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Termite Resistance of Furfuryl Alcohol and Imidacloprid Treated Fast-Growing Tropical Wood Species as Function of Field Test

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Abstract: In general fast-growing tree species harvested at a young age has substantial amount of sapwood. It also contains juvenile wood, which has undesirable inferior physical and mechanical properties. Having sapwood and juvenile wood in the trees makes them very susceptible to be attacked by biological deterioration specifically termites in a tropical environment. The main objective of this study was to investigate the termite resistance of four fast-growing Indonesian wood species treated with furfuryl alcohol and imidacloprid. Wood specimens from sengon (*Falcataria moluccana*), jabon (*Anthocephalus cadamba*), mangium (*Acacia mangium*), and pine (*Pinus merkusii*) were impregnated with furfuryl alcohol, using tartaric acid and heat as well as treated with imidacloprid for the polymerization process. All of the specimens were exposed to environmental conditions in the field for three months. Based on the findings in this work, the untreated control samples had higher weight loss values and lower protection levels than those of imidacloprid-treated and furfurylated samples of all four species. It appears that furfurylation and imidacloprid treatment of such fast-growing species had a significant impact regarding their resistance against termite so that their service life can be extended during their utilization.

Keywords: furfurylated wood; imidacloprid treatment subterranean termite attack; ground test; percent weight loss; fast-growing tropical woods

1. Introduction

Having elevated temperature and humidity in Indonesia as a tropical country is an ideal condition for termite attack on wood and wood products throughout the year. The annual economic loss caused by termites on wood-based material in buildings was approximately reached USD 1 billion [1]. This economic loss could increase in the future because the timber supply in the country has recently shifted from natural growth to plantation forests, which have a short period of harvesting plans.

Non-poisonous compounds that chemically modify the wood are being used to replace traditional preservatives to extend the service life of wood products. One important issue is to assess the efficacy of environmentally friendly chemicals and approaches. In previous work, evaluated the termite resistance of European beech modified by impregnating different aqueous solutions of glycerol maleate or polyglycerol maleate at different concentrations, namely 10% or 40%, *w/w* into the wood followed by thermal treatment at three temperature levels of 180 °C, 200 °C, or 220 °C [2]. Field tests conducted for one year in Bogor, West Java, Indonesia, showed that all wood samples treated with the combination of chemical and thermal modification had significantly higher termite resistance than that of untreated and thermally modified samples.

In another study, [3] reported results for four wood species, namely sengon, jabon, mangium and pine that had been impregnated with methyl methacrylate (MMA) and then in-ground exposed to termites for three months. Untreated control and imidacloprid-treated samples were also prepared for comparison purposes. The MMA-treated samples had increased resistance against subterranean termite attack during in-ground testing, but the level was lower than that of imidacloprid-treated wood. In another work, acetylated rubber-wood (*Hevea brasiliensis*) flakeboard samples with a weight percent gain of 18% were kept in the field for 12 weeks. It was found that weight loss and protection level of untreated flakeboard were 83.6% and 0.0, while corresponding values for acetylated flakeboard were 8.7% and 9.0, respectively [4]. Other wood modification techniques have also been investigated to develop better products and a more eco-friendly process [5]. Among these methods, furfurylation is considered one of the most effective modification techniques.

Furfurylation involves modification of wood with furfuryl alcohol (FA). FA can be obtained through the hydrogenation of pentosans present in agricultural and wood by-products [6]. Furfurylation of wood has been considered a promising one and studied with regard to ecotoxicity, physical and mechanical properties, dimensional stabilization, and durability of products [7]. Furfurylation of wood may also enhance its resistance to termite attack. Hadi et al. studied furfurylation of three wood species, namely Scotch pine (*Pinus sylvestris*), agathis (*Agathis dammara)* and sengon, and then exposed samples to dry wood termites (*Cryptotermes cynocephalus*) in laboratory tests and to subterranean termites (*Macrotermes gilvus*) in in-ground tests [8]. The results showed that furfurylated wood specimens with a weight percentage gain (WPG) of more than 40% were highly resistant to attack by both dry wood and subterranean termites. Furfurylation is believed to be a safe process for the environment [9].

The process has many advantages, with an excellent potential furfurylation yielding excellent and eco-friendly material [10]. A chemical catalyst is needed to induce the FA molecules to polymerize each other or to graft the wood for a typical furfurylation process. Sejati et al. reported that tartaric acid could be used as a catalyst for the furfurylation of beech wood. However, this catalyst has not been used in tropical wood, including the fast-growing wood species of plantation forests [11].

Imidacloprid with a molecular formula of $C_9H_{10}CIN_5O_2$ is an insecticide within the class of the neonicotinnodis chemicals which is widely used for insect control including termite and carpenter ants in preservation of wood based materials. It is produced to imitate nicotine which can naturally be found in many plants [12]. Products having imidacloprid could come in various forms such as liquid, particles or powder form. Currently, there are several hundred products or even more having imidacloprid that are for sale in the USA [12]. Since it has high water solubility value of $0.51 g \cdot L^{-1}$ it breaks down in water very quick.

Currently, there is little or no information on termite resistance of furfurylated and imidacloprid-treated four tropical wood species. Therefore the objective of this study was to determine the termite resistance of furfurylated and imidacloprid treated fast-growing tropical wood species, namely sengon, jabon, mangium, and pine, using small specimens exposed through in-ground testing. Also, the resistance of furfurylated specimens with those of untreated control and imidacloprid-treated specimens were compared to each other so that such species can be used more efficiently under the environmental conditions.

2. Materials and Methods

2.1. Materials

Trees of fast-growing tropical species, namely sengon, jabon, mangium as hardwoods and pine as a softwood were harvested from plantation forests in the Bogor area, West Java, Indonesia. The trees were 6–10 years old having a breast height diameter of approximately 20 cm. Logs were converted into flat sawn lumber before specimens for in-ground testing were sawn from the lumber. Specimens had 2 cm by 0.8 cm in cross-section and 20 cm length. Cellulose content values of 49.4%, 69.4%, 52.4%, and 54.9% are for sengon, mangium, jabon, and pine, respectively and other chemical contents of each species are displayed in Table 1 [13].

Table 1. Chemical contents of four species used in this work [13].

Chemicals		Sengon	Mangium	Jabon	Pine
	Cellulose (%)	49.4	69.4	52.4	54.9
	Lignin (%)	26.8	19.7	25.4	24.3
	Hemicellulose (%)	15.6	16	16.2	14
	Ash (%)	0.6	0.68	0.8	1.1
	Silica (%)	0.2	n.a.	0.1	0.2
Extractive	Ethanol-benzene (%)	3.4	5.6	4.7	6.3
	Cold water (%)	3.4	n.a.	1.6	0.4
	Hot water (%)	4.3	9.8	3.1	3.2
	NaOH 1% (%)	19.6	14.8	18.4	11.1

Samples were dried to 12% moisture content (MC), weighed, and then placed in a tank applying a vacuum at 600 mmHg for 30 min. For furfurylation, a solution of FA mixed with tartaric acid (20:1, *v/v*) was streamed into the tank during vacuum release, followed by the application of pressure at 10 kg·cm^{-2} for 30 min. Following the impregnation process, each sample was wrapped with an aluminum foil and placed in an oven at a temperature of 100 °C for 24 h for FA polymerization. In the next step, the aluminum foil was removed from the samples, and they were weighed for calculation of the polymer loading. The samples were kept at room temperature for conditioning for three weeks. Weight percent gain (WPG) values of the samples were determined through weighing individual specimen before treatment at oven-dried condition (W_1). Then the oven-dried weight of the sample was also determined following impregnation with FA (W_2) so that the WPG was calculated based on the following formula:

$$\text{WPG}\ (\%) = (W_2 - W_1)/W_1 \times 100\% \quad (1)$$

Untreated control and imidacloprid-treated specimens were also considered for the experiment for comparison purposes. For imidacloprid treatment, specimens with 12% MC were treated with a 3% imidacloprid solution using the same vacuum-pressure process as used for the furfurylation. Retention of the preservative was also measured by weighing the specimens before and after the preservation process. A total of ten samples were used for each treatment combination. Chemicals used for the experiments were supplied by Our Chemicals, Fisher, Jakarta, Indonesia.

2.2. Subterranean Termite Field Test

Untreated, imidacloprid treated, and furfurylated specimens were embedded in-ground for the field test to determine their resistance against to subterranean termite field test of the samples was carried out in the Arboretum of the Forestry Faculty, Bogor Agricultural University (IPB), Bogor, Indonesia. The field test was carried out by vertically inserting each specimen into the ground to three-fourths of its length for the exposure period lasted for three months, as shown in Figure 1 [14]. At the end of the test period, the samples were lightly brushed to clean residual soil before visually inspection and weighed after they were oven-dried. The microclimate in the surrounding area during the test period, mid-October 2019 until mid-January 2020, had an average rainfall of 23.5 mm·d^{-1} ranging from 0.0 to 141.0 mm·d^{-1}, average relative humidity of 82.5% ranging from 61.0% to 96.0% [15].

Figure 1. Subterranean termite field test.

2.3. Analysis of the Data

To analyze the effect of wood species and treatment upon weight loss and protection level, a completer blocked randomized design was employed. The block was four wood species, namely sengon, jabon, mangium and pine while the treatments were control, imidacloprid treatment, and furfurylation. When the results of the variance analysis indicated a significant difference among factors, the mean comparison was done using Duncan's multiple range test to identify the group that were significantly different from other groups at 95% confidence level [16].

3. Results and Discussion

The values of untreated wood densities of sengon, jabon, mangium and pine were 0.29, 0.31, 0.60, and 0.67 g·cm^{-3}, respectively, which were similar to those reported by Hadi et al. [3]. All wood specimens were cut from fast-growing young tree species therefore the wood was classified as low to medium density.

Weight percent gain (WPG) for each species was determined by weighing the specimens before treatment at oven-dried condition (W_1). Later the oven-dried weight of each sample was also determined following impregnation with FA (W_2) and WPG values were calculated based on the following formula:

$$WPG\ (\%) = (W_2 - W_1)/W_1 \times 100\%. \quad (2)$$

Furfurylated wood samples were darker in color than that of untreated samples, which was in line with findings of Hadi et al. (2005) [3]. Also, tests of Dong et al. (2014) showed that FA treated with only 50% FA solution, resulted in darker specimens. The dark color of the samples is generated by the conjugated structure derived from the aliphatically linked poly-furfuryl alcohol [17]

It was found that the WPGs of sengon, jabon, mangium, and pine were 62.1%, 133.7%, 20.1%, and 33.3%, respectively. Since lower-density wood has more void space larger volume could be occupied by a liquid. Sengon had a much lower WPG than jabon despite both types of wood having similar densities. This could possibly due to and interlocking grain orientation of sengon and its high extractive content [18]. Pari reported that sengon heartwood contained 19.6% extractive substances soluble in NaOH, including carbohydrate derivatives (cellobiose, glucose, xylose, arabinose, ribose, oligosaccharide, and pentasaccharide), and long-chain fatty acid (capriate, myristic acid, myristoleic acid, pentadecylic acid, palmitic acid, margaric acid, stearic acid, oleic acid, linoleic acid, and arachidonic acid) [19]. In a previous work, it was determined that the extract of jabon wood contained phenol (pyrocatechol, 4-methyl catechol, 2-methoxy-4-methyl phenol, and 4-methoxy phenol), phenolic acid (quinic acid), long long-chain fatty acids (hexadecanoic acid, linoleic acid, stearic acid, and methyl linolenic acid), carboxylic amine acids (carbamic acid), carbohydrate derivatives (levoglucosan and mome inositol), and coumarin (scopoletin) [20].

Mangium and pine had lower WPGs, which was likely because they had much higher densities than those of sengon and jabon. Despite having a higher density of pine being a softwood had a higher WPG than mangium in this study. This finding can be explained by pine being a softwood, unlike hardwood species, mangium. Typically softwoods have less complicated anatomical characteristics than hardwoods, thus they are easily penetrated by liquid or gaseous substances during any treatment processes.

