Resistance of Wood on Subterranean Termites Attack: Relationship Between Wood Price and Natural Resistance Class

Hendra Kurniawan Maury[1&4], Rudi Dungani[2*], Intan Ahmad[3] and Ramadhani Eka Putra[3]

[1]Biology Doctoral Program, School of Life Sciences and Technology, Institut Teknologi Bandung, Bandung 40132, Indonesia
[2]Forestry Technology Research Group, School of Life Sciences and Technology, Institut Teknologi Bandung, Sumedang 45363, Indonesia
[3]Biological Resources Management Research Group, School of Life Sciences and Technology, Institut Teknologi Bandung, Bandung 40132, Indonesia
[4]Biology Department, Universitas Cenderawasih, Jayapura 99224, Indonesia
rudi67@itb.ac.id

Abstract. Termite damage poses a significant challenge in Indonesian timber construction. This study examines the economic importance of wood by considering both termite resistance and cost-effectiveness. We evaluate the feeding preferences of *Coptotermes curvignathus* termites and the natural resistance of various wood species. In single feeding preference tests conducted over 21 days, Merbau and Teak wood were found to be unpreferred by termites, while Sumatran champor, Keruing, and Sengon wood species exhibited weight loss, indicating preference. Pine, Mangium, and Light red meranti wood were highly preferred by termites. The highest termite mortality was observed in Teak wood, while Pine wood had the lowest mortality. In multiple feeding preference tests within colonies (Modified Wood Block Test Standard method, 90 days), we classified wood resistance levels. Merbau was deemed very resistant, Teak as resistant, Sumatran champor and Sengon as moderately resistant, and Keruing, Light red meranti, Mangium, and Pine as poor in resisting termite infestation. Examining the relationship between natural resistance and wood price for the studied species, Merbau emerged as the most economical choice, followed by Sengon, Sumatran camphor, Teak, Pine, Acacia, Light red Meranti, and Keruing. This research highlights that wood resistance class may not always align with the economic value of wood. These findings can inform wood selection in timber construction, balancing termite resistance and cost-effectiveness.

Keywords: Economic aspect, natural resistance, termites, wood price

S. Gandaseca et al. (eds.), *Proceedings of the International Conference on Science, Technology and Social Sciences – Biology Track (ICONSTAS-BIO 2023)*, Advances in Biological Sciences Research 43,

https://doi.org/10.2991/978-94-6463-536-2_22

1 Background

The use of wood for housing construction, besides having advantages, also carries the risk of damage due to attacks by wood destroying organisms, especially termites (Insecta: Isoptera). Termite infestation cases occur in almost all regions in Indonesia with huge economic losses. According to reference [1], losses due to termite attacks on residential buildings owned by the community reached 1.67 trillion rupiah per year, while losses on government buildings were estimated at 100 billion annually [2]. These economic losses continue to grow along with the increase in settlement growth. Potential losses nationally in 2015 were estimated at 8.68 trillion rupiah [3]. The increasing trend of wood consumption and land clearing for housing development are the main contributing factors to the increasing losses due to termite infestation in the future.

Some research indicates that the subterranean termite *Coptotermes curvignathus* Holmgren is the type of termite that causes the most damage to building construction wood. The distribution is also very wide and very common in various regions in Indonesia with a long attack range (90 meters from the nest). The nests are found 3-6 meters below the ground with tunnels as wide as 6 mm [4,5]. Meanwhile, termite feeding preference is a response to stimuli originating from wood. Differences in the chemical content (extractive substances) of wood can affect the selection of preferred food [6-8].

Most of the timber consumed for building construction in Java is imported from outside Java [9]. Timber imported from outside Java has an impact on increasing the selling price of timber. The price of sawn timber varies greatly based on the timber's natural resistance class and size. Timber with a good resistance class (class I - II), generally has a high price. This condition causes people with low expenditure power to choose low-priced timber from durability classes III – V, to fulfill the required quantity of timber. The use of construction timber from these durable classes is very vulnerable to subterranean termite attack, therefore it is necessary to study the level of economy in the types of wood commonly used in housing construction in Indonesia, by linking the natural resistance to subterranean termites *C. curvignathus* and the price of wood. The results of this study are expected to provide input for the selection process of building wood and the development of building wood protection policies in Indonesia.

