MATERIAL AND METHODS

Sengon, jackfruit, and teak wood particles were used as raw materials. Particles were screened to pass 2 mm. In order to investigate the effect of the removal hot water extractives on the binderlessboard properties, two kinds of particles were used in this research i.e particles without and with boiling pretreatment. Boiling pretreatment was done by soaking the particles in hot water with temperature 100±2^{0}C for 3 hours. Extractive content was calculated by weighing the samples before and after pretreatment. After pretreatment, all of particles were then air-dried for about 10 days.

The particles were then hand-formed into a mat by using forming box, followed by hot pressing into particleboard. Binderless particle boards were made using hot pressing system at temperature 180^{0}C for 15 minutes. The target densities of all binderless boards were 0.7 g/cm^3, with the dimension size was 25 cm x 25 cm x 0.7 cm. Three boards were manufactured in each condition. Prior to the evaluation of the mechanical and physical properties, the boards were conditioned at ambient conditions for about 10 days. The properties of the binderless particleboards were then evaluated basically according to the JIS A 5908-2003.

RESULT AND DISCUSSION

Hot water extractive content of particles could be shown in Table 1.

Table 1. Percent hot water extractive of particles

Wood species	Hot water extractives (%)
Sengon	9.8
Jackfruit	6.28
Teak	4.68

Hot water extractives of sengon particles in this research were higher when compared to jackfruit and teak particles. Figure 1 shows the condition of untreated and heat-treated particles. It showed that after pretreatment, the particles size become smaller and darker.

Figure 1. Untreated and heat-treated particles

Physical properties

All of binderless boards in this study could be manufactured without any delamination, with the range of board densities was 0.66–0.73 g/cm^3. The moisture content of the binderlessboards in the range of 6.8 to 8.4%, meeting the requirements of JIS A 5908 for particleboard. There are no significant differences between the moisture of the different panels with a probability of 95%.

The thickness swelling and water absorption are shown in Table 2. Thickness swelling varies between 5.8 and 14.7%. Almost of binderlessboard could meet the requirements of JIS A 5908 for particleboard. After pretreatment, the thickness swelling of sengon and teak binderlessboards tend to increase. However, pretreatment did not affect significantly on the thickness swelling value. These binderlessboards had a good dimensional stability compared to spruce and pine binderlessboard (Angles et al.,1999), which its thickness swelling varies between 12 and 37%.

Water absorption values of binderlessboards in this research are between 45 and 75% (% weight gained), which is relatively same with spruce and pine binderlessboards (Angles et al.,1999). However, the values were higher compared to bamboo binderlessboard (26 to 35%). Wood species, pretreatment and its interaction were not significantly affected on the water absorption value of binderlessboards. However, in case of sengon and teak binderlessboards, the water absorption of boards tend to increase when using the particles after pretreatment. Particles after boiling pretreatment become more smaller than before. This trend were also found in the bamboo particleboard, where binderlessboard made from fine particles had higher water absorption compared to board made from coarse particles (Widyorini et al., 2011).

Table 2. Thickness swelling and water absorption of binderless particleboard

Binderless particleboard	Thickness swelling (%)		Water absorption (%)	
	No pretreatment	Boiling pretreatment	No pretreatment	Boiling pretreatment
Sengon	7.9	14.7	58.6	74.7
Jackfruit	7.5	6.1	48.1	44.9
Teak	5.8	10.5	51.9	64.3

Mechanical properties

Figure 2 shows internal bond strength of binderlessboard. Binderlessboard made from jackfruit provided highest internal bond strength compared to other binderlessboard and met the requirements of JIS A 5908 for particleboard. Binderlessboards made from teak and sengon have relatively same in internal bond strength. Based on the Figure 2, it showed that after removal the hot water extractives, the internal bond strength of jackfruit binderlessboard became increase. The mean value of internal bond strength of binderlessboard made from jackfruit particles without and with boiling pretreatment was 1.73 kg/cm^2 and 1.96 kg/cm^2, respectively. Otherwise, the pretreatment didnot affect on the value of internal bond strength of teak and sengon binderlessboards. Hot water extractive usually contains *tannins*, gums, *sugars,* starches, and coloring matter. Removing extractive could improve bonding properties of bagasse binderlessboards, while it did not affect on properties of kenaf core binderlessboard (Widyorini et al., 2006). It showed that effect of extractive on self-bonding would depend on the type of extractive component. Further chemical analysis on the extractive of jackfruit particle is interesting, considering that only jackfruit binderlessboard could meet requirement of standard.

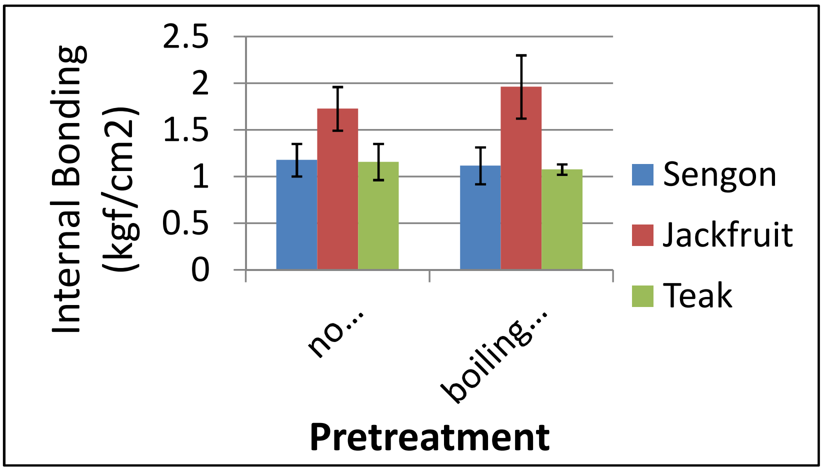

Figure 2. Internal bond strength of binderlessboards

Table 3 shows the values of modulus of rupture and modulus of elasticity of binderlessboards. The mean value of modulus of rupture varies between 27 to 67 kgf/cm^2. Statistical analysis showed that interaction of wood species and pretreatment affected significantly on modulus of rupture. In case of jackfruit and teak binderlessboard, removal of extractives could increase the modulus of rupture of binderlessboards.

Table 3 also shows that removal of extractives tends to increase modulus of elasticity. Pretreatment affected significantly on the value of modulus of elasticity of binderlessboards. Modulus of elasticity of binderlessboards in the range of 7,935 to 17,246 kgf/cm^2, which its were relatively low compared to standard for particleboard.

Based on the result, it showed that removal of extractives could improve only the properties of jackfruit binderlessboard. Widyorini et al. (2006) found that by removing the hot water extractives in bagasse particles, which were highly contained residual sugar, the mechanical properties of binderlessboards were increased. It is interesting to further analyze the extractives of jackfruit wood that affected in the self-bonding.

Table 3. Modulus of Rupture and Modulus of Elasticity of binderless particleboard

Binderless particleboard	Modulus of Rupture (kgf/cm^2)		Modulus of Elasticity (kgf/cm^2)	
	No pretreatment	Boiling pretreatment	No pretreatment	Boiling pretreatment
Sengon	67	52	13,023	14,091
Jackfruit	42	62	7,935	12,886
Teak	27	48	10,797	17,246

CONCLUSIONS

The interaction of wood species and pretreatment affected only on modulus of rupture of binderless board.Binderless particleboard made from jackfruit had highest internal bond strength compared other binderlessboards. Removing of hot water extractives could increase modulus of elasticity of the boards. The optimum properties could be obtained for jackfruit binderlessboards with boiling pretreatment, where the properties of the binderlessboards were 6% of thickness swelling, 45% of water absorption, 1.96 kgf/cm^2 of internal bonding, modulus of rupture 62 kgf/cm^2, and modulus of elasticity 12886 kgf/cm^2.

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