Binderless Particleboard Resistance to Termite Attack

S. Suhasman
Y. S. Hadi
M. Y. Massijaya
A. Santoso

Abstract

Three particleboard types, including urea-formaldehyde (UF), melamine-formaldehyde (MF), and binderless, were made from three wood species, sengon (*Paraserianthes falcataria*), gmelina (*Gmelina arborea*), and mindi (*Melia azedarach*). Wood particle sizes of 10 to 20 mesh were manufactured for the 30 by 30 by 0.7-cm (length by width by thickness) boards, with 0.75 g/cm^3 as the density target. Binderless particleboards were made through particle activation with hydrogen peroxide and ferrous sulfate as the catalyst, and the boards were hot pressed at 180°C for 12 minutes. For the purpose of comparison, conventional particleboards were made with UF and MF, with the resin level at 10 percent and the boards hot pressed at 120°C for 7 minutes. All particleboards were conditioned for 8 months prior to testing against the subterranean termite (*Coptotermes curvignathus* Holmgren) in laboratory and field tests, and against the dry wood termite (*Cryptotermes cynocephalus* Light) in laboratory tests. Results showed that wood species affected particleboard resistance in both of the subterranean termite tests and that the type of particleboard affected board resistance in field tests. Particleboard from sengon wood had the lowest resistance in both tests, followed by from gmelina and mindi woods, and particleboards with UF and MF resins had better resistance than binderless particleboard in field tests. Particleboard type and wood species did not affect board resistance to dry wood termite attack.

Environmental problems from the use of formaldehyde-based adhesives in particleboard manufacture have prompted researchers to develop methods to produce particleboard without adhesive. Several methods have been studied, including steam injection (Widyorini et al. 2005), enzymatic activation (Widsten et al. 2004), direct hot pressing (Hashim et al. 2011), and oxidation treatment (Karlsson and Westermark 2002, Widsten et al. 2003), to produce binderless particleboard or fiberboard. Unfortunately, research reports have been more focused on physical and mechanical properties of the boards and their bonding mechanisms, and so far there has been no report of binderless particleboard resistance to termites. Our previous studies (Suhasman et al. 2010, 2011) showed that binderless particleboard made of several wood species from a community forest has physical and mechanical properties that fulfill the Indonesian National Standard 03-2105-2006 (Standar Nasional Indonesia [SNI] 2006a) and Japanese Industrial Standard A 5908-2003 (Japanese Standards Association [JSA] 2003), which indicates that the prospects for binderless particleboard manufacturing technology are promising.

The study on use of wood species from a community forest was driven by the very limited log supply from natural forests for the wood industry in Indonesia. Log supply from community forests reached about 2 million m^3 in 2009, nearly half the 4.6 million m^3 harvested from natural forests (Ministry of Forestry 2010). The logs from community forests are generally harvested at a young age (4 to 6 y) and contain a lot of juvenile wood and sapwood proportion. This wood is more susceptible to termite attack compared with wood that is harvested at a mature age, as mentioned by Lukmandaru and Takahashi (2008), who found that 8-year-old teak wood (*Tectona grandis*) was more susceptible to termite (*Reticulitermes speratus* Kolbe) attack than teak that was 30 and 51 years old.

The authors are, respectively, Associate Professor, Forest Products Utilization and Processing Lab., Hasanuddin Univ., Makassar, Indonesia (suhasman@yahoo.com); Professor and Professor, Biocomposite Lab., Bogor Agric. Univ., Bogor, Indonesia (yshadi@indo.net.id [corresponding author], mymassijaya@yahoo.co.id); and Biocomposites Scientist, Forest Products Research Inst., Bogor, Indonesia (asanto10@yahoo.com). This paper was received for publication in March 2012. Article no. 12-00044.

Forest Prod. J. 62(5):412–415.