2 Methods

The wood species used in this study were eight building wood species that are classified as commercial species, have high supply potential and are quite widely used for building materials or furniture in Indonesia (Table 1).

Table 1. Species and common name of eight construction wood analyzed

Species	Common name
Tectona grandis L. f.	Teak
Acacia mangium Willd.	Mangium
Pinus merkusii Jungh et de Vr.	Pine
Shorea leprosula Miq.	Light red meranti
Dryobalanops aromatica Gaertn.	Sumatran camphor
Intsia bijuga O. Ktze.	Merbau
Dipterocarpus borneensis V. SI.	Keruing
Paraserianthes falcataria (L) Nielsen.	Sengon

From each type of wood, the sapwood was taken to make blocks measuring 5 x 5 x 100 cm. The blocks were sawn back into test samples measuring 10 x 10 x 20 mm. All test samples were dried in an oven (102 ± 3ºC) for 24 hours until the moisture content was 12 - 18% (W1).

The termite species used in this study were *C. curvignathus* Holmgren (Isoptera: Rhinotermitidae) from colonies that had been bred for six months or more at the Forest Products Pest and Disease Laboratory, Inter-University Research Center - Life Sciences, Institut Pertanian Bogor.

In the single feeding preference test outside the colony, the test samples were placed in glass jars (8.5 cm high, 5 cm diameter) containing 30 g of sand moistened with 6 ml of water. 200 worker termites and 20 soldier termites of *C. curvignathus* were placed in each jar. All glass bottles were kept in a dark room for 21 days. Responses measured were weight loss of test samples and mortality of *C. curvignathus* termites.

The multiple feeding preference test within the colony, based on the standard modified wood block test (MWBT) [10], uses fiber glass containers with dimensions of 70 cm x 50 cm x 100 cm containing colonies of subterranean termites *C. curvignathus* that have been reared for six months or more. All test samples for all wood species were randomly placed on wire mesh and then placed on the soil surface of the *C. curvignathus* termite colonies in the thermitarium. The response measured was the weight loss of the test specimens.

Observations were made after the test reached day 21, for the single feeding preference test and 90 days for the multiple feeding preference test within the colony, by taking back all test samples. The test samples were cleaned of dead termites and termite bite marks, then put back into the oven (102 ± 3ºC) for 24 hours to determine the weight loss of the test samples and weighed again (W2). The calculation of how many termites survive for the single feeding preference test outside the colony is used to determine the mortality of termites in each wood.

The responses that were measured in the *C. curvignathus* subterranean termite feeding preference test were as follows:

$$WL = \frac{W_1 - W_2}{W_1} \times 100 \quad (1)$$

Where:
WL = Weight lost (%)
W_1 = dry weight of sample wood before feeding (g)
W_2 = dry weight of sample wood after feeding (g)

Termite mortality was calculated by counting the live termites at the end of the experiment. The following equation was used to calculate the percentage of termite mortality:

$$Mortality\ (\%) = \frac{(number\ of\ death\ workers)}{200} \times 100 \quad (2)$$

To determine differences in average weight loss in various types of wood, Duncan's multiple distance test was carried out, while the natural resistance class was based on the classification of reference [11] as presented in Table 2.

Table 2. Classification of the resistance of test samples to subterranean termites in the multiple feeding preference test within colonies [11]

Weight lost (%)	Resistance class
0	Very resistant
1-15	Resistant
16-40	Moderately resistant
41-75	Poor
>75	Very poor

Economic aspect analysis was calculated by using following formula, the smaller the value, the better the economic ranking:

$$Economic\ value\ = \frac{price\ (Rp)}{Relative\ Resistance} \quad (3)$$

3 Results and Discussion

The feeding preferences of the subterranean termite *C. curvignathus* Holmgren in a single feeding preference test outside the colony varied across various types of wood. The results of the study showed that the lowest (very least preferred) food preference for the termite *C. curvignathus* occurred on Merbau wood (*Intsia bijuga*), while Teak wood (*Tectona grandis*) was quite preferred. Meanwhile, the highest termite food preferences (liked and highly preferred) are Sengon wood (*Paraserianthes falcataria*), Sumatran camphor (*Dryobalanops aromatica*), and keruing (*Dipterocarpus borneensis*) for preferred food preferences; Pine wood (*Pinus merkusii*), Mangium (*Acacia mangium*) and Light red meranti (*Shorea leprosula*) for very favorable food preferences.

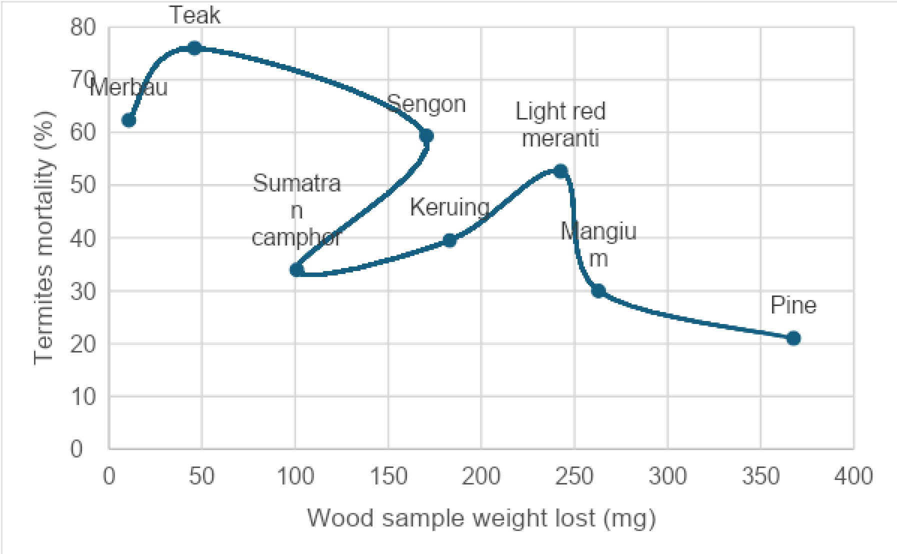

Fig. 1. Relationship between weight loss of test samples and mortality of termites in the single feeding preference test

Pine, Mangium and Light red meranti wood lost weight more than 200 mg, Pine (367.67 mg), Mangium (262.87 mg) and Light red meranti (245.57 mg). Sumatran camphor, Keruing and Sengon wood lost between 100 – 200 mg in weight, whereas Sumatran camphor wood (170, 43 mg), Keruing (183.00 mg) and Sengon wood (130.93 mg). Merbau and Teak are types of wood that are less preferred by subterranean termites *C. curvignathus*, both types of wood lose weight between 0 – 50 mg, Merbau (10.67 mg) and Teak (46.08 mg).

The highest mortality of *C. curvignathus* occurred in Teak wood (76%) (Fig. 1), while the weight loss was only 46.08 mg. The lowest termite mortality occurred in Pine wood (21%) with a weight loss of 367.67 mg (Fig. 1). The toxic content of Teak wood extractive substances (quinones) [12,13] is the main cause of the high mortality of *C. curvignathus*, whereas in Pine the opposite occurs. The second largest mortality occurred in Merbau (62.3%), where the weight loss was very low (10.67 mg). This shows that the main trigger for mortality in termites is starvation, it is thought that the extractive substances in Merbau wood (polyphenol) are repellent, so they are resistant to termite attacks [14,15]. The third largest mortality was in Sengon wood (59.3%). Although Sengon wood only contains 4.95% extractive substances, extractive substