TERMITE RESISTANCE OF JABON WOOD IMPREGNATED WITH METHYL METHACRYLATE

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HADI YS, RAHAYU IS & DANU S. 2015. Termite resistance of jabon wood impregnated with methyl methacrylate. Jabon (*Anthocephalus cadamba*) wood specimens were impregnated for 10, 20 and 30 min with monomer methyl methacrylate (MMA) and then polymerised by ^{60}Co gamma radiation (10 and 30 kGy). After the polymerisation process, polymer loadings were calculated. For comparison, control specimen was prepared using untreated wood. All wood specimens were tested for resistance to subterranean termite (*Coptotermes curvignathus*) in the laboratory for 4 weeks according to the Indonesian standard. At the end of the test period, wood specimen weight loss, resistance class, termite mortality and feeding rate were determined. Results showed that the average polymer loading reached 69% and the MMA wood had better resistance to subterranean termite than untreated wood. The untreated wood belonged to resistance class V (very poor resistance) but MMA wood was rated as class II (resistant). Compared with untreated wood, MMA wood also had less weight loss (77.7%), a lower termite feeding rate (73%) and increased termite mortality (20.9%). Impregnation period, radiation dose and interaction of both of these factors affected wood weight loss and termite feeding rate. The best combination treatment was 30 min of MMA impregnation and 30 kGy of radiation.

Keywords: Subterranean termite, weight loss, resistance class, mortality, feeding rate

INTRODUCTION

Since 2000, plantation forests have been supplying about 60% of logs for the wood industry. The Indonesian government has established 4.3 mil ha of plantation forest towards sustainable forest management (Anonymous 2011). Other sources of plantation logs are community forests and greening activities that cover an area of about 1 mil ha, which is predominantly planted with fast-growing tree species such as jabon (*Anthocephalus cadamba*), sengon (*Paraserianthes falcataria*), mangium (*Acacia mangium*) and gmelina (*Gmelina arborea*). Logs from tree plantations are mostly from young trees aged 5–8 years. This juvenile wood has inferior physical–mechanical properties as well as less resistance to attack by termites compared with mature wood.

Buildings in Indonesia have traditionally been constructed from mature wood. Nevertheless, damage to these structures due to termite attack was associated with economic losses of approximately USD200 mil in 1995 (Rakhmawati 1995). In 2000, losses were USD200–300 mil (Yoshimura & Tsunoda 2005). It is likely that losses will increase in future if juvenile wood from plantation forests is not preserved prior to being used as building materials.

Methyl methacrylate (MMA) has been incorporated into wood to improve its physical–mechanical properties and resistance to biodeterioration. The final product is durable and does not contain toxic chemicals. MMA wood has better mechanical properties than untreated wood in terms of its modulus of rupture, modulus of elasticity, compression strength and hardness (Li et al. 2012, Wang et al. 2012). The degree of polymer loading gain will affect physical and mechanical properties linearly as demonstrated by Ding et al. (2008) who polymerised MMA into five hardwood and one softwood species and found that the density was enhanced by as much as 45 to 130% depending on species.

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MMA wood has also been shown to improve biodeterioration resistance. MMA wood had improved durability in terms of dimensional stability, water repellency, decay resistance and acid resistance compared with untreated wood (Li et al. 2010). It was also reported that MMA poplar had 69.8% improved decay resistance against brown fungus (*Gloeophyllum trabeum*) and 81.4% against white fungus (*Phanerochaete chrysosporium*) compared with untreated poplar (Li et al. 2011). MMA wood had effectively improved performance against subterranean termites (*Coptotermes formosanus*) even after severe leaching cycles (Kartal et al. 2004). In a study using wood plastic, it was reported that four polystyrened wood species from Poland with polymer loadings of 88–135% had more resistance towards subterranean termite (*Coptotermes curvignathus*) attack than untreated wood (Hadi et al. 1998).

The purpose of this work was to determine the resistance of MMA jabon wood against subterranean termite attack in laboratory tests. Wood specimens were impregnated with monomer MMA for 10, 20 and 30 min and irradiated with ^{60}Co gamma ray radiation at 10 or 30 kGy. For purposes of comparison, untreated wood was also prepared as control.