The resistance of particleboard to termite attack is an important parameter to assess the quality of the product because of the high level of damage caused by the insects. In Indonesia, there are two termite species that attack commercial and residential buildings frequently: the subterranean termite (*Coptotermes curvignatus* Holmgren) and the dry wood termite (*Cryptotermes cynocephalus* Light). Nandika et al. (2003) stated that losses caused by both termites are estimated at 2.80 trillion rupiahs or US$294 million in 2000. Numerous factors affect particleboard resistance to termite attack, such as raw material species, raw material treatment, resin type, and the presence and proportion of sapwood. Particleboard made from different wood species has different resistance to termite attack. Hadi et al. (2011) found that particleboard composed of high-density wood was more resistant to subterranean termite attack than lower density wood, as indicated by lower product weight loss and termite feeding rate. The influence of adhesive type against termite attack was suggested by Weaver and Owen (1992), but existing studies have not reported binderless particleboard resistance against termite attack. This study was aimed at evaluating the resistance against termite attack of binderless particleboard made from three wood species from a community forest.

Methods

Particleboard manufacture

Since the current research was focused on the comparison between binderless particleboard and conventional particleboards using urea-formaldehyde (UF) or melamine-formaldehyde (MF) adhesive, this research was conducted by using three wood species as raw materials. The three wood species from a community forest, namely, sengon (*Paraserianthes falcataria*), gmelina (*Gmelina arborea*), and mindi (*Melia azedarach*), were purchased from a wood material supplier. Particle sizes were 10 to 20 mesh, and binderless particleboards were made according to the method of Suhasman et al. (2011). The oxidation process of sengon wood was done with 5 percent hydrogen peroxide based on ovendry particle weight (wt/wt) and 5 percent ferrous sulfate based on hydrogen peroxide weight (wt/wt); the other two wood species were oxidized with 15 percent hydrogen peroxide (wt/wt) and 7.5 percent ferrous sulfate (wt/wt). The different amount of hydrogen peroxide and ferrous sulfate for gmelina and mindi woods compared with sengon wood were referred to in our previous study (Suhasman et al. 2011). In this study, the best physical and mechanical properties for binderless particleboard made from gmelina and mindi woods were found in the boards produced using 15 percent hydrogen peroxide and 7.5 percent ferrous sulfate, while the best characteristic for sengon binderless particleboard was found in the board produced using 5 percent hydrogen peroxide and 5 percent ferrous sulfate. The boards were hot pressed at 180°C for 12 minutes and 25 kg/cm^2 pressure and then conditioned at room temperature for 8 months. The moisture content of the boards prior to test was 7 to 10 percent determined by the ovendrying method.

For the purpose of comparison, UF and MF resins were used to manufacture particleboards with a resin level of 10 percent based on the ovendry weight of wood particles. The boards were hot pressed at 120°C for 7 minutes with the same pressure and conditioning period as the binderless particleboards. Board size was 30 by 30 by 0.7 cm (length by width by thickness), and 0.75 g/cm^3 was the density target.

Subterranean termite test

For the subterranean laboratory test, the termites were collected from the arboretum of the Forestry Faculty at Bogor Agricultural University in Indonesia. Collected termites were placed in a dark room in the laboratory with litter and wood for acclimatization for a month. Five 2 by 2 by 0.7-cm particleboard specimens were placed in 450- to 500-mL wide-mouth round glass jars with a bottom area of 25 to 30 cm^2. Two hundred grams of moist sand (7% moisture content under water holding capacity) and 200 healthy and active worker subterranean termites (*C. curvignathus*) were added to each glass jar, and the glass jars were placed in a dark room at 25°C to 30°C at more than 70 percent relative humidity for 4 weeks. To maintain the humidity, glass jars were weighed every 3 days and water was added if moisture loss was more than 2 percent. At the end of the test, particleboard weight loss percentage based on ovendry weight was determined (SNI 2006b). Fewer than 10 percent of the termites were still alive at the end of the test.