Gross retention or retention is the amount of preservative mass in kg which entering into the 1 m^3 wood as function of concentration of preservative and it was calculated using the following formula:

Gross retention ($kg{\cdot}m^{-3}$) = [entered preservative to the wood (kg)/volume of wood the wood (m^3)] × concentration of preservative. Gross retention values of imidacloprid preservative in sengon, jabon, mangium, and pine were 6.29, 12.51, 6.06, and 8.85 $kg{\cdot}m^{-3}$, respectively,

3.1. Wood Weight Loss

During three months of in-ground testing, the wood specimens were attacked by subterranean termites that were identified as *Macrotermes gilvus* Hagen. Figure 2 illustrates subterranean termite soldiers found on the samples left in the field. The post-exposure wood specimens are shown in Figure 3. The percent weight losses (% WLs) of each species and treatment are displayed in Table 2. Analysis of variance Duncan's multiple range tests of each wood species and treatment are shown in Tables 3–5, respectively.

Figure 2. Subterranean soldier termite that found on the specimens.

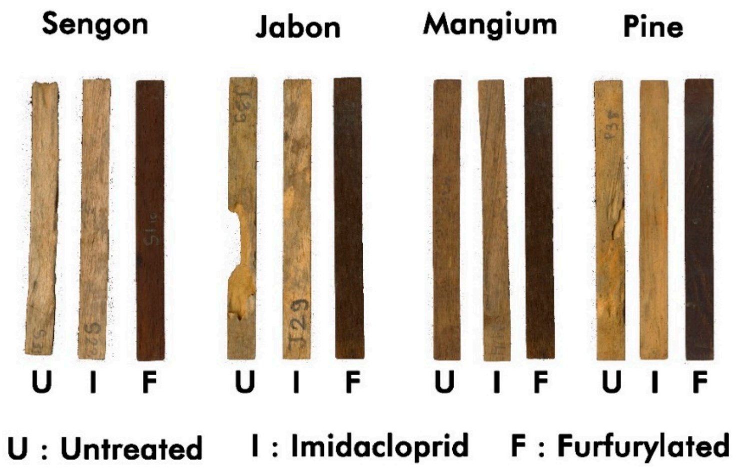

Figure 3. Wood specimens after three months of exposure in the field.

Table 2. Weight loss of wood specimens (%).[a]

Treatment	Wood Species			
	Sengon	Jabon	Mangium	Pine
Untreated	6.70 (6.29)	30.35 (33.15)	5.24 (3.90)	9.30 (9.72)
Imidacloprid	6.63 (3.50)	12.52 (5.31)	5.11 (1.10)	2.22 (1.32)
Furfurylated	3.52 (2.27)	3.31 (1.37)	3.67 (2.10)	3.14 (1.57)

[a] Values in parentheses are standard deviations.

Table 3. Variance analysis of percent weight loss.

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4280.441	5	856.088	6.951	0.000
Intercept	7009.242	1	7009.242	56.912	0.000
Wood species	2417.373	3	805.791	6.543	0.000
Treatment	1863.068	2	931.534	7.564	0.001
Error	14,040.085	114	123.159		
Total	25,329.768	120			

Table 4. Duncan's multi-range test of percent weight loss and protection level on wood species. (The same letters in each column are not statistically different ($p \leq 0.05$) according to Duncan's multiple range test.)

Wood Species	% Weight Loss	Protection Level
Mangium	a	a
Pine	a	a
Sengon	a	a
Jabon	b	b

Table 5. Duncan's multi-range test of percent weight loss and protection level on treatment. (The same letters in each column are not statistically different ($p \leq 0.05$) according to Duncan's multiple range test).

Wood Species	% Weight Loss	Protection Level
Furfurylation	a	a
Imidacloprid	a	b
Untreated	b	c

Wood species and treatment were highly significant for % WL as can be seen in Table 3. According to the data in Table 4, jabon had the highest % WL and was significantly different from the other wood species, but were not significantly different from each other. In other words, jabon was the most susceptible to be attacked by termites. The % WLs of all untreated woods in this study were similar to those investigated in past work except for sengon being much lower, 6.7% in this work compared to 18.3% for previous work, for jabon 30.4% to 24.7%, mangium 5.2% to 8.2%, and pine 9.3% to 11.1%, respectively [3]. In addition, the four wood species were suitable for inclusion in laboratory tests against subterranean termites conducted following the Indonesian National Standard SNI 7207-2014 (Badan Standarisasi Nasional, 2014). Based on the SNI 7207-2014 and laboratory results test, sengon, jabon, mangium, and pine were classified as very poor resistance or class V (the lowest class, from I to V) [21–23], and jabon was classified as poor resistance or class IV [23] to very poor resistance or class V [24]

Furfurylation and imidacloprid-treated samples were not different from each other, but both of them were different from untreated specimens as displayed in Table 4. It appears that both treatments resulted in samples with better resistance than that of control specimens. It could be concluded that furfurylation enhanced resistance of the samples to subterranean termite attack, as indicated by the % WL of furfurylated wood being only one-fourth (0.26) that of untreated wood. These results align with those determined in past studies [22–24]. Furfurylation involves a chemical reaction with wood through cross-linkages or even penetration into the wood cell wall, thus changing the wood cell wall [25–27]. These changes apparently allow furfurylated jabon wood to become more resistant to termite attack than untreated wood but are not for the other wood species.

For the imidacloprid-treated samples, the % WL was about half (0.51) that of untreated wood. Chemicals such as imidacloprid are used for termite control in plantation forest management. For example, Sinarmas Company in Riau (Sumatra, Indonesia) uses fipronil, chlorfenapyr, indoxacarb, as well as imidacloprid in plantation forest areas [28]. Moreover, using imidacloprid to preserve wood is common throughout the world for termite control [29,30]

3.2. Protection Level

Protection levels associated with each wood species and treatment are shown in Table 6, analysis of variance is listed in Table 7, and Duncan's multiple range tests of each wood species and treatment are shown in Tables 4 and 5. Wood species and treatment significantly affected the protection level. Duncan's multiple range tests showed that jabon had the lowest protection level (value of 7.6), which was significantly different from the other three wood species. Sengon, mangium, and pine were not significantly different from each other, with protection values of 8.6, 8.9, and 9.1, respectively. In other words, jabon was the most susceptible among the samples. Table 8 also displays WPG and retention values of the specimens.

Table 6. Protection level of specimens. [a]

Treatment	Wood Species				
	Sengon	**Jabon**	**Mangium**	**Pine**	**Average**
Untreated	7.7 (1.6)	5.7 (3.3)	8.4 (1.3)	7.7 (2.0)	7.4
Imidacloprid	8.5 (1.1)	7.5 (0.5)	8.8 (0.4)	9.8 (0.4)	8.7
Furfurylated	9.5 (0.5)	9.6 (0.7)	9.6 (0.7)	9.8 (0.4)	9.6
Average	8.6	7.6	8.9	9.1	

Values in parentheses are standard deviations.

Wood attacked by termites, and the other three wood species had similar protection levels. In terms of treatment, the protection level of furfurylated wood was the highest, followed by imidacloprid treated wood and untreated wood was the lowest. In other words, regarding the protection level, the furfurylation treatment and imidacloprid-preserved woods could enhance the protection level. In addition, compared with heat treatment of wood reported by Ra et al., furfurylation had better termite resistance during exposure in the field test in our study [31].

Considering % WL and protection level, it could be summarized that furfurylation treatment could enhance resistance to subterranean termite attack of the wood, and the resistance was similar to imidacloprid treated wood.

Table 7. Variance analysis of protection level.

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	142.417	5	28.483	14.413	0.000
Intercept	8772.300	1	8772.300	4439.042	0.000
Wood species	40.567	3	13.522	6.843	0.000
Treatment	101.850	2	50.925	25.770	0.000
Error	225.283	114	1.976		
Total	9140.000	120			

Table 8. Weight percent gain (WPG) and retention values of the samples (Numbers in parentheses are standard deviations).

Wood Species	Furfurylated (%)	Retention Imidacloprid (kg·m^{-3})	WPG of Furfurylation (%)
Sengon	64.1 (4.6)	6.3 (0.5)	7.2
Jabon	133.7 (9.5)	12.5 (1.0)	8.7
Mangium	20.1 (2.6)	6.1 (0.6)	4.8
Pinus	33.3 (2.6)	8.9 (0.4)	9.4

4. Conclusions

Based on our experimental findings, the following conclusions can be drawn:

1. Untreated jabon wood has the lowest resistance to subterranean termite attack while untreated sengon, mangium, and pine have equal resistance.
2. Based on percent weight loss or protection level, furfurylated woods enhance resistance to subterranean termite attack, as shown through in-ground testing for 3 months, and the performance is similar with that of imidacloprid-treated wood.

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References

1. Nandika, D. Termite attack in the whole country. In Proceedings of the Termite National Seminar, Hotel Santika, Taman Mini, Jakarta, Indonesia, 16 April 2015.
2. Mubarok, M.; Militz, H.; Darmawan, I.W.; Hadi, Y.S.; Dumarçay, S.; Gérardin, P. Resistance against subterranean termite of beech wood impregnated with different derivatives of glycerol or polyglycerol and maleic anhydride followed by thermal modification: A field test study. *Eur. J. Wood Wood Prod.* **2020**, *78*, 387–392. [CrossRef]
3. Hadi, Y.S.; Massijaya, M.Y.; Zaini, L.H.; Abdillah, I.B.; Arsyad, W.O.M. Resistance of methyl methacrylate-impregnated wood to subterranean termite attack. *J. Korean Wood Sci. Technol.* **2018**, *46*, 748–755. [CrossRef]
4. Hadi, Y.S.; Darma, I.G.K.T.; Febrianto, F.; Herliyana, E.N. Acetylated rubber-wood flakeboard resistance to bio-deterioration. *For. Prod. J.* **1995**, *45*, 64–66.

5. Epmeier, H.; Westin, M.; Rapp, A. Differently modified wood: Comparison of some selected properties. *Scand. J. For. Res.* **2004**, *19*, 31–37. [CrossRef]
6. Baysal, E.; Ozaki, S.K.; Yalinkilic, M.K. Dimensional stabilization of wood treated with furfuryl alcohol catalyzed by borates. *Wood Sci. Technol.* **2004**, *38*, 405–415.
7. Lande, S.; Westin, M.; Schneider, M. Properties of furfurylated wood. *Scand. J. For. Res.* **2004**, *19*, 22–30. [CrossRef]
8. Hadi, Y.S.; Westin, M.; Rasyid, E. Resistance of furfurylated wood to termite attack. *For. Prod. J.* **2005**, *55*, 85–88.
9. Gerardin, P. New alternatives for wood preservation based on thermal and chemical modification of wood-a review. *Ann. For. Sci.* **2016**, *73*, 559–570. [CrossRef]
10. Dong, Y.; Yan, Y.; Zhang, S.; Li, J. Wood/polymer nanocomposites prepared by impregnation with furfuryl alcohol and nano-SiO_2. *BioResource* **2014**, *9*, 6028–6040. [CrossRef]
11. Sejati, P.S.; Imbert, A.; Charbonnier, C.G.; Dumarcay, S.; Fredon, E.; Masson, E.; Nandika, D.; Priadi, T.; Gerardin, P. Tartaric acid catalyzed furfurylation of beech wood. *Wood Sci. Technol.* **2017**, *51*, 379–394. [CrossRef]
12. Imidacloprid. Factsheet, OregonStateUniversity, Corvallis, OR, USA. 2010. Available online: http://npic.orst.edu/factsheets/imidagen.html (accessed on 30 August 2020).
13. Badan Standardisasi Nasional (BSN). *Indonesian National Standard 7207-2014. Uji Ketahanan Kayu Terhadap Organisme Perusak Kayu [Test for Resistance of Wood on Wood Deterioration Organism]*; BSN: Jakarta, Indonesia, 2014.
14. ASTM International. *American Standard Testing Material D 1758-06. Standard Test Method of Evaluating Wood Preservatives by Field Test with Stakes*; ASTM International: West Conshohocken, PA, USA, 2006.
15. BMKG (Bureau of Meteorology, Climatology and Geophysics). *Pusat Data Online (Center of online data). Central Database*; BMKG: Jakarta, Indonesia, 2020.
16. Tague, N.R. *The Quality Toolbox*, 2nd ed.; ASQ Quality Press: Milwaukee, WI, USA, 2005.
17. Choura, M.; Belgacem, N.M.; Gandini, A. Acid-catalyzed plycondensation of furfuryl alcohol: Mechanisms of chromophore formation and cross-linking. *Macromolecules* **1996**, *29*, 3839–3850. [CrossRef]
18. Martawijaya, A.; Kartasujana, I.; Kosasi, K.; Prawira, S.A. *Atlas Kayu Indonesia Jilid II (Indonesian Wood Atlas Vol II)*; Forest Products Research and Development Center, Ministry of Forestry: Bogor, Indonesia, 2005.
19. Pari, G. *Zat Ekstraktif Kayu Sengon (In Indonesian) (Data on Extractive Content of Sengon Wood)*; Data Rimba 218/XXIII; Perum Perhutani: Jakarta, Indonesia, 1998.
20. Anisah, L.A. Antidiabetic Activities of Extractives Substances from Jabon (*Anthocephalus cadamba* (Roxb.) Miq) and Samama (*A. macrophyllus* (Roxb.) Havil) Plants [dissertation]. *Indones. J. Chem.* **2018**, *18*, 66–74. [CrossRef]
21. Hadi, Y.S.; Massijaya, M.Y.; Abdillah, I.B.; Pari, G.; Arsyad, W.O.M. Color change and resistance to subterranean termite attack of mangium (*Acacia mangium*) and sengon (*Falcataria moluccana*) smoked wood. *J. Korean Wood Sci. Technol.* **2020**, *48*, 1–11. [CrossRef]
22. Arinana, A.; Tsunoda, K.; Herliyana, E.N.; Hadi, Y.S. Termite-susceptible species of wood for inclusion as a reference in Indonesian standardized laboratory testing. *Insects* **2012**, *3*, 396–401. [CrossRef]
23. Arsyad, W.O.M.; Basri, E.; Hendra, D.; Trisatya, D.R. Termite resistance of impregnated jabon wood (*Anthocephalus cadamba* Miq.) with combined impregnant agents. *J. Korean Wood Sci. Technol.* **2019**, *47*, 451–458. [CrossRef]
24. Febrianto, F.; Pranata, A.Z.; Septiana, D.; Arinana, A.; Gumilang, A.; Hidayat, W.; Lee, S.H.; Hwang, W.J.; Kim, N.H. Termite resistance of the less known tropical woods species grown in West Java, Indonesia. *J. Korean Wood Sci. Technol.* **2015**, *43*, 248–257. [CrossRef]
25. Lande, S.; Westin, M.; Schneider, M. Development of modified wood products based on furan chemistry. *Mol. Cryst. Liq. Cryst.* **2008**, *484*, 367–378. [CrossRef]
26. Esteves, B.; Nunes, L.; Pereira, H. Properties of furfurylated wood (*Pinus pinaster*). *Eur. J. Wood Wood Prod.* **2011**, *69*, 521–525. [CrossRef]
27. Li, W.; Wang, H.; Ren, D.; Yu, Y.S.; Yu, Y. Wood modification with furfuryl alcohol catalyzed by a new composite acidic catalyst. *Wood Sci. Technol.* **2015**, *49*, 845–856. [CrossRef]

28. Sagitarianto, F.; Ulpah, S.; Morais, W.; Tjahjono, B. Termites investigation on forest plantation area in Riau, Sumatera Indonesia. In Proceedings of the 13th Pacific Rim Termite Research Group Conference, Taipei, Taiwan, 12–13 February 2020; p. 184.
29. Reid, B.L.; Brinkman, R.; Smith, G.; Ishizaka, K.; Palis, B.; Villiers, V.D. Imidacloprid use in termite control operations globally and changing use patterns in the United States. In Proceedings of the 4th International Conference on Urban Pests, Charlestown, SC, USA, 7–10 July 2002; pp. 355–368.
30. Lempang, M. Sifat dasar dan potensi kegunaan kayu jabon merah (Basic properties and potential uses of red jabon wood). *For. Res. J. Wallacea* **2014**, *3*, 163–175.
31. Ra, J.B.; Kim, K.B.; Leem, K.H. Effect of heat treatment conditions on color change and termite resistance of heat-treated wood. *J. Korean Wood Sci. Technol.* **2012**, *40*, 370–377. [CrossRef]

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