Biological Resistance of Jabon Wood Against Subterranean and Drywood Termites after Combined Impregnation and Compression Treatment

Jamaludin Malik, Adi Santoso, Jasni, and Barbara Ozarska

Abstract

This study investigated Jabon wood [*Anthochepalus cadamba* (Roxb) Miq) impregnated with natural phenolic resin from Merbau extractives (ME) and subjected to hot compression treatments. The resistance of this wood to subterranean termites (*Coptotermes curvignathus* Holmgren) and drywood termites (*Cryptotermes cynocephalus* Light) was tested. The types of pre-treatments utilized were impregnation, repeated-impregnation, hot compression, and a combined treatment of impregnation and hot compression. The impregnation pre-treatment used crude ME and selected polymerized ME (PME22 and PME33). The resistance evaluation was based on the weight loss of the samples according to the Indonesian standard of SNI 7207. Untreated samples of jabon were classified as class V (susceptible) against subterranean termites and class IV (non-resistant) against drywood termites. Impregnation using only ME improved the resistance of Jabon wood against subterranean termite from class V to class IV. Against drywood termites, it changed from class IV to III and II. The resistance class of III against subterranean termites resulted from the treatments of most types of polymerized ME. Thus, it can be concluded that the extractives contributed greatly to the protection of a less durable wood species against termite attack. Merbau extractives also distinctly improved the resistance of jabon wood from class IV (non-resistant) to class II (resistant).

Keywords: resistance, subterranean termite, drywood termite, impregnation, hot compression.

Introduction

Although there are differences in opinion as to whether wood preservation should be included in the field of wood modifications, it can be found in many studies that biocidal treatments improve wood durability. Taking environmental awareness into account, Homan and Jorissen (2004) and Hill (2006) proposed the exclusion of biocidal treatments and thus the separation of wood preservation from wood modification, stating that it should not involve the production of a product that contains toxic residues. However, wood preservation does meet at least one of the criteria of wood modification; according to Hill (2006), wood modification may be used to bring about an improvement in decay resistance and dimensional stability, reduce water sorption, improve weathering performance, etc. Wood modification alters the properties of materials to prevent the loss of enhanced performance during the lifetime of a wood product. For example, using conventional technologies, the decay resistance of wood can be increased by the application of wood preservatives (e.g., boron, creosote, etc.) (Hill 2006; Coggins 2008).

Recently, wood preservation has changed in regards to biocide toxicity, which can be attributed to increasing legislative environmental pressure and awareness (Villanueva *et al*. 2013). Consequently, many bioactive termite control compounds have been withdrawn from the market in the past decade due to environmental or toxicity concerns (Little *et al*. 2010). Therefore, non-biocidal and environmentally friendly alternative modification methods, such as the chemical or thermal modification of the wood cell wall, are in high demand (Hill 2006).

There have been various studies on eco-friendly treatments to improve resistance against biological attack. He *et al*. (2011) treated fast-growing poplar wood (*Populus euramericana*) from a 15 year-old plantation by impregnation using styrene (ST) and a combined solution of glycidyl methacrylate (GMA)-ST at a 1:4 molar ratio. Specimens to be tested for termite resistance were cut to the dimensions of 6.4 mm (L) by 25 mm (T) by 25 mm (R). Before the impregnation, the samples were oven-dried at 103 ± 2 °C for 24 h. Impregnation was conducted through vacuum at 0.05 MPa for 15 min, 0.1 MPa for 30 min, and then immersed in the solution at ambient pressure for 3 h. The untreated and treated wood specimens were exposed to subterranean termites (*Coptotermes formosanus*) in containers at a normal environmental temperature (25 ± 2 °C). The results showed that ST-treated polymer infused wood (PIW) exhibited 5.4 times higher resistance to termites than untreated wood; GMAST-treated PIW showed 9.3 times higher resistance. The weight losses of ST-treated and GMA-ST-treated PIWs were 4.6 and 2.7%, respectively.

Unsal *et al*. (2009) studied the resistance of solid wood specimens from Scotch pine (*Pinus sylvestris* L.) with dimensions of 250 mm by 500 mm by 18 mm against *Reticulitermes flavipes* Kollar (Eastern subterranean termites). Solid panels were first hot-pressed at 120 or 150 °C and a pressure of either 5 or 7 MPa for 60 min. For the termite test, five specimens (20 mm by 20 mm by panel thickness) were used for each treatment group. The specimens were placed in a glass container with moist sand and 1 g of *R. flavipes*. The containers were maintained at 25 °C and 80% relative humidity (RH) for four weeks. The compression treatment resulted in the improved resistance of wood against termite attacks. Samples treated with compression at 7 MPa and 120 °C gave higher resistance than the other treated samples and the controls.