MATERIALS AND METHODS

Materials

Six-year-old jabon wood from Bogor Indonesia was used to determine resistance to subterranean termite attack. Logs with a diameter of approximately 40 cm was cut into lumber and then trimmed into sample pieces for the subterranean termite test. Heartwood and sapwood parts were not clearly distinguished. The sample size for the subterranean termite test was 2.5 cm (width) × 0.5 cm (thickness) × 2.5 cm (length) according to the Indonesian standard (SNI 2006). Three samples were used for each treatment combination.

Air-dried wood samples were placed in a vacuum at 8 atm for 30 min, followed by immersion in monomer MMA solution for 10, 20 or 30 min as the first treatment factor. Next, the wood samples were wrapped in aluminum sheet and exposed to ^{60}Co gamma radiation at 10 or 30 kGy as the second treatment factor. After the aluminum sheet was removed, wood samples were weighed to calculate polymer loading. For comparison, untreated wood was included as control.

Subterranean termite test

Specimens were placed in glass containers with 200 g of sterilised river sand, 50 mL of water and 200 healthy and active workers of *C. curvignathus* termites from a laboratory colony (Figure 1). The containers were put in a dark room at a temperature of 25–30 ^{o}C and 80–90% relative humidity for 4 weeks and weighed each week. If the moisture content of the sand decreased by 2% or more, water was added to achieve the 25% moisture content. At the end of the 4 weeks, wood specimens were oven dried and weight loss, termite mortality and termite feeding rate were determined using the following formulae.

$$\text{Weight loss} = (W_1 - W_2)/W_1 \times 100\%$$

where W_1 = weight of oven-dried sample prior to the test (g) and W_2 = weight of oven-dried sample after the test (g).

$$\text{Termite mortality} = (T_1 - T_2)/T_1 \times 100\%$$

where T_1 = number of live termites prior to the test and T_2 = number of live termites after the test.

In order to calculate the feeding rate, we assumed that termites died linearly with time, and feeding rate was calculated according to the following equation:

Feeding rate (mg/termite/week) = (weight of wood eaten by termites)/(live termite × test period).

Wood resistance class against subterranean termites was determined by referring to SNI (2006) as shown in Table 1.

Data analysis

A 3 × 2 factorial in a completely randomised design was used to analyse the data. The first factor was impregnation period in MMA solution (10, 20 or 30 min) while the second factor, dose of gamma radiation (10 or 30 kGy). Duncan's multiple range test was used for further analysis if the factor was significantly different. To

Figure 1 Container used in the subterranean termite test

analyse the effect of MMA wood upon untreated wood, Dunnet test was applied with equal sample numbers.

RESULTS AND DISCUSSION

The density of the untreated jabon wood was 0.35 g cm^{-3} (Hadi et al. 2013). This density was low because jabon tree is a fast-growing species and trees were cut at 6 years of age, i.e. they were very young trees. Density gains of MMA jabon wood samples were equal to the polymer loadings (Hadi et al. 2013). The amount of polymer loading, weight loss of wood sample, resistance class, termite mortality and termite feeding rate after a 4-week subterranean termite test and Dunnet test for untreated woods are shown in Table 2. According to analysis of variance, impregnation periods of 10, 20 and 30 min and radiation doses of 10 and 30 kGy did not differ significantly in their effects on MMA polymer loading and termite mortality. Average polymer loading for all combination treatments reached 69 ± 18% and this amount of polymer loading was high enough because jabon wood had low density. This value was higher than the loading of 13–26% reported by Gupta et al. (2004) who did MMA impregnation and polymerisation with gamma radiation up to 30 kGy in rubber wood polymer. However, hardening with MMA treatment increased density of poplar woods by only 2.2 to 2.6 times depending on the clone (Ding et al. 2012). The polymer loading of jabon wood could potentially be higher if the process of inserting monomer into the wood was done via a compregnation process. Unfortunately, the standard deviation of polymer loading for the treatment of 10 kGy with 10 min immersion reached 57% of the mean value. This was due to variation in wood properties.

Weight loss of untreated wood reached 24.2 ± 1.0% while MMA wood had weight loss of only 5.4 ± 1.1%. Weight loss of wood specimen was affected by impregnation period, radiation dose and the interaction of these factors. Impregnation period of 30 min had the lowest weight compared with 10 and 20 min. Weight loss was highest in 20 min-impregnated wood samples exposed to 10 kGy radiation. The lowest weight loss was observed when 30 min-impregnated wood samples were exposed to 30 kGy radiation. However, the periods of radiation were not significantly different in Duncan's multiple range test. For the radiation dose factor, radiation of 30 kGy resulted in lower weight loss compared with 10 kGy radiation dose. Results of this study are in line with those of Hisham and Anwar (2005) who stated that

Table 1 Resistance class against subterranean termite

Resistance class	Classification	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

According to SNI (2006)

Table 2 Polymer loading, wood weight loss, resistance class, termite mortality and termite feeding rate in subterranean termite test

Impregnation period (min)	Radiation dose (kGy)	Polymer loading (%)	Wood weight loss (%)	Termite mortality (%)	Feeding rate (mg termite^{-1} week^{-1})
10	10	61 ± 35	5.45 ± 0.09 cd	98.22 ± 1.39	14.65 ± 1.27 bcd
20	10	52 ± 7	6.80 ± 1.02 b	94.67 ± 0.67	18.34 ± 3.85 b
30	10	76 ± 1	5.76 ± 0.74 bcd	96.00 ± 0.67	14.85 ± 0.89 bcd
10	30	88 ± 11	5.91 ± 0.49 bc	96.22 ± 0.38	16.35 ± 1.48 bc
20	30	64 ± 7	4.60 ± 0.24 de	97.33 ± 0.67	12.89 ± 0.74 cd
30	30	74 ± 2	3.89 ± 0.24 e	97.56 ± 1.39	11.14 ± 1.61 d
Untreated wood			24.2 ± 1.0 a	76 ± 2	65 ± 3 a
Dunnet test			1.54*	2.75*	5.05*

* = Significantly different ($p < 0.05$); same letters in a row indicate that the values are not statistically different, values are means and standard deviations of three replicates

percentage weight loss following decay of MMA-modified cane was significantly reduced by longer impregnation period.

Based on weight loss, we were able to describe the wood resistance class according to the Indonesian standard (SNI 2006). Control wood was in class V which meant very poor resistance against subterranean termite attack and MMA wood was class II, i.e. resistant. This rating meant that MMA was very effective in increasing wood resistance against termites. According to Hadi et al. 2005, higher polymer loading may produce resistance class I (very resistant wood).

Termite mortality was not affected by impregnation period and radiation doses but separately, interaction of both factors was significant. Termite average mortality in MMA wood reached 97% meaning almost all termites died. This value is about 20.9% higher than the untreated wood (76% mortality). Termite mortality for untreated wood was high because the test was conducted in a room without controlled temperature and humidity, but it was suitable for the test. MMA is not toxic to termites, but it creates a barrier for termites and prevents them from reaching the wood. Higher polymer loading would result in stronger barrier and greater resistance. MMA jabon wood was more resistant than control against *C. curvignathus* subterranean termites.

Termite feeding rate on untreated jabon wood was 65 mg termite^{-1} week^{-1}. This value is lower than the standard feeding rate on pine (*Pinus merkusii*), i.e. 79 mg termite^{-1} week^{-1} (Arinana 2011). The MMA wood had much lower feeding rate of 17 mg termite^{-1} week^{-1}, i.e. 27% compared with untreated wood rate. Impregnation period, radiation doses and interaction of both factors significantly affected feeding rate. The lowest feeding rate was in treatment of 30 min impregnation and 30 kGy radiation.

CONCLUSIONS

Average polymer loading reached 69% in MMA wood and it had better resistance against subterranean termite attack than untreated wood. The untreated wood belonged to resistance class V, i.e. very poor resistant, but MMA wood rated resistance class II, resistant. Compared with untreated wood, based on Table 2, MMA wood had a 77.7% lower weight loss, 73% lower termite feeding rate and 20.9% higher termite mortality. The impregnation period, radiation dose and interaction of both factors affected wood weight loss and termite feeding rate. The best combination treatment in terms of lowest wood weight loss and termite feeding rate was 30 min of MMA impregnation and 30 kGy radiation.

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