Field test

Eight 10 by 2 by 0.7-cm particleboard specimens were placed between two pieces of 2-cm-thick plywood with 1-cm stickers on both sides. The boards were placed horizontally on the ground and covered with dark cloth in the field (arboretum of Bogor Agricultural University Campus) for 6 weeks (Fig. 1). The test was carried out in September and October 2011. The degree of attack was monitored using sample control for 1, 2, 3, 4, 5, and 6 weeks of exposure. In the sixth week, sample control was heavily attacked. At the end of the test, the degree of failure of the particleboard was determined according to Pablo and Garcia (1997), as shown in Table 1. Each sample was visually observed, and the sample condition was determined.

Dry wood termite test

Dry wood termites were taken from the laboratory collection. A glass tube (3 cm in height by 1.8 cm in diameter) was placed on the center of five 5 by 2 by 0.7-cm particleboard specimens, and 50 worker dry wood termites (*C. cynocephalus*) were introduced into the glass tube. The samples were then put in a dark room for 12 weeks, and wood weight loss percentage was determined at the end of the test (SNI 2006b). Fewer than 10 percent of termites were alive at the end of the test for gmelina and mindi woods, and for sengon wood, fewer than 15 percent of the termites were still alive at the end of the test.

Data analysis

A 3×3 factorial in a completely randomized design was used to analyze the data. The first factor was wood species, namely, sengon, gmelina, or mindi, and the second factor was the type of particleboard, namely, binderless, UF, or MF. Duncan's test was used for further analysis if the factor was significantly different.

Results

The densities of the three wood species were 0.33 g/cm^3 for sengon, 0.42 g/cm^3 for gmelina, and 0.55 g/cm^3 for mindi, and these wood species belonged to the same durability class,

Figure 1.—Sample on the ground and covered with dark cloth.

not resistant to very not resistant, based on Indonesian standard classification (Martawijaya et al. 1989). All wood was from a community forest and still young (4 to 6 y), containing a lot of juvenile wood and sapwood proportion.

Subterranean termite test

Weight loss percentage in laboratory tests and degree of failure of particleboard specimens in field tests are shown in Tables 2 and 3, respectively. The analysis of variance is shown in Table 4, and Duncan's test for further analysis is shown in Table 5. The data in these tables show that wood species significantly affected the weight loss percentage of particleboard specimens in laboratory tests, and the further tests in Table 2 show that sengon particleboard had the greatest value, 8.7 percent, compared with other particleboards, 5.2 and 6.0 percent for gmelina and mindi, respectively. The last two particleboards were not significantly different from each other. Sengon wood had the largest amount of weight loss because its density was the lowest, resulting in it being more susceptible to termite damage. A similar result was suggested by Hadi et al. (2010), who stated that mindi wood was more resistant than sugi wood because of the difference in its density. Furthermore, particleboard type and interaction of particleboard type and wood species did not affect weight loss of the board, which indicated that binderless particleboard resistance to subterranean termite attack did not differ significantly from that of conventional particleboard made with UF and MF resins.

For field tests, both wood species and particleboard type affected failure degree of the particleboards, and interaction of both factors did not significantly affect this result. Sengon particleboard had the highest value with an average score of 97, followed by gmelina and mindi (with average scores of 84 and 43, respectively). These values were apparently affected by the wood density of the raw material for the particleboard. Based on their analysis of six hardwood species, Arango et al. (2006) suggested a significant inverse association between percentage of mass lost with termite attack and the specific gravity of the wood; in other words, wood with a higher specific gravity has more resistance to *Reticulitermes flavipes* Kollar termites. With regard to the particleboard type, binderless particleboard had the largest

Table 1.—Particleboard failure degree.

Sample condition	Score
No damage	0
Slightly attacked, 1%–25% failure	40
Moderately attacked, 26%–50% failure	70
Heavily attacked, 51%–75% failure	90
Very heavily attacked, 76%–100% failure	100

Table 2.—Board weight loss percentage by subterranean termite attack in laboratory tests.

Board type	Wood species[a]			Average
	Sengon	Gmelina	Mindi	
Binderless	11.33 ± 4.83	3.80 ± 1.30	5.74 ± 2.73	6.96
Urea-formaldehyde	6.77 ± 2.14	5.08 ± 2.02	5.36 ± 2.72	5.74
Melamine-formaldehyde	8.03 ± 3.10	6.84 ± 5.80	6.84 ± 2.59	7.24
Average	8.71	5.24	5.98	

[a] Average ± standard deviation of five replicates.

Table 3.—Board failure degree by subterranean termite attack in field tests.

Board type	Wood species[a]			Average
	Sengon	Gmelina	Mindi	
Binderless	100 ± 0.0	99 ± 3.5	59 ± 27.5	86
Urea-formaldehyde	93 ± 13.9	83 ± 21.2	35 ± 14.1	70
Melamine-formaldehyde	99 ± 3.5	69 ± 26.4	35 ± 14.1	68
Average	97	84	43	

[a] Average ± standard deviation of eight replicates.

Table 4.—Analysis of variance results.[a]

Source of variance	Significance level		
	ST laboratory test	ST field test	Dry wood termite
Wood species	0.023[b]	0.000[c]	0.306 NS
Board type	0.457 NS	0.000[c]	0.486 NS
Wood species × board type	0.261 NS	0.097 NS	0.570 NS

[a] ST = subterranean termite; NS = not significantly different.
[b] Significantly different ($P = 0.05$).
[c] Highly significantly different ($P = 0.01$).

Table 5.—Duncan's test for further analysis.[a]

Factor	ST laboratory test	ST field test
Wood species		
Sengon	A	D
Gmelina	B	E
Mindi	B	F
Board type		
Binderless	C	G
Urea-formaldehyde	C	H
Melamine-formaldehyde	C	H

[a] ST = subterranean termite. The same letters in a column indicate that the factors are not statistically different.

Table 6.—Weight loss percentage in the dry wood termite test.

Board type	Wood species[a]		
	Sengon	Gmelina	Mindi
Binderless	4.25 ± 0.95	3.32 ± 1.17	1.98 ± 1.25
Urea-formaldehyde	4.59 ± 2.08	2.96 ± 1.17	1.72 ± 0.66
Melamine-formaldehyde	2.04 ± 1.23	1.58 ± 0.59	2.78 ± 1.40

[a] Average ± standard deviation of five replicates.

value with the average score of 86, and this value was different from conventional particleboards, namely, UF and MF particleboards, with average values of 70 and 68, respectively. The conventional particleboards were not different from each other, and it was suggested that formaldehyde played a role in making particleboard more resistant to termite attack. In both the laboratory and field tests, sengon and binderless particleboards were more susceptible to attack by the subterranean termite.

Dry wood termite test

Weight loss percentage of particleboard in the dry wood termite test is shown in Table 6, and the analysis of variance is shown in Table 4. From these data, it is apparent that wood species, particleboard type, and interaction of these factors did not significantly affect weight loss of particleboard. Sengon and binderless particleboards had the highest values compared with the other wood species and particleboard types, respectively, which was similar to the subterranean termite test.

Conclusions

Wood species affected particleboard resistance to subterranean termites in both laboratory tests and field tests, and particleboard type affected resistance in field tests. Particleboard from sengon wood was found to have the lowest resistance to subterranean termites in both tests, followed by particleboard from gmelina and mindi woods. In field tests, particleboards with UF and MF resins had better resistance to subterranean termite attack than binderless particleboard. In the dry wood termite test, wood species, particleboard type, and interaction of the two factors did not affect particleboard resistance to termite attack.

Acknowledgments

We acknowledge the sponsorship of the Ministry of Education and Culture of Indonesia for conducting this research through National Strategic competitive research grant (2009 to 2011), and we acknowledge the assistance of Bogor Agricultural University and Hasanuddin University, both in Indonesia, for supporting the research.

Literature Cited

Arango, R. A., F. Green, K. Hintz, P. K. Lebow, and R. B. Miller. 2006. Natural durability of tropical and native woods against termite damage by *Reticulitermes flavipes* (Kollar). *Int. Biodeterior. Biodegrad.* 57:146–150.

Hadi, Y. S., E. Fajriani, D. Hermawan, M. Y. Massijaya, and N. Hadjib. 2011. Resistance of particleboard made from fast growing species to subterranean termite attack. *In:* Proceedings of the 8th Conference of the Pacific Rim Termite Research Group, February 28–March 1, 2011, Bangkok, Thailand; Pacific Rim Termite Research Group. pp. 142–145.

Hadi, Y. S., T. Nurhayati, and J. Jasni. 2010. Smoked wood as an alternative for wood protection against termites. *Forest Prod. J.* 60(6):496–500.

Hashim, R., N. Said, J. Lamaming, M. Baskaran, O. Sulaiman, M. Sato, S. Hiziroglu, and T. Sugimoto. 2011. Influence of press temperature on the properties of binderless particleboard made from oil palm trunk. *J. Mater. Design* 32:2520–2525.

Japanese Standards Association (JSA). 2003. Particleboards. Japanese Industrial Standard (JIS) A 5908-2003. JSA, Tokyo.

Karlsson, O. and U. Westermark. 2002. Resin-free particleboard by oxidation of wood. *In:* Proceedings of the 6th Pacific Rim Bio-Based Composites Symposium and Workshop on the Chemical Modification of Cellulosics, November 10–13, 2002, Portland, Oregon; Oregon State University. pp. 149–153.

Lukmandaru, G. and K. Takahashi. 2008. Variation in the natural termite resistance of teak (*Tectona grandis* Linn. Fil) wood as a function of tree age. *Ann. Forest Sci*. 65(7):708.

Martawijaya, A., I. Kartasujana, Y. I. Mandang, S. A. Prawira, and K. Kadir. 1989. Indonesian Wood Atlas. Vol. 2. Forestry Research and Development Agency, Forestry Ministry, Bogor, Indonesia.

Ministry of Forestry. 2010. Statistik 2009. Directorate of Natural Forest Development, Directorate General Forest Products. Ministry of Forestry, Jakarta, Indonesia.

Nandika, D., Y. Rismayadi, and F. Diba. 2003. Termite: Behavior and Control. Muhammadiyah University Press, Surakarta, Indonesia.

Pablo, M. R. S. and C. M. Garcia. 1997. Natural durability of anahau (*Livistona rotundifolia* Lam. Mart.). *Forest Prod. Res. Develop. Inst. J.* 23:69–76.

Standar Nasional Indonesia (SNI). 2006a. Particleboard. SNI 03-2105-2006. National Standardization Bureau, Jakarta, Indonesia.

Standar Nasional Indonesia (SNI). 2006b. Wood and wood products resistance test to wood destroying organisms. SNI 01.7207-2006. National Standardization Bureau, Jakarta, Indonesia.

Suhasman, M., Y. Massijaya, Y. S. Hadi, and A. Santoso, 2010. Hydrogen peroxide and ferrous sulfate activated wood particles for binderless particleboard. *J. Trop. Wood Sci. Technol*. 8(1):1–8.

Suhasman, M., Y. Massijaya, Y. S. Hadi, and A. Santoso. 2011. Particle oxidation time for the manufacture of binderless particleboard. *Wood Res. J.* 2(1):9–18.

Weaver, F. W. and N. L. Owen. 1992. The isocyanate-wood adhesive bond. *In:* Proceedings of the Pacific Rim Bio-Based Composites Symposium, November 9–13, 1992, Rotorua, New Zealand; New Zealand Forest Research Institute.

Widsten, P., P. Qvintus-Leino, S. Tuominen, and J. E. Laine. 2003. Manufacture of fiberboard from wood fibers activated with Fenton's reagent ($H_2O_2/FeSO_4$). *Holzforschung* 57:447–452.

Widsten, P., S. Tuominen, P. Qvintus-Leino, and J. E. Laine. 2004. The influence of high defibration temperature on the properties of medium-density fiberboard (MDF) made from laccase-treated softwood fibers. *Wood Sci. Technol*. 38:521–528.

Widyorini, R., T. Higashihara, J. Xu, T. Watanabe, and S. Kawai. 2005. Self-bonding characteristics of binderless kenaf core composites. *J. Wood Sci*. 39:651–662.