Other studies conducted on various wood species using eco-friendly preservatives also revealed a bio-resistance improvement against termite attacks. A phenolic resin (PF) can enhance the decay and termite resistance of particleboard (Kajita and Imamura 1991). Impregnation with dimethyloldihydroxy-ethyleneurea (DMDHEU) can prevent the sapwood of Scots pine (*Pinus sylvestris*) from weight losses in contact with subterranean termites (Militz *et al*. 2011). Little *et al*. (2010) showed that termites avoid wood that contains relatively high levels of synthetic or natural antioxidants that are benign to humans. Consequently, the reason why some heartwoods are naturally resistant to termites may be that they contain relatively high levels of phenolic extractives, which have antioxidant properties.

In Indonesia, termite attack is the most important problem in wood utilization because 85% of wood species in the country are susceptible to biodeterioration, and only 15% are classified into durable classes (class I and II) (Martawijaya 1996; Martawijaya and Barly 2010). There are approximately 200 species of termites living in forest, farming, estate, settlement, and business areas (Nandika 2015). Financial losses resulting from termite attacks have continuously increased from IDR 1.67 billions in 1995 to IDR 8.68 billions in 2015 (Rakhmawati 1996; Nandika 2015).

This paper examined the effect of impregnation treatment on jabon wood (*Anthochepalus cadamba* (Roxb) Miq), using natural phenolic resin from Merbau extractives (ME) combined with hot compression treatments. The resistance of treated vs. untreated wood was tested against subterranean (*Coptotermes curvignathus* Holmgren) and drywood (*Cryptotermes cynocephalus* Light) termites. Because jabon wood is of the lowest class of durability (class V), it has limited uses (Hidayat 2012; Martawijaya *et al*. 1989).

Materials and Methods

Wood Sample Preparation

Five-year-old jabon wood was harvested and sawn. Samples were prepared only from sapwood with various dimensions. All samples were kiln-dried to 12% moisture content and then grouped and coded based on the pre-treatment given. The sample dimensions followed the BSN (2014) standard for wood resistance testing against wood destroying organism with the dimensions of 25 mm (L) by 25 mm (T) by 5 mm (R) and was used for the impregnation and testing against subterranean termites. Samples with the dimensions of 50 (L) mm by 25 mm (T) by 25 mm (R) were prepared for impregnation and testing against drywood termites. Four replicates of the samples were made for each treatment.

The types of pre-treatments were impregnation, repeated-impregnation, hot compression, and a combined treatment of impregnation and hot compression. The impregnation pre-treatment used crude Merbau extractives (ME) and selected polymerized Merbau extractives (PME22 and PME33). The Merbau extractives were obtained from boiling Merbau wood sawdust in hot water (70 – 80 °C) (Malik *et al*. 2016). Samples with the impregnation treatment were divided into three groups according to how many times the treatment was done (one, two, or three impregnations) and were coded accordingly, as shown in Table 1.

Pre-Treatment by Impregnation

Impregnation treatment was conducted in a vacuum-pressure vessel (a vertical container with 6" in diameter; non-lethal service; local made) as a pre-treatment for jabon wood samples before biologically testing their termites. The samples were placed into open-top containers in a vacuum-pressure unit, which was connected by a hose to the container with liquid of polymerized Merbau extract (Fig. 1a). The tube containing the samples was vacuumed using the compressor at a power of 0.1 kg/cm^2 for 30 min. The vacuum was then released, and the impregnation liquid filled the container, which caused the liquid level to be 10 cm higher than the submerged wood samples. Pressure was then applied and maintained at 15 kg/cm^2 for 1 h.

Impregnation was carried out 2 to 3 times to investigate the effect of replication on termite attacks. The second and third impregnations were applied with the same procedure. Each impregnation was done after the samples from the previous impregnation were conditioned at room temperature (28 °C) to reach a constant weight (Fig. 1b). All specimens were drained and stored in a conditioning room at 12% moisture content until a constant weight was obtained.

