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Original Article

Termite Resistance of Impregnated Jabon Wood (*Anthocephalus Cadamba* Miq.) with Combined Impregnant Agents[1]

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ABSTRACT

Jabon (*Anthocephalus cadamba* Miq.) is a fast-growing species that exhibits a lower natural resistance than that exhibited by the timber sourced from natural forests. Jabon's resistance to termite attack can be improved by impregnating its wood structure with poisonous organic materials. This study examined jabon's resistance to termite attack when impregnated with wood vinegar and an animal adhesive. The wood specimens were impregnated using sengon wood vinegar and an animal adhesive (8% and 10%, respectively) using a vacuum pressure machine. The specimens were tested for their resistance to subterranean and dry-wood termites according to Indonesian National Standard (SNI 7207-2014). The results denoted that jabon impregnated with wood vinegar and an animal adhesive concentration of at least 8% with the addition of 4% borate was effective to resist termite attacks. The impregnated jabon exhibited a lower weight loss and higher termite mortality when compared with those exhibited by the control specimens. Thus, the resistance class improved from class IV to class I.

Keywords: impregnation, jabon, termite, wood resistance, wood vinegar

1. INTRODUCTION

Since 2000 fast growing plantations have supplied at least 60% of timber plantation in Indonesia (Hadi *et al*., 2015). Fast growing wood species has low natural resistance, particularly against termites attack. Previous study reported that economic losses from wood structure damage as a result of termites attack were almost 8.7 billion rupiahs (Nandika, 2015). Improvement of its physical quality is indispensable to increase its resistance against termites attack.

Jabon wood (*Anthocephalus cadamba* Miq.) is one of the potential fast growing species in Indonesia. Jabon contains more juvenile wood that has inferior physical and mechanical properties and lower natural resistance compared to mature wood (Lestari *et al*., 2018; Hermawan *et al*., 2012). Its resistance is classified as class IV-V or poor resistance (Martawijaya *et al*., 2005). To improve physical and mechanical properties and its resistance, impregnation of organic and inorganic compounds into wood structure by soaking or using vacuum pressure tube can be performed (Hadi *et al*., 2018; Hartono *et al*., 2016; Oh and Park, 2015). Wood vinegar as a by-product from pyrolysis process of

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ligno-cellulose biomass can be applied as organic impregnant (Bridgwater, 2012; Lee *et al*., 2011; Tiilikkala *et al*., 2010). In 2015, sawn wood production capacity in Indonesia reached 1,939,586.19 m^3, where 5.89% sourced from sengon wood (*Falcataria moluccana*) (Central Bureau of Statistics, 2016). Sawn wood processes generated wastes such as slabs, wood bark and sawdust that could be utilized as wood vinegar or wood distillate. Wood vinegar contains polycyclic aromatic hydrocarbon compounds. The compounds comprise numerous major components such as phenol, formaldehyde, organic acid, ketones, hydrocarbon, ester, alcohols and some heterocyclic materials (Haji, 2013; Tascioglu *et al*., 2012; Kim *et al*., 2008). Wood vinegar contains compounds that poisonous to bacteria (Lee *et al*., 2010), fungi (Okutucu *et al*., 2011; Islam *et al*., 2009) and termite (Oramahi and Yoshimura, 2013; Hadi *et al*., 2010). It could be argued that wood vinegar could be used as wood natural preservative (Verma *et al*., 2009). Wood vinegar from coconut husks, sugarcane (*Arundo donax* sp.), laban (*Vitex pubescens*) increased mortality of *Odontotermes* sp., *Reticulitermes flavipe* in *Pinus sylvestris* L. and C. *curvignathus*, consecutively (Oramahi *et al*., 2014; Temiz *et al*., 2013; Wititsiri, 2011).

The purpose of this study was to determine the resistance of impregnated jabon wood with various treatment combinations against subterranean and dry-wood termites.

2. MATERIALS and METHODS

2.1. Study site/materials

Five-year-old jabon from community forest in Sukabumi, West Java was tested against subterranean (*Coptotermes curvignathus* Holmgren) and dry-wood (*Cryptotermes cynocephalus* Light) termites attack. Wood vinegar was generated from slabs and wood bark of five-year-old sengon. Animal adhesive resin was composed from hides, bones, cartilage and tendons of animal. Borate was used as preservative.

2.2. Preparation of sample test, animal adhesive and impregnant agents

Five replications for each treatment with a dimension of 2.5 cm × 2.5 cm × 0.5 cm and 5 cm × 2 cm × 2 cm were made for subterranean and dry-wood termites test, respectively. Three kg of sengon slabs and wood barks were put in a modified condensed drum and pyrolyse (dry distillation) at 200-400°C(Darmadji *et al*., 2000). Smoke was then condensed into liquid. The liquids collected in the condenser were about 1.5 litres.

Animal adhesive was in solid form. Thus, it should be distillated to soften the adhesive. The animal adhesive was mixed with 66°C destilled water its application to the wood (Conner, 2001). Impregnant agents used in the study were a mixture of wood vinegar and animal adhesive resin with the later concentration 8% and 10%. The addition of 4% borate in the formula was aiming for contrasting the resistance of impregnated jabon with the untreated impregnated jabon.

All samples were oven dried at 63°C to reach 10% moisture content. Those samples were then weighed and placed in a 10-litre-vacuum-pressure tube for 30 minutes. The tube was filled with impregnant agent and vacuum at 12 kg/cm^2 pressure for 60 minutes. Afterwards, all samples were dried in the oven at 63°C to reach 10% moisture content, and weighed.

2.3. Testing the chemical components of impregnant agents

Samples of mixed wood vinegar and animal adhesive were analysed using Gas Chromatography Mass Spectometry (GC-MS) Shimadzu GC-MS-QP 2010S. Column and injection oven temperature was set to 280°C while pyrolyzer temperature was set at 300°C with 101.0 kPa in 50 minutes (Fowlis, 1995).

2.4. Testing the resistance of impregnated jabon to termites attack

The Indonesian National Standard (SNI 7207-2014) was referred to test the resistance of impregnated jabon to termites attack (Indonesian National Standard Bureau, 2014). The resistance to subterranean termite attack was tested with the following procedures. Samples were put in glass containers with 200 gr of moist sand which has 7% moisture content under water holding capacity and 200 sound and active workers of subterranean termites. The containers were then placed in a dark room for four weeks. After four weeks, the samples were oven-dried.

The resistance of impregnated jabon to dry-wood termite attack was tested by placing 1.8 cm diameter and 3 cm height glass tube at the widest side of the samples. Fifty sound and active workers of dry-wood termites were put into the tube. The tube was placed in a dark room for twelve weeks. After twelve weeks, the samples were oven-dried.

At the end of the observation, weight loss and termites mortality were determined. As a control, the resistance test of impregnated jabon to termites attack with the absence of borate was also performed. As a standard, SNI 7207-2014 was applied for classifying wood resistance to subterranean and dry-wood termites attack (Indonesian National Standard Bureau, 2014).

2.5. Data analysis

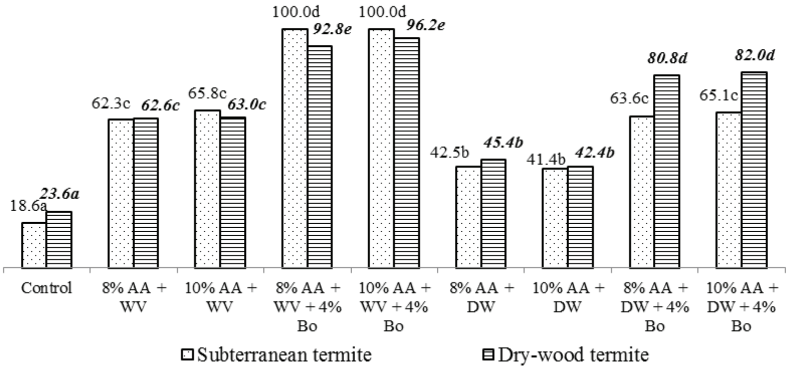
Completely Randomized Design with single factor was performed using SPSS ver.23. There were five replications of eight combinations of impregnant agents and one control samples. Analysis of Variance was used to determine the influence of treatment to weight loss and termite mortality. Duncan’s test was carried out for further analysis if the factor was significantly different (Steel and Torrie, 1995).

3. RESULTS and DISCUSSION

3.1. Termite mortality

Termite mortality is one of the parameters to assess the efficacy of preservative to increase the resistance of wood to termite attack (Ngadianto *et al.* 2011). The analysis of variance showed that the impregnation of wood vinegar and animal adhesive into jabon wood has significant effect on mortality rate of subterranean and dry-wood termites attack ($P<0.05$). Subterranean and dry-wood termite mortality of impregnated and control jabon was presented in Fig. 1.

As shown in Fig. 1, termite mortality in control jabon was the lowest (18.6% for subterranean and 23.6% for dry-wood termites) compared to the impregnated jabon. Subterranean and dry-wood termite mortality in impregnated jabon with mixed animal adhesive and distilled water was around 41.4%-42.5% and 42.4%-45.4%, respectively. Furthermore, the resistance of impregnated jabon with animal adhesive and wood vinegar to termite infestation was improved. The difference concentration of animal adhesive used in this research was based on the previous studies (Basri *et al*., 2016; Basri *et al*., 2015). It was shown that the 8% of animal adhesive was superior to dimension stability and density (Basri *et al*., 2015). However, 12% of animal adhesive was not effective to the physical properties of impregnated jabon wood (Basri *et al*., 2015). It was reported that the denser particleboard was more resistant to termite attack in comparison to less denser particleboard (Indrayani *et al*., 2014). Therefore, 8% and 10% of animal adhesive were applied in this research to test the effective concentration on termite resistance. The mortality rate for subterranean and dry-wood termites was 62.3%-65.8% and 62.3%-65.8%, consecutively. The efficacy of wood vinegar as anti-termite agent depends on its concentration and chemical composition (Oramahi *et al*., 2014).



Remarks: Means followed by the same letter(s) in the same column are not significantly different at the 5% probability level according to Duncan's test

Fig. 1. Termite mortality of impregnated and control jabon.

Termite mortality rate in impregnated jabon with mixed animal adhesive (8% and 10%) and wood vinegar with the addition of 4% borate was the highest compared to other treatments. Formula used in this treatment was very effective in increasing wood resistance, as the mortality rate for subterranean and dry-wood termites was 100%. This is in line with earlier study which revealed that the resistance of Japanese cedar (*Cryptomeria japonica*) and white cedar (*Melia azedarach*) against termite attack was increased by preserving with mangium wood vinegar and 5% borate (Hadi *et al*., 2010). This study, however, used lessen borate concentration yet adequate to enhance toxicity of chemical compounds in the wood vinegar. The mixture of animal adhesive, wood vinegar and borate resulted in more resistant wood compared to the mixture formula of animal adhesive and wood vinegar. Borate is a natrium active compound that tends to absorp fluid. Wood vinegar compounds will bond with wood organic compounds which will fill lumen and cell wall (Suryono, 2009). The addition of 4% borate in mixed animal adhesive and distilled water formula enabled the impregnated jabon to reach 63.6%-65.1% and 80.8%-82.0% mortality rate of the subterranean and dry-wood termites (Fig. 1). Nevertheless, mortality rate which is under 90% was disfavour since it implies that the wood does not durable to infestation. To resist from termite attack it required minimum concentration of 7.5% boric acid-water solution and to reach 98% of subterranean termite mortality rate, 10% boric acid-water solution was added (Darmono *et al*., 2013).

Analysis of chemical components revealed that sengon wood vinegar was dominated by phenol 2,6-dimethoxy, 2-propenoic acid and 3-phenyl compounds (Table 1). Those chemical compounds, however, less toxic to subterranean and dry-wood termites attack as indicated by low mortality rate (<70%) of subterranean and dry-wood termite (Fig. 1). It could be argued that phenolic and carboxylic acid compounds were bonded with other chemical compounds, such as dimethyl, hydroxyl, phenyl propan and acetic acid, thus lessen its toxicity to termite infestation (Table 1).

The addition of 4% borate into the formula augmented termite mortality to more than 90%. Further, it reached 100% of mortality rate of dry-wood termite. It is assumed that the adding of borate in wood vinegar could enhance toxic in its chemical compounds.

Borax ($Na_2B_4O_7 \cdot 10H_2O$) is a mixed of high concentrated sodium salt with pH 9.5 (alkaline) and could be used as wood preservative (Suheryanto, 2012). The

Table 1. Chemical components concentration of impregnant agents

No	Chemical components	Impregnant agents concentration (%)		
		WV	8% AA + DW + 4% Bo	8% AA + WV + 4% Bo
1	Phenolic groups			
	• Phenol, 2,6-dimethoxy	20.84	-	23.45
	• Phenol, 2,5-dimethyl	2.15		4.16
	• 2-Hydroxyphenol	8.25	-	10.34
	• Phenol, 2-methoxy-4-methyl	7.22	-	9.15
	• Phenol, 2-ethyl	1.60	-	3,16
	• Phenol, 4-(2-aminopropyl)	0.86	-	2.22
2	Carboxylic groups			
	• 2-Propenoic acid, 3-phenyl	19.72	17.5	21.74
	• Benzenepropanoic acid, methyl ester	7.79	5.25	9.15
	• Hexadecanoic acid, methyl ester	4.78	3.00	6.91
	• Octadecanoic acid, methyl ester	3.25	2.43	0.34
	• 3-amino-2-benzyl-butanoic acid	1.34	0.62	2.49
	• Pterine-6-carboxylic acid	1.36	0.46	2.04

Remarks: WV=wood vinegar; AA=animal adhesive; DW=distilled water; Bo=borate.

sodium salt is a soft crystal which consists of boron compound (Sumaryanto *et al*., 2013) and has toxic insecticidal activity to protozoa (Ewart and Cookson, 2014). Termites secrete cellulose with the aid of digestive enzymes that are produced by protozoa in their gut (Hu *et al*., 2011; Poinar, 2009). The application of optimal concentration of borate in preserved wood would kill protozoa in their gut. Thus, cellulose could not be digested, termites would be starving, stress and cannibalism would be likely to occur (Nandika, 2015; Hu *et al*., 2011; Poinar, 2009). Cannibalism is an adaptive behaviour to survive in the colony (Haifig *et al*., 2017).

3.2. Resistance to termite attack

The average of impregnated jabon resistance to termite attack is presented in Table 2. Based on analysis of variance, treatments applied in the study had significant effect to mass loss ($P<0.05$).

Mass losses of the untreated (control) jabon were 17.73% for subterranean and 20.40% dry-wood termites. Compared to other treatments, these proportions were the highest. Due to its low resistance to subterranean and dry-wood, control jabon was categorized as class IV. Similarly, impregnated jabon with mixed animal adhesive and distilled water fell into class IV as it mass loss were 13.40% and 12.21% for subterranean termite; 13.77% and 12.94% for dry-wood termite, with 8% and 10% animal adhesive concentration, respectively. Animal adhesive is nontoxic to wood destroying organisms. Animal adhesive is a protein colloid adhesive which is derived from hides, bones, tendons and cartilage. This adhesive dissolves in hot water and would harden when it is cooled (Ebnesajjad, 2010). Animal adhesive in impregnant formula plays an important role as a bonding agent or reinforcing wood structure (Basri *et al*., 2016).

Wood vinegar contained carboxylic and phenolic compounds that poisonous to termite, while borate only contained carboxylic compound (Table 1). However, those chemical compounds should be bonded together

Table 2. Jabon resistance against termites attack

Treatment	Subterranean termite (*C. curvignathus* Holmgren)		Dry-wood termite (*C. cynocephalus* Light)	
	Mass loss (%)	Resistance class	Mass loss (%)	Resistance class
Control	17.73 ± 2.49 e	IV	20.40 ± 0.66 e	IV
8% AA+WV	10.72 ± 1.48 c	III	7.68 ± 1.74 c	III
10% AA+ WV	10.57 ± 0.42 c	III	6.14 ± 1.49 c	III
8% AA+ WV +4% Bo	3.33 ± 0.79 a	I	1.92 ± 1.18 a	I
10% AA+ WV +4% Bo	2.87 ± 1.42 a	I	1.57 ± 0.94 a	I
8% AA+DW	13.40 ± 0.70 d	IV	13.77 ± 1.81 d	IV
10% AA+DW	12.21 ± 0.76 cd	IV	12.94 ± 1.47 d	IV
8% AA+DW+4% Bo	8.87 ± 0.96 b	III	4.23 ± 0.67 b	II
10% AA+DW+4% Bo	8.79 ± 0.87 b	III	3.87 ± 0.44 b	II

Remarks: WV=wood vinegar; AA=animal adhesive; DW=distilled water; Bo=borate. Means followed by the same letter(s) in the same column are not significantly different at the 5% probability level according to Duncan's test

to impose high toxic to termite. In this study, carboxylic and phenolic compounds were bonded with other chemical compounds, as stated earlier.

The addition of 4% borate in wood vinegar was significantly increase jabon resistance to subterranean and dry-wood termite from class IV to class I. This could be explain as the mixture of borate and wood vinegar formed more reactive chemical reaction and increase its toxic to subterranean and dry-wood termites. Further analysis should be performed to develop more robust carboxylic and phenolic compounds-based formula which durable to termite attack in contrast to the efficacy of borate.

4. CONCLUSION

Impregnated jabon with at least 8% animal adhesive and wood vinegar raised its resistance to termite infestation. However, since the mortality rate was still below 70% such treatments were still inadequate to struggle from subterranean and dry-wood termites attack. Resistance class of impregnated jabon with animal adhesive and wood vinegar against subterranean and dry-wood termites attack slightly increased from class IV to class III and from class IV to class II, consecutively.

The addition of 4% borate in mixed animal adhesive and wood vinegar was efficient to resist from termites attack. It seems borate plays important factor for this matter. This treatment was made the lowest mass loss of impregnated jabon and reached more than 90% of mortality rate. Thus, the resistance class of jabon wood improved from class IV to class I.

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