Smoked Wood as an Alternative for Wood Protection against Termites

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Abstract

Mindi wood (*Melia azedarach*) and sugi wood (*Cryptomeria japonica*) were smoked for 15 days using mangium wood (*Acacia mangium*), and for comparison purposes, wood preserved with 5 percent borax, polystyrened wood, and untreated control wood were prepared. All of the wood specimens were tested for resistance to (1) subterranean termites (*Coptotermes curvignathus* Holmgren) in the laboratory, (2) dry wood termites (*Cryptotermes cynocephalus* Light) in the laboratory, and (3) subterranean termites in the field or via in-ground tests. The results showed that (1) mindi wood was more resistant than sugi wood to subterranean termite and dry wood termite attacks; (2) with regard to the Indonesian termite test standard, smoke treatment increased wood resistance to termite attacks, matching the highest resistance class of subterranean termites and dry wood termites; and (3) mindi wood offered equal resistance compared with polystyrened wood and wood preserved with borax, but in terms of the in-ground test, the smoke treatment did not affect wood resistance to termite attack, presumably because of leaching that occurred during the exposure test.

Prior to the year 2000, the demand for Indonesian logs was 20 to 29 million m^3 per year, and more than 90 percent of this demand was supplied by the natural forest stands, but in the period 2000 to 2008, log production ranged from 9 to 32 million m^3 per year, approximately 63 percent of which was supplied from plantation grown wood (calculated from Ministry of Forestry 2002, 2009). Plantation forest will be more important in supplying the demand for logs in the future in order to ensure sustainable forest management, and about 4.3 million hectares of fast-growing species have been developed, with a cutting cycle of 10 to 15 years (e.g., mangium [*Acacia mangium*], sengon [*Paraserianthes falcataria*], pine [*Pinus merkusii*], and mindi [*Melia azedarach*]; Anonymous 2005, Ministry of Forestry 2009). Mindi tree is generally planted by community- and state-owned enterprises because of its fast growth rate. In Bogor the 10-year tree has a 38-cm diameter, with a 10-m branch free stem, and the wood density is 0.53 g/cm^3 (0.42 to 0.65 g/cm^3), a strength class (II to III) equal to that of mahogany (*Swietenia mahagoni*) and red meranti (*Shorea* sp.) woods, and a durability of Class IV to V or poor to very poor resistance (Forest Research and Development Agency 2001).

Wood from plantation forests generally contains a large amount of juvenile wood, which is inferior in physical–mechanical properties as well as in biodeterioration resistance when compared with old growth wood. Even the existing houses in Indonesia are primary built with old growth wood; however, the economic losses of various buildings as a result of termite attack measured in 1995 were about US$200 million (Rakhmawati 1995), and in 2000 termite losses were from US$200 million to US$300 million (Yoshimura and Tsunoda 2005). It is likely that these losses will increase in the future if the juvenile wood from plantation forests is not preserved prior to its use for building materials.

The service life of timber can be extended by using various chemical treatment methods, but most chemical treatments have some adverse effects on the environment in terms of pollution and are also considered poisonous to humans and other living organisms. Hadi et al. (2005) stated that natrium pentachlorophenol was very effective for wood preservation purposes prior to 2000, but in the early 21st century it was banned in almost every country because of its toxicity to living organisms and the environment. The Indonesian Standard SNI 03-3528-1994 recommended that appropriate preservatives for timber are borax, copper-chrome-arsenate (CCA), copper-chrome-boron (CCB), copper-chrome-fluoride (CCF), and boron-fluoride-chrome-

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arsenate (BFCA); Hoesin (2007) and Kartal and Ayrilmis (2005) claimed that blockboard specimens with boron-treated veneers demonstrated increased durability against decaying fungi and termite attack.

Polystyrened wood also can be considered for wood preservation. Hadi et al. (2002, 2003) impregnated monostyrene into pine (*P. merkusii*), sengon (*P. falcataria*), and rubberwood (*Hevea brasiliensis*) and polymerized it with heat (at 60°C) for 24 hours. Next they tested for *Trametes versicolor* (a white rot fungus), *Tyromyces palustris* (a brown rot fungus), subterranean termite, and marine borer, and the results showed that among the three tested woods, pine had the greatest resistance to white rot and brown rot fungal attacks, and the polystyrene wood had much greater resistance than untreated wood to brown rot fungi, white rot fungi, subterranean termite, and marine borer attacks. Devi et al. (2003) found that the biodegradability of polystyrene wood was improved upon treatment with styrene.

Wood smoke contains a large number of polycyclic aromatic hydrocarbons, and it is composed mainly of phenols, aldehydes, ketones, organic acids, alcohols, esters, hydrocarbons, and various heterocyclic compounds (Stołyhwo and Sikorski 2005). Sunen et al. (2003) studied the activity of smoke wood condensates against bacteria *Aeromonas hydrophila* and *Listeria monocytogenes* in vacuum-packaged, cold-smoked rainbow trout stored at 4°C, and the results showed that all smoke extracts showed activity against *A. hydrophila*.

Mangium wood has an average density of 0.51 g/cm^3 (0.34 to 0.71 g/cm^3; Hadjib et al. 2007), is a fast-growing species, and the silviculture technique copies system regeneration can be applied to tree stands. Mangium stands are intensively planted and can reach about 1 million hectares (Sudrajat 2007); the research concerning use of wood is also intensively done. The wood is used for fiber production, furniture, building materials, and charcoal production. Nurhayati et al. (2005) analyzed mangium wood vinegar, a condensate from wood smoke, which consists of acetic acid, methanol, phenol, *o*-cresol, furfural, and cyclohexane. The smoke is a by-product created during the pyrolyzation process used to make charcoal, and while it has not yet been used as waste because it evaporates into the air, it could potentially be useful as a preservative of wood.

The purpose of this work was to determine the resistance of smoked mindi and sugi (*Cryptomeria japonica*) woods to subterranean termite attack in laboratory tests and in the field or via in-ground tests and to determine the resistance to dry wood termite attack in laboratory tests. The wood specimens were smoked with mangium wood for 15 days, and for comparison purposes, untreated wood specimens (as a control), polystyrened wood, and preserved wood with borax were also tested.

Materials and Methods

Materials

Mindi wood specimens from Bogor, West Java, Indonesia, and sugi specimens from Japan were used to determine termite attack resistance. Air-dried mangium wood was pyrolyzed to produce charcoal, and the resulting smoke (a by-product) was used for smoking the wood specimens over the course of 15 days, the smoking period referenced in the work of Hadi et al. (2009). Pyrolysis was performed in a metal drum with a 200-liter capacity, and then the smoke was passed into another drum prior to placement in the smoking chamber. For comparison purposes, the following were prepared: (1) polystyrened wood, as a reference for wood plastic; (2) wood preserved with 5 percent borax, as a reference for conventional wood preservation; and (3) untreated wood (as a control).

To prepare the polystyrened wood, air-dried wood was vacuumed at 600 mm Hg for 30 minutes; this was followed by immersion in monomer styrene, with pressure applied at 10 kg/cm^2 for 30 minutes. The wood samples were wrapped in aluminum sheets and put into the oven at 100°C for 24 hours. After removing the aluminum cover, the sample wood was weighed for polymer styrene loading calculations. In the case of the borax treatment, wood specimens were soaked in 5 percent borax (mixture of borax and boric acid in 1:1.5 ratio, wt/wt) for 24 hours using a cold soaking process. All of the treated specimens were conditioned at room temperature for 1 month prior to testing. The specimen dimensions of the mindi and sugi woods were 2 by 0.8 cm in cross section or width by thickness, respectively, and the length of the samples was determined according to the test purposes; each test was replicated five times.

Subterranean termite test

Five wood specimens measuring 2.5 by 2 by 0.8 cm (length by width by thickness, respectively) were placed in a 450- to 500-mL wide-mouth round glass jar with a bottom area of 25 to 30 cm^2, and 200 g of moist sand (7% moisture content under water holding capacity) and 200 healthy and active worker subterranean termites (*Coptotermes curvignathus* Holmgren) were placed in each jar. The glass jars were placed in a dark room for 4 weeks. Each week the bottles were weighed, and if the moisture content of the sand was reduced by 2 percent or more, water was added to reach the moisture content standard. At the end of the test, wood weight loss and termite mortality percentages and the resistance class of the wood were determined; the results are provided in Table 1 (Standar Nasional Indonesia [SNI] 2006).

Dry wood termite test

Five wood specimens measuring 5 by 2 by 0.8 cm (length by width by thickness, respectively) were placed in the center of a glass tube (3-cm height by 1.8-cm diameter), and 50 worker dry wood termites (*Cryptotermes cynocephalus* Light) were introduced into the glass tube. The samples were placed in a dark room for 12 weeks. At the end of the test, as with the subterranean termite test, wood weight loss and termite mortality percentages, and the resistance class of the wood were determined; the results are provided in Table 2 (SNI 2006).

Table 1.—Resistance class against subterranean termites (SNI 01.7207-2006).

Sample condition	Mass loss (%)
I: Very resistant	<3.52
II: Resistant	3.52–7.50
III: Moderate	7.50–10.96
IV: Poor	10.96–18.94
V: Very poor	>18.94

Table 2.—Resistance class against dry wood termites (SNI 01.7207-2006).

Sample condition	Mass loss (%)
I: Very resistant	<2.0
II: Resistant	2.0–4.4
III: Moderate	4.4–8.2
IV: Poor	8.2–28.1
V: Very poor	>28.1

In-ground test

Five wood specimens measuring 20 by 2 by 0.8 cm (length by width by thickness, respectively) were vertically buried 15 cm deep in the ground soil in Bogor, West Java, Indonesia, for a period of 3 months. At the end of the test, the degree of wood failure was determined, as described in Table 3 (Pablo and Gracia 1997).

Data analysis

A 2 $\times$ 4 factorial in completely randomized design was used to analyze the data; the first factor was wood species, namely mindi and sugi, and the second factor was wood treatment type, namely control wood, smoked wood, polystyrened wood, and preserved wood with borax. Duncan's test was used for further analysis if the factor was significantly different.

Results and Discussion

For mindi wood, retention of 5 percent borax reached 5.22 kg/m^3; for sugi wood, retention reached 12.2 kg/m^3. The polystyrene polymer loading of mindi reached 41.0 percent, and that of sugi reached 74.9 percent. Sugi wood was more easily penetrated with borax and styrene monomer because of its low density (0.34 g/cm^3) compared with that of mindi wood (0.43 g/cm^3), and Hadjib et al. (2000) also determined that lower density wood had a higher retention rate in the case of Impralit CCB 3 percent preservative. For smoked wood, after the smoking process some chemical residues were deposited on the surfaces, which were indicated by a longer smoking period resulting in darker color.

Table 3.—Wood failure degree.

Sample condition	Score
No damage	0
Slight attack, 1%–25% failure	40
Moderate attack, 26%–50% failure	70
Heavy attack, 51%–75% failure	90
Very heavy attack, 76%–100% failure	100

Subterranean termite test

After 4 weeks of testing against subterranean termites in the laboratory, the wood weight loss and termite mortality of both wood species were measured; results are shown in Table 4. The resistance class is outlined in Figure 1, the results of the analysis of variance are shown in Table 5, and the results of Duncan's test are shown in Table 6.

According to Table 4, control mindi wood showed greater resistance to termite attack than did control sugi wood, which was indicated by the lower wood weight loss and higher termite mortality of mindi wood. With regard to weight loss percentage for control woods, mindi belongs to Resistance Class III, indicating moderate resistance, and sugi belongs to Resistance Class V, indicating very poor resistance (SNI 2006). Mindi wood has a higher density than sugi wood, with the result that mindi is potentially more resistant than sugi. This finding, mentioned by Arango et al. (2006), is based on their analysis of six hardwood species, which indicated a significant inverse association between percentage of mass lost and specific gravity; in other words, wood with a higher specific gravity has more resistance to *Reticulitermes flavipes* Kollar termites.

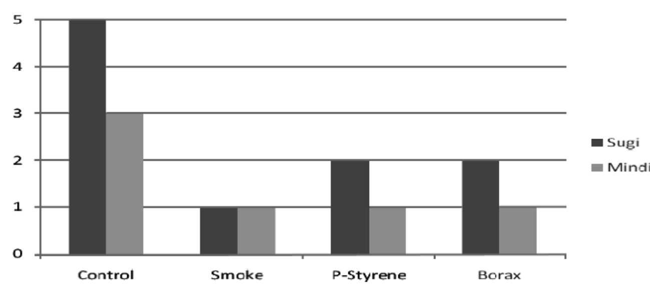

Figure 1.—Resistance class to subterranean termites (SNI 2006).

Table 5.—Results of analysis of variance.[a]

Item	Wood species (A)	Treatment (B)	Interaction (AB)
Subterranean termite			
Wood weight loss	**	**	**
Termite mortality	**	**	**
Dry wood termite			
Wood weight loss	**	**	**
Termite mortality	**	**	**
In-ground test			
Attack degree	**	**	**

[a] ** = highly significant difference ($P < 0.01$).

Table 4.—Wood weight loss and termite mortality (±standard deviation) for subterranean termite test.

Treatment	Sugi		Mindi	
	Weight loss (%)	Mortality (%)	Weight loss (%)	Mortality (%)
Control	45.4 ± 5.4	3.8 ± 1.6	10.3 ± 3.1	61.3 ± 4.2
Smoked	0.78 ± 0.82	100 ± 0	0.64 ± 0.33	100 ± 0
Polystyrene	6.94 ± 2.41	68.1 ± 29.6	1.34 ± 0.98	100 ± 0
5% Borax	7.2 ± 4.2	100 ± 0	2.78 ± 1.60	100 ± 0

Table 6.—Results of Duncan's test.[a]

No.	Test	Sugi				Mindi			
		Control	Smoked	Polystyrene	Borax	Control	Smoked	Polystyrene	Borax
1	Subterranean termite								
	Weight loss	A	C	B	B	B	C	C	C
	Mortality	C	A	B	A	B	A	A	A
2	Dry wood termite								
	Weight loss	A	C	C	C	B	C	C	C
	Mortality	E	A	B	A	D	A	C	A
3	In-ground test								
	Attack degree	A	A	CD	A	AB	BC	D	D

[a] The same letter in each row indicates that values are not significantly different ($P > 0.05$).

According to the data presented in Tables 5 and 6, smoke treatment significantly affected wood resistance to subterranean termite attack, which was indicated by lower wood weight loss and higher termite mortality compared with the control wood. With regard to wood weight loss percentage, the resistance class of both smoked woods increased to Class I (very resistant). Compared with the other treatments, smoked sugi wood was more resistant than polystyrened wood and wood preserved with borax, but smoked mindi wood had the same resistance when compared with both treated woods. It can be concluded, then, that smoke treatment can be applied for wood preservation and that this treatment is equally effective compared with polystyrened wood and wood preserved with borax with regard to the subterranean termite test.

Dry wood termite test

After 12 weeks of testing dry wood termites in the laboratory, the wood weight loss and termite mortality of both wood species were measured; both are shown in Table 7. The resistance class is depicted in Figure 2, results of the analysis of variance are presented in Table 5, and the results of Duncan's test are presented in Table 6. Mindi wood controls had better resistance than sugi wood controls, which was indicated by lower wood weight loss and higher termite mortality. With regard to wood weight loss, control sugi wood belongs to Class IV (indicating poor resistance to dry wood termite attack), and mindi wood belongs to Class III (indicating moderate resistance; SNI 2006).

According to the data presented in Tables 5 and 6, smoke treatment could increase wood resistance to dry wood termite attack, which was indicated by lower wood weight loss and higher termite mortality compared with the control wood. Both smoked woods became Resistance Class I (very resistant to dry wood termite attack), and these results were not different from those associated with polystyrened wood and wood preserved with borax. Smoke treatment can be applied for wood preservation for mindi and sugi, and this treatment is equally effective compared with polystyrened wood and wood preserved with borax with regard to the dry wood termite test.

In-ground test

Wood failure degree after a 3-month in-ground test is shown in Table 8, analysis of variance results are described in Table 5, and Duncan's test results are shown in Table 6.

According to Duncan's test (Table 6), smoke treatment did not statistically affect termite attack resistance, or both smoked wood species showed the same degree of wood failure compared with control wood. Both mindi wood and sugi smoked wood had a higher wood failure degree compared with polystyrened wood and wood preserved with

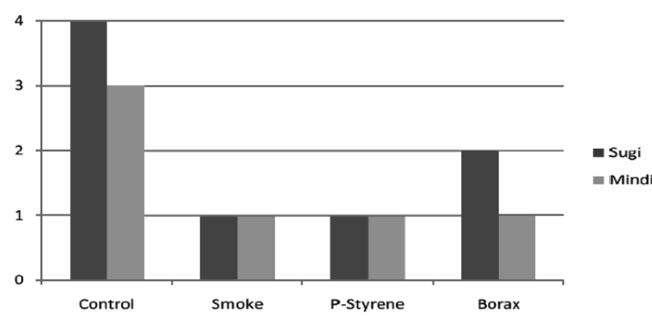

Figure 2.—Resistance class to dry wood termites (SNI 2006).

Table 8.—Wood failure degree (±standard deviation) for in-ground test.

Treatment	Sugi	Mindi
Control	100 ± 0.0	72 ± 20.5
Smoked	78 ± 11.0	46 ± 13.4
Polystyrene	34 ± 37.1	14 ± 31.3
5% Borax	94 ± 13.4	8 ± 17.9

Table 7.—Wood weight loss and termite mortality (±standard deviation) of dry wood termite test.

Treatment	Sugi		Mindi	
	Weight loss (%)	Mortality (%)	Weight loss (%)	Mortality (%)
Control	16.8 ± 5.7	22.0 ± 5.1	6.19 ± 1.65	44.4 ± 10.8
Smoked	1.20 ± 0.71	100 ± 0	0.91 ± 0.28	100 ± 0
Polystyrene	1.61 ± 0.72	83.6 ± 10.2	1.39 ± 0.87	68.8 ± 4.8
5% Borax	2.34 ± 1.38	100 ± 0	1.94 ± 0.85	100 ± 0

borax. The ineffectiveness of the smoke treatment could stem from the possibility that the chemicals from the smoke were leached during the exposure test, whereas the Bogor site test has high precipitation, with a rate of more than 4,000 mm/y. For the other treatment, borax preservative for sugi wood did not enhance resistance to subterranean termite attack, but borax treatment for mindi wood provided greater resistance against termite attack. Polystyrened wood showed greater resistance compared with the other wood treatments. Both wood species were more likely to deteriorate by termite attack, and it was clearly evident that significant fungal attack had not occurred.

Conclusion

Based on the findings in this work, it could be concluded that mindi wood was more resistant than sugi wood in terms of subterranean termite and dry wood termite attacks because mindi wood had a density of 0.43 g/cm^3 and sugi wood a density of 0.34 g/cm^3. By using mangium wood for the smoking process during a 15-day period, smoke treatment increased the resistance class of sugi and mindi woods to Class I against subterranean termites and dry wood termites (per the Indonesian standard), and the resistance class was the same as that of the polystyrened wood and the borax-treated wood. However, for the in-ground test, the smoke treatment did not affect the resistance of the wood to termite attack, probably because of the leaching that occurred during the exposure test.

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