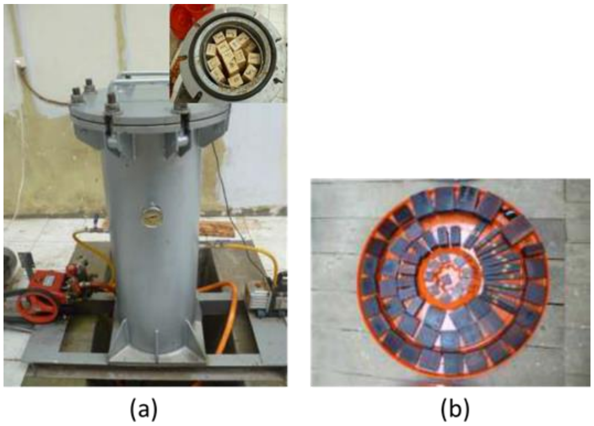

Figure 1. Treating sampels in a vacuum pressure vessel (a) and conditioning them (b).

Pre-Treatment by Hot Compression

Hot compression pre-treatment was conducted in an open machine system (ex Becker and Van Hullen, Germany). The wood samples, 400 x 400 mm, were placed on the working table or hot plate. The maximum pressure force was 64 T, and the maximum temperature 200 °C. In this experiment, the working pressure applied to the samples was 10 kg/cm^2 for 20 min at a temperature of 150 °C until the compressed samples reached a selected compression ratio (CR), i.e. 33% and 50%.

Termite Tests

The treated and untreated wood samples were exposed to subterranean termites (*Coptotermes curvignathus*, Holmgren) drywood termites (*Cryptotermes cynocephalus*, Light). The test procedures were according to the Indonesian National Standard for wood resistance testing against wood destroying organisms (BSN 2014).

Exposure to Subterranean Termites. Ten samples from each pre-treatment were placed on the base of a cylindrical test container/glass jar (100 mm diameter) in a standing position. Next, 200 g of unsterilised sand with a moisture content (MC) of approximately 7% (under water holding capacity) and 200 subterranean termites were added to the container (Fig. 2). Each container was prepared for each pre-treatment. All containers were placed in a dark room at normal environmental temperatures, ranging from 28 to 32 °C, for 4 weeks. If the MC of the sand decreased more than 2%, water was sprayed into the jar to keep the current sand MC equal to the initial MC (approximately 7%). The termite test containers were examined every week at the same time, and the dead termites were removed and tallied. The living termites in each container were counted after 4 weeks of exposure to subterranean termites. At the end of the test period, all of wood samples were washed, dried at 60 ± 2 °C for 48 h, and weighed. The weight loss of the specimens was then calculated using Eq (1).

$$\boldsymbol{P = \frac{W1 - W2}{W2} x\ 100} \qquad (1)$$

where P was the mass (weight) loss (percent), W1 was the weight of the sample before feeding (g) and W1 was the weight of the sample after feeding (g).

Table 1. The Code of Samples Used for Termite Test

Code	Treatment
A	Untreated samples as the control
B	Impregnated using ME for 1x
C	Impregnated using ME for 2x
D	Impregnated using ME for 3x
E	Impregnated using PME22 for 1x
F	Impregnated using PME22 for 2x
G	Impregnated using PME22 for 3x
H	Impregnated using PME33 for 1x
I	Impregnated using PME33 for 2x
J	Impregnated using PME33 for 3x
K	Combined treatment of impregnation using PME 33 (1x) + Hot pressing by 33% CR
L	Combined treatment of impregnation using PME 33 (1x) + Hot pressing by 50% CR
M	Impregnated using ME (1x)+ Hot press by 33% CR
N	Impregnated using ME (1x)+ Hot press by50% CR
O	Hot press by 33% CR without impregnation
P	Hot press by 50% CR without impregnation

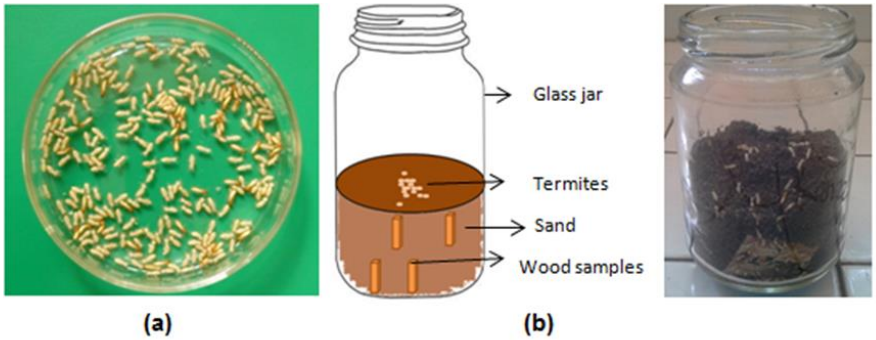

Figure 2. Subterranean termites (a) and the containers used in the investigation.

Table 2. Resistance Classes of Woods to Subterranean Termite (BSN 2014)

Class	Weight Loss (%)	Class of Resistance
I	< 3,5	Very resistant
II	3.51 – 7.52	Resistant
III	7.53 – 10.96	Moderately resistant
IV	10.97 – 18.94	Non-resistant
V	> 18.94	Susceptible

The resistance classes of examined jabon wood samples were determined based on weight loss, the number of living termites, and the degree of attack (Table 2 and Table 3) (BSN 2014).

Table 3. Degree of Subterranean Termites Attack (BSN 2014)

Sample Condition	Degree of Attack (% damage)
No damage on surface area	0 – 5
Slightly attacked	5 – 15
Moderately attacked	16 – 35
Heavily attacked	36 – 50
Very heavily attacked	> 50

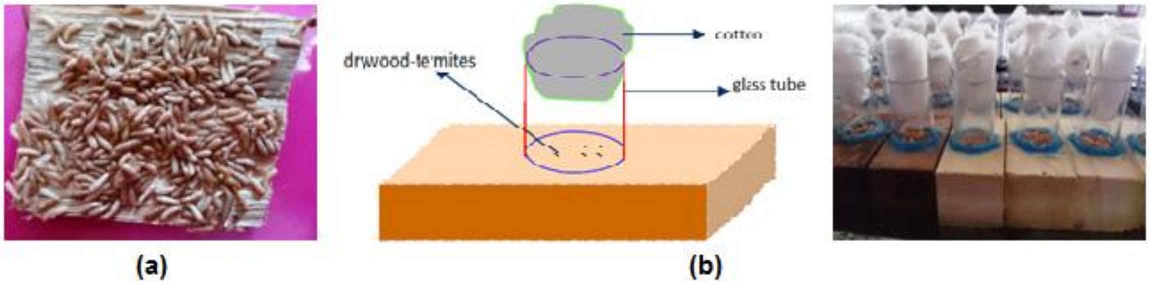

Figure 3. Drywood termites (a) and feeding method for its attack investigation (b)

Table 4. Resistance classes of wood to drywood termite (BSN 2014)

Class	Weight loss (%)	Class of resistance
I	< 2	Very resistant
II	2 – 4,4	Resistant
III	4.45 – 8.2	Moderately resistant
IV	8.3 – 28.1	Non-resistant
V	>28.1	Susceptible

Exposure to Drywood Termite. A glass tube (diameter, 18 mm; height, 30 mm) was placed vertically on the wide side of each wood sample. A total of 50 healthy, active worker termites were placed inside the tube, and the top of the tube was covered by cotton (Fig. 3). All samples were stored in a dark room for 12 weeks. At the end of the test period, the wood samples were washed, dried at 60 ± 2 °C for 48 h, and weighed. The weight loss was calculated using Eq. (2).

$$P = \frac{W_1 - W_2}{W_2} x100 \qquad (2)$$

where W1 was the oven-dried weight of the specimen before feeding and W2 was the oven-dried weight of the specimen after feeding. Resistance classes were determined based on weight loss and the number of living termites (Table 4), whereas the degree of attack was determined using the same method employed for subterranean attack. The resistance classes of examined jabon wood samples were determined based on weight loss, the number of living termites, and the degree of attack (Table 2 and Table 3) (BSN 2014).

Data Analysis

The weight loss data obtained from both investigations of the samples exposed to drywood and subterranean termites were recorded according to the type of treatments. The wood samples were then classified into the resistance class according to BSN (2014). To determine the differences in weight loss and the living termites, an analysis of variance was conducted. A further analysis of Duncan post difference test was done to point out the differences between the treatments.

Results and Discussion

Resistance Against Subterranean Termites

Table 4 presents weight loss, termite mortality, and the degree of attack of treated and untreated jabon wood used to determine its resistance against subterranean termites. To determine the weight loss and the living termites, an analysis of variance was conducted. The results revealed that there was a significant difference in weight loss (F calc = 21.06 > F table = 1.84) and living termites (F calc = 28.49 > Ftable = 1.84). Furthermore, the Duncan post difference test was carried out to determine the differences in the effect of each pre-treatment to the weight loss.

Table 4 and Fig. 4 show that the highest weight loss of 19.12% occurred on the untreated (control) samples. Regarding the class of resistance, the untreated samples (A) belonged to class V, as the weight loss was more than 18.94% (BSN 2014). This result was in accordance with the Indonesian wood database, which classified the durability of jabon into class V. It is the lowest class of resistance against termite attack. The highest weight loss of the control samples was followed by treatment B (impregnated once using Merbau extractive (ME)), treatment C (impregnated twice using Merbau extractives, ME), and treatment D (impregnated three times using ME), with weight losses of 16.61%, 16.41%, and 15.25%, respectively. All of these samples were classified as class IV (non-resistant to termite attack).

In contrast, the lowest weight loss was obtained in the samples with treatment G (impregnated three times using polymerized ME (PME) type 22) by 4.40%, treatment L (impregnated once using PME 33 and hot pressing with 50% CR), treatment M (impregnated once using ME + hot press by 33% CR), and treatment K (impregnated once using PME 33 + hot press by 33% CR), with weight losses of 5.20%, 6.5%, and 6.52%, respectively. All four of these treatments resulted in resistance class II (resistant to termite attack). Other impregnated samples using PME (treatments E, F, H, I, J, N, O, and P) improved the resistance against termites to class III (moderately resistant to termite attack). This result was similar to the result of a study in which jabon was impregnated with methyl methacrylate (MMA). In that case, the resistance was improved from class V to II (Hadi *et a*l. 2015). In general, based on weight loss, the samples with all different treatments (B through P) showed higher resistance against subterranean termite attack, with improvement from class V (non-resistance) to class IV (treatments B, C, and D), III (treatments E, F, H, I, J, N, O and P), and II (treatments G, K, L, and M).

In terms of resistance or durability class, according to Seng (1990), class V means that the wood is susceptible to termites or other destroying organisms' attack. Consequently, the wood is very quickly damaged or possesses low durability if it is constantly in contact with moist ground. Even if the wood is sheltered and has no moist ground contact, the durability of the wood would still be short. However, if the timber is well maintained and periodically painted, the lifetime of the wood can reach 20 years, which also depends on the species.

Table 5. Weight loss, resistance, and the degree of attack of subterranean termites (*Coptotermes curvignathus* Holmgren) against Jabon wood.

Treatment	Weight Loss (%)		Resistance Class	Mortality			Degree of Attack (%)
	X ± Sd	*		%	X ± Sd	*	
A (Control)	18.12 ± 2.30	a	V	22.38	28.17 ± 2.69	d	37.50
B	16.61 ± 1.77	ab	IV	25.75	30.47 ± 1.97	cd	36.25
C	16.40 ± 0.99	ab	IV	24.88	29.91 ± 1.14	cd	36.25
D	15.25 ± 1.61	bcde	IV	29.25	32.73 ± 1.37	c	32.50
E	8.79 ± 3.27	cde	III	38.25	38.20 ± 1.09	b	17.50
F	8.95 ± 2.13	cde	III	35,5	36.54 ± 2.82	b	23.75
G	4.40 ± 1.44	g	II	50.75	45.43 ± 2.49	b	17.25
H	8.88 ± 2.82	cde	III	36.88	37.36 ± 2.74	a	22.50
I	9.59 ± 1.75	cd	III	38.75	38.56 ± 1.95	b	22.50
J	9.85 ± 0.61	c	III	37.25	37.60 ± 2.05	b	25.00
K	6.52 ± 1.20	defg	II	52.00	46.15 ± 2.00	b	18.75
L	5.20 ± 1.76	fg	II	52.13	46.22 ± 0.75	a	16.50
M	6.15 ± 2.37	efg	II	40.38	39.44 ± 2.08	b	17.50
N	7.87 ± 0.42	cdef	III	40.88	39.38 ± 1.71	b	18.00
O	7.88 ± 2.37	cdef	III	38.50	38.35 ± 1.38	b	20.00
P	9.93 ± 1.88	c	III	36.88	37.36 ± 2.72	b	18.25

Remarks: A through P refers to Table 1; (*) The mean value followed by the same letter means no significant difference ($p = 0.05$) was determined based on Duncan post hoc test; Sd = Standard deviation.

