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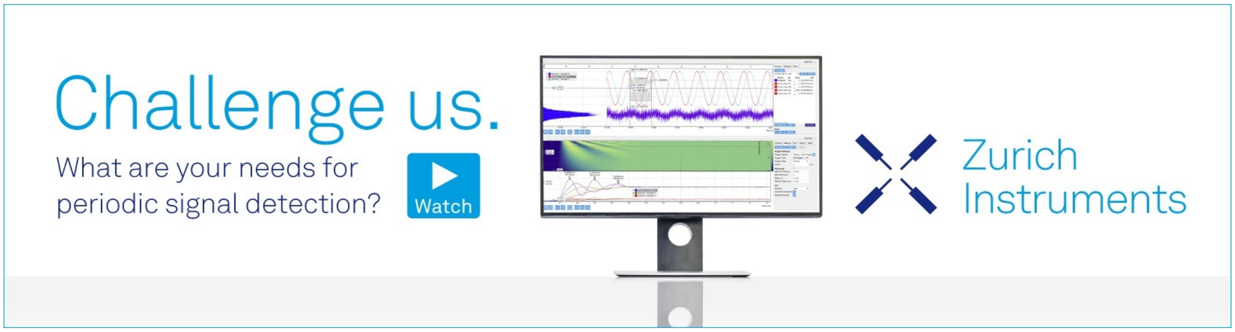

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Biodegradability of Four Wood Species Treated by Gamma-Irradiation and Its Applicability to the Termite Management

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Abstract. Dry wood termites, *Cryptotermes cynocephalus*, is one of the most damaging termites of wood. It mainly attacks furniture. For furniture export, the pest-free certificate from the quarantine department is indispensable. This study aimed at understanding the level of eating preference of termites on four Indonesian exotic kinds of wood namely: *Eusideroxylon zwageri, Tectona grandis, Swietenia mahagoni,* and *Anthocephalus cadamba*. The woods were radiated by gamma-ray 300 Gy. A further test on dry wood against termites employed Japanese industrial standard (JIS 2009). The results showed that the level of wood damage after the irradiation was different from non-irradiated wood. The best wood after radiation was *Eusideroxylon zwageri* while the most susceptible to termites was *Anthocephalus cadamba*. After radiation, the highest termites' mortality level was at *Tectona grandis*. This study suggests that gamma-ray radiation from various types of wood furniture for the export purpose can increase the resistance of wood against termites.

Keywords: *Cryptotermes cynocephalus*, dry wood, radiation, wood

INTRODUCTION

In the last two decades, about 40 % of Indonesian are using four wood species such as *Eusideroxylon zwageri*, *Tectona grandis, Swietenia mahagoni,* and *Anthocephalus cadamba* [1]. The strength class: (I) are equal to *Eusideroxylon zwageri, Tectona grandis,* (II to III) is comparable to *Swietenia mahogany* and *Anthocephalus cadamba* woods, but durability class (IV to V) shows poor resistance to biodeterioration [2]. Existing housing in Indonesia was built with mature wood. However, the economic cost of damage to various buildings due to termite attack was around USD200 000 000 to USD300 000 000 [3]. Therefore, the needs of wood preservation are essential. The preservation method can extend the service life of timber, and it currently consists of adding toxic chemicals or preservatives to the wood.

The technique of controlling dry wood termites in Indonesia has never existed. An effort is needed to establish controlling technique with baiting system. Research that has been done in developed countries such as Japan is through using gamma-irradiation 100 kGy to 1 000 kGy. The results show that gamma irradiation 500 can attract termites to prefer wood. Gamma-irradiation can cause degradation of wood cellulose. The higher the dose used, the more degenerated the polymerization of cellulose. The results showed that the wood's cell wall is induced by gamma-irradiation in the range between 100 kGy to 1 000 kGy [2].

Unfortunately, there has been no information about termite resistance of the gamma-irradiated wood. Gamma-irradiated wood is easily bitten and taken by termites due to the relatively lower content of cellulose. Gamma-irradiation helps termites to eat wood, where the gamma-irradiated wood might be suitable for the substrate of bait toxicant in the termite management system. An ideal substrate is highly resistant to microbial infection (decay and

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sap-staining fungi and molds) and vulnerable to termites at the same time. Since some microbial infection naturally discourages the termite to gain access to bait stations and in contrast low termite resistance is likely to attract termites [5]. The purpose of this study was to determine resistance and termite feeding rates in treated wood. Samples of *Eusideroxylon zwageri, Tectona grandis, Swietenia mahagoni,* and *Anthocephalus cadamba* gamma-irradiation treatments respectively and were exposed to dry wood termite attacks in laboratory tests.

MATERIALS AND METHODS

Materials

The woods species *Eusideroxylon zwageri, Tectona grandis, Swietenia mahagoni,* and *Anthocephalus cadamba* from Indonesia were used to determine termite attack resistance. Tree treatments were applied to separate wood samples of each species. The wood samples were then wrapped in aluminium foil and placed in an oven at 100 °C for 24 h. The uncovered wood samples were then weighed for weight gain calculation. All treated woods were conditioned at room temperature for three months before the tests. Untreated wood was also prepared as a control for the experiments in this study. All wood samples were 0.8 cm by 2 cm in cross-section in the longitudinal direction for dry wood termite tests, respectively. Three replications were performed for tests. Air dried wood samples were placed in a vacuum at 8 atm for 30 min as the first treatment factor. Next, the wood samples were wrapped in aluminium sheet and exposed to gamma-irradiation at 300 kGy as the second treatment factor. After the aluminium sheet was removed, wood samples were weighed to calculate polymer loading. For comparison, untreated wood was included as the control. Tukey test was performed to analyse which specific groups' means (compared with each other) are different.

Termites

As test organisms, pseudergates of *Cryptotermes cynocephalus* were collected from infested timbers in Bogor, Indonesia. The termites were than extracted from the timbers and kept in plastic containers with lids containing small wood blocks of Douglas fir (*Eusideroxylon zwageri, Tectona grandis, Swietenia mahagoni,* and *Anthocephalus cadamba)* as both a food source and harborage. The containers with the termites were kept in a termite culturing room of Entomology Laboratory, Universitas Negeri Semarang at 28 °C with relative humidity (RH) higher than 85 % in darkness for at least 1 wk before testing to ensure that only healthy termites would be used in the experiment. Termite mortality rate and sample weight loss were recorded.

$$\text{Sample weight loss} = \frac{\text{ODS1} - \text{ODS2}}{\text{ODS1}} \times 100\ \%$$

ODS1 is oven-dried sample before test, while ODS2 is oven-dried sample after test.

RESULTS AND DISCUSSION

Weight loss (WL) of wood samples and their associated resistance class, termite mortality, and termite feeding rate after 12 wk of the dry wood termite test are shown (Table 1). The untreated *Pinus mercusii* had 4.0 ± 0.07 % WL of treated by acetylation or with smoke belongs to the same class as untreated wood, but WL of both treated woods was significantly lower than untreated wood. Untreated *Pinus mercusii* wood belongs to resistance class IV (poorly resistant), but the treated wood belongs to class I to III (very resistant to moderately resistant).

Weight loss (WL) of wood samples and their associated resistance class, termite mortality, and termite feeding rate after 12 wk of the dry wood termite test are shown (table 2). Untreated *Pinus mercusii* had 4.0 ± 1.4 % WL, of its weight, 3.3 times the WL percentage of mindi. Termite mortality for untreated mindi was 46.0 ± 6.0 %, while that for sugi was only 21.3 ± 7.0 %. According to resistance class rating for dry wood termite, untreated *Pinus mercusii* is included in class IV (poorly resistant) [1].

Table 1 explains that in three months, one termite can reduce the wood load in Table 2. The table above showed that the samples experienced the most consecutive weight loss are *Anthocephalus cadamba, Tectona grandis, Swietenia mahagoni* and *Eusideroxylon zwageri*. Meanwhile, *Pinus mercusii* as control reduced the weight of wood as much as 0.46 mg per tail.

TABLE 1. Wood weight loss of the gamma irradiation test 300 kGy for *Eusideroxylon zwageri, Tectona grandis, Swietenia mahagoni,* and *Anthocephalus cadamba* only, (n = 3).

Samples	Wood Weight Loss
Anthocephalus cadamba	1.37 ± 0.58
Tectona grandis	1.06 ± 0.75
Swietenia mahagoni	0.89 ± 0.29
Eusideroxylon zwageri	0.30 ± 0.14
Pinus mercusii (Control)	0.47 ± 0.07

TABLE 2. Termite mortality of the gamma irradiation test 300 kGy for *Anthocephalus cadamba, Eusideroxylon zwageri, Tectona grandis, Swietenia mahagoni,* and *Pinus mercusii,* (n = 3).

Sample	Daily Termite Mortality Percentage (Mean ± SD)							
	7	14	21	28	35	42	49	53
A. cadamba 1	13 ± 11.34	26.29 ± 0.49	29.57 ± 0.53	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0
A. cadamba 2	13 ± 11.34	25.29 ± 0.49	29.57 ± 0.53	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0
A. cadamba 3	9.29 ± 7.48	20.14 ± 1.07	25.71 ± 0.76	28 ± 0	28 ± 0	28 ± 0	29.14 ± 0.38	30 ± 0
T. grandis 1	20 ± 11.6	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0
T. grandis 2	19.71 ± 11.13	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0
T. grandis 3	18.86 ± 11.32	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0
S. mahagoni 1	9.71 ± 6.9	18.71 ± 1.25	24.71 ± 2.93	28.43 ± 0.98	30 ± 0	30 ± 0	30 ± 0	30 ± 0
S. mahagoni 2	20.29 ± 12.87	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0
S. mahagoni 3	9.57 ± 6.65	18.57 ± 1.4	28 ± 3.21	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0
E. zwageri 1	10.86 ± 8.61	28 ± 2	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0
E. zwageri 2	15.43 ± 12.3	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0
E. zwageri 3	6.43 ± 5.16	23.57 ± 5.03	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0	30 ± 0
P. mercusii 1	11.57 ± 10.13	24.57 ± 0.98	28.71 ± 0.76	29 ± 0	29 ± 0	29 ± 0	29 ± 0	29.25 ± 0.5
P. mercusii 2	9.14 ± 7.47	20.14 ± 1.35	24.71 ± 0.76	25 ± 0	26.71 ± 0.76	28 ± 1	29 ± 0	29.75 ± 0.5
P. mercusii 3	10 ± 8.25	22.43 ± 2.88	27.86 ± 0.38	28 ± 0	29 ± 0	29 ± 0	30 ± 0	30 ± 0
F value	3.258	2.386	1.666	0.539	2.888	3.2	2.23	2.286
Sig.	0.059*	0.121*	2.333*	0.711*	0.079*	0.062*	0.138*	0.132*
Tukey HSD sig.	0.61	0.166	0.35	0.745	0.115	0.102	0.193	0.195

*There is a significant difference if the value of sig. < 0.05. The above data were tested using one way ANOVA test with advanced test using Tukey test. Since the sig value at the percentage of termite mortality > 0.05 then there is no average difference between tree species and the percentage of termite mortality per day.

The table above shows that *Tectonia grandis* has a high durability class because it can cause dead termites on day 14, followed by ironwood, mahogany, and jabon. The most durable samples are *Tectona grandis*, *Eusideroxylon zwageri*, *Swietenia mahagoni*, *Anthocephalus cadamba,* and *Pinus mercusii*. Meanwhile, pine wood (control), without treatment until the last day, termites are still able to survive to eat.

Gamma-ray radiation can increase the power pull termite *Cryptotermes cynocephalus* to devour wood. We know that teak and ulin is the most durable wood species in Indonesia. However, after irradiation treatment, the results show that high duration timber is still deadly for termites by day 14. *Eusideroxylon zwageri*, *Tectona grandis*, *Swietenia mahagoni,* and *Anthocephalus cadamba*. The gamma-irradiated *Eusideroxylon zwageri, Tectona grandis, Swietenia mahagoni,* and *Anthocephalus cadamba* sapwood were tested for its biological resistance and potential as the substrate of toxicants in termite bait system. Laboratory evaluations showed that the decay resistance of *Eusideroxylon zwageri, Tectona grandis, Swietenia mahagoni,* and *Anthocephalus cadamba* sapwood did not change after gamma-irradiation due to the continuous matrix of the cell wall. On the other hand, a decreased degree of polymerization of cellulose by gamma-irradiation resulted in the raised feeding activity of the dry wood termite, *Cryptotermes cynocephalus* in the no choice laboratory test. Besides, gamma-irradiation could protect from decaying fungi [6]. This discovery that gamma-irradiation of wood enhanced termite feeding insisted on the necessity of further research to discuss the applicability of gamma-irradiated wood to the bait substrate in termite management program. Additional laboratory evidence indicated the superiority of the gamma-irradiated wood as the bait substrate to non-durable and moderately durable wood such as heartwood of *Eusideroxylon zwageri, Tectona grandis, Swietenia mahagoni, and Anthocephalus cadamba* [7].

The gamma-irradiated *Eusideroxylon zwageri, Tectona grandis, Swietenia mahagoni,* and *Anthocephalus cadamba* were finally examined for their potential as the bait substrate (matrix) for termite management. Noviflumuron or hexaflumuron, insect growth regulators (IGRs), was impregnated into the gamma-irradiated wood, and *Cryptotermes cynocephalus* workers were forced to eat the treated wood blocks [8, 9]. The termite workers were then fed on untreated filter paper to record the number of dead termites with time. The gamma irradiation favourably helped termites eat more wood with noviflumuron or hexaflumuron. The results of this bioassay demonstrated that both IGRs did not lose their slow acting and low dose dependent characteristics required as the bait toxicant.

All these results strongly support that gamma-irradiation at 300 kGy is feasible in converting nondurable wood into the more suitable substrate of bait toxicants and that further studies should be planned to demonstrate the usefulness of gamma-irradiated wood in the field where the alternative food source is always available. The gamma-irradiated wood should be examined regarding its attracting and arresting ability as well under the field conditions to establish environmentally benign termite management as a result of the commercialization of gamma-irradiation technology [10].

CONCLUSION

The most durable woods after treatment with gamma-ray radiation 300 kGy consecutive are *Tectona grandis, Eusideroxylon zwageri, Swietenia mahagoni, Anthocephalus cadamba,* and *Pinus mercusii.* The effects of gamma-ray radiation 300 kGy only attract termites but do not give effect to kill termites directly. Radiation technique using 300 kGy gamma-rays can be used as a baiting system technology for termite control.

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