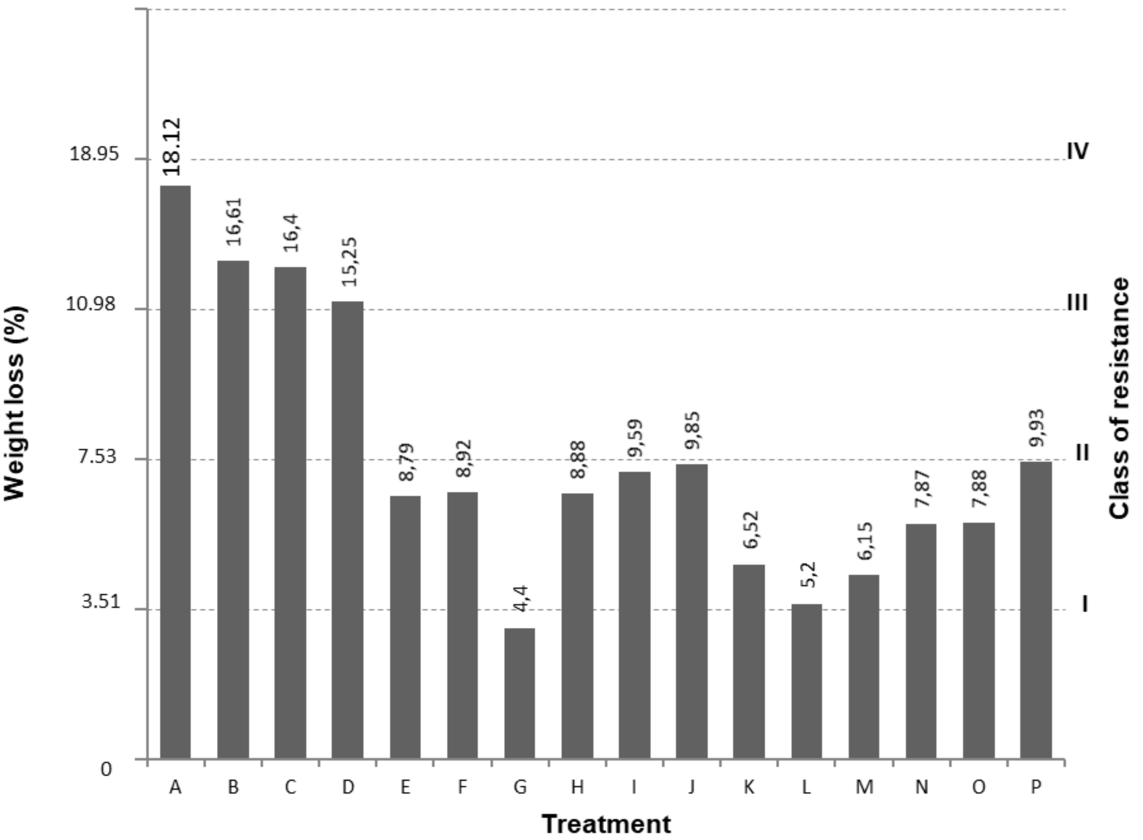

Figure 4. Weight loss of treated and untreated jabon wood due to subterranean termite attack.

Besides weight loss, mortality and the degree of attack are also used to determine wood resistance against termite attack. Based on the mortality, the more termites that are dead during the test, the more resistant the wood samples are against termite attack. The highest mortality rate occurred on the samples with treatments L, K, and G, with the mortality of 52.13%, 52.0%, and 50.75%, respectively (Table 4). Other treatments resulted in a mortality rate ranging from 24.88% to 40.88%. The mortality of the control samples was 19.12%. To determine which treatment was most efficient in protecting jabon wood from subterranean termite attack, Table 4 presents Duncan's multiple range test, which showed the same resistance class due to the same weight loss percentage. The treatments that improved wood durability to class II were G, K, L, and N. However, the samples of K, L, and N treatments needed hot compression treatment. Treatment G (impregnation using PME22 three times) could be considered the preferred treatment, as it is the easiest and simplest treatment and is a more affordable treatment than others (K, L and M) that resulted in the same resistance class against subterranean termites.

Resistance Against Drywood Termites

Similar to resistance against subterranean termites, the parameters used to evaluate the resistance against drywood termites were weight loss and mortality. The results are presented in Table 5 and Fig. 5. Analysis of variance was done to determine the differences in weight loss as well as mortality for different treatments. The results showed that there were significant differences for weight loss amongst treated and untreated samples (F calc = 4.47 > F table = 1.84) as well as for mortality (F calc (2.87) > F table = 1.84). Further analysis by the Duncan post hoc test was carried out to determine the differences in weight loss as well as mortality among the treatments.

Table 6 and Fig. 5 revealed that the highest weight loss occured in group A (control – untreated) samples by 8.36%. Based on the resistance to termite classes, the untreated samples fell into class IV, in which the range of weight loss was 8.3% to 28.10%. Next, the treated samples of groups B, C, E, F, H, I, K, L, O, and P (Table 1) with weight losses ranging from 5.03% to 7.18% were classified into class III durability. The lowest weight loss due to drywood termite attack occured in the group of treated samples J, N, M, D, and G, by 3.04%, 3.55%, 3.84%, 3.89%, and 4.27%, respectively, which classified these samples as resistance class II. The higher the weight loss gained due to drywood termite attack, the lower the wood durability. Based on the above results, jabon wood resistance against drywood termites can be improved from class IV to class III and II through impregnation and compression treatments.

Table 6. Weight loss, resistance, and mortality of drywood termites (*Cryptotermes cynocephalus* Light) against Jabon wood.

Treatment	Weight Loss (%)	Resistance Class	Mortality (%)		Degree of Attack (%)
	X ± Sd*		%	X ± Sd*	
A (Control)	8.36 ± 1.51 a	IV	41,5	40.10 ± 1.74 e	25
B	5.90 ± 1.30 bc	III	44.5	41.82 ± 3.95 de	22.5
C	5.26 ± 1.07 bcde	III	46.5	42.99 ± 2.55 cde	20
D	3.99 ± 2.23 cde	II	59.0	51.07 ± 13.71 ab	15
E	6.98 ± 1.11 ab	III	50.0	45.00 ± 2.05 bcde	17.5
F	5.85 ± 1.40 bcd	III	51.5	45.86 ± 1.10 abcde	16.25
G	4.27 ± 1.41 cde	II	52.0	46.15 ± 0.94 abcde	13.75
H	5.87 ± 3.19 bc	III	52.5	46.44 ± 3.03 abcde	17
I	5.03 ± 0.08 bcde	III	50.5	45.29 ± 1.96 bcde	15.25
J	3.04 ± 0.66 e	II	57.0	49.05 ± 3.49 abc	13.75
K	5.35 ± 1.32 bcde	III	51.5	45.86 ± 1.10 abcde	14.25
L	5.16 ± 0.49 bcde	III	62.0	52.01 ± 4.98 ab	14.25
M	3.85 ± 0,49 cde	II	60.0	50.78 ± 1.91 ab	11.25
N	3.55 ± 0.20 de	II	63.0	52.57 ± 2.87 a	11.25
O	7.18 ± 1.52 ab	III	57.0	47.59 ± 1.72 abcd	21.25
P	6.87 ± 0.81 ab	III	51.5	45.86 ± 1.10 abcde	18.25

Remarks: A through P refers to Table 1; (*) The mean value followed by the same letter means no significant difference (p = 0.05) was determined based on Duncan post hoc test; Sd = Standard deviation.

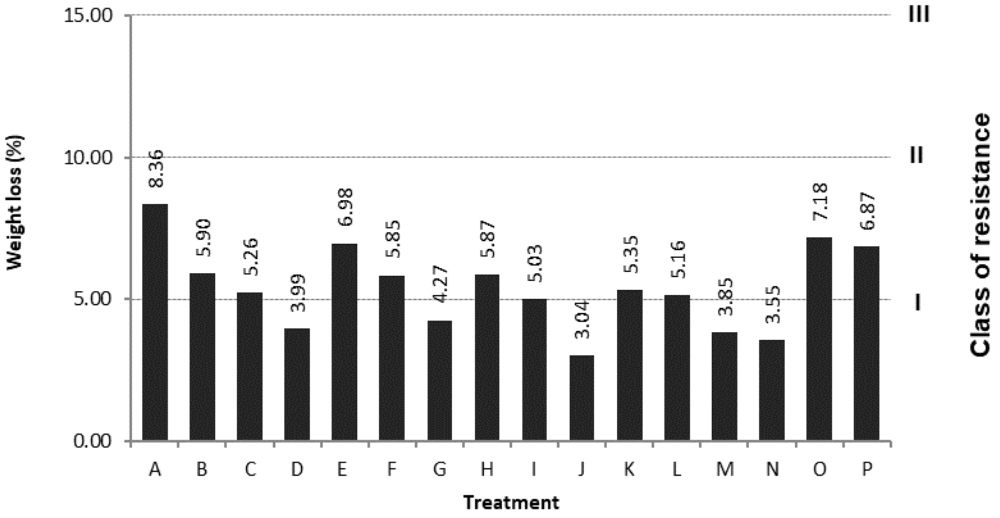

Figure 5. Weight loss of treated and untreated jabon wood due to drywood termite attack.

The best treatment from the five treatments that resulted in class II can be determined by comparing the weight loss of these treatments with Duncan's multiple range test (Table 5). The table showed that the lowest weight loss belongs to treatment J (impregnated three times using PME33). However, Duncan's post hoc test revealed that at p = 0.05 the treatment did not make a significant difference in weight loss with the treatments of D, G, M, and N. As a result, these treatments are in the same class of resistance against drywood termites.

To choose the best treatment, the cost, safety factors, and technical aspects should be considered. However, based on the value of weight loss, treatment J resulted in the lowest weight loss. As mentioned above, this treatment did not show a significant difference with treatment D. Therefore, treatment D was considered the most efficient in preventing jabon wood from drywood termite attack because of its cost (as there is no cost for other materials to make the polymer), its simplicity (as there is just the need for Merbau extractives for the treatment) and the safeness (it is the only natural compound required for the treatment).

This treatment did not need the polymerization process for Merbau extractives. Meanwhile, treatment G required polymerization to make polymerized Merbau extractives (PME) and the triple impregnation process. This can be an expensive and time consuming process. The samples of group M and N were made by impregnation with Merbau extractive and followed by hot compression by a 33% and 50% compression ratio, respectively. Both treatments were safe and an environmentally friendly, but required high energy for hot compression.

In terms of drywood termite mortality, the highest mortality of the drywood termites occured on the treated wood of N (63%), L (62%), and M (60%) (Table 5). In contrast, the lowest mortality occurred on samples A, B, and C by 41.5%, 44.5%, and 46.5%, respectively. Based on the results, stronger treatments led to higher mortality. This means that the treatment of jabon wood increased its resistance against drywood termite attack.

This result is in line with the general theory of the role of extractive substances on the durability of wood, according to which extractives can protect wood against some biological damage or insect attack (Hillis 1987; Sjöström 1993; Shmulsky and Jones 2011). Syofuna *et al*. (2012) treated the wood of two susceptible species against termites and fungal decay, *Pinus caribaea* and *Antiaris toxicaria* using extractives obtained from *Milicia excelsa*, *Albizia coriaria*, and *Markhamia lutea*. The authors concluded that the extractives contributed greatly to the protection of less durable wood species against termite attack. In this study, Merbau extractives also distinctly improved the resistance of jabon wood from class IV (non-resistant) to class II (resistant).

Conclusions

Based on the testing of treated and untreated jabon wood against subterranean and drywood termites, this study showed that untreated samples of jabon belong to class V (susceptible) against subterranean termite and class IV (non-resistant) against drywood termite (BSN 2014).

The impregnation treatments and hot compression improved the resistance of jabon wood against subterranean and drywood termite attack. Impregnation using only Merbau extractives improved the resistance of jabon wood against subterranean termite from class V to class IV and against drywood termite from class IV to classes III and II.

Resistance class III against subterranean termites originated from the treatments of E, F, H, I, J, N, O, and P. Meanwhile, the same class of resistance against drywood termite attack was achieved by the treatments of B, C, E, F, H, I, K, L, O, and P.

Treatments G, K, L, and M for exposure to subterranean termites and treatments D, G, J, M, and N for exposure to drywood termites resulted in the resistance class of II. The treatment of J and D are recommended to prevent jabon wood against subterranean and drywood termite attacks, respectively.

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Jamaludin Malik and Adi Santoso
Research Centre for Biomass and Bioproducts,
National Research and Innovation Agency (BRIN),
Jl. Raya Jakarta-Bogor Km. 46, Bogor 16911, Indonesia.
Tel.   : +62 811-1933-3603
E-mail : jamaludin.malik@brin.go.id

Jasni
A retired researcher from the Forest Products Research and Development Center

Barbara Ozarska
Honorary Professor,
School of Ecosystem and Forest Sciences,
The University of Melbourne,
Burnley Campus, 500 Yarra Boulevard, Richmond, Victoria 3121, Australia.
Tel.   : +61 3 9035 6800
E-mail : bo@unimelb.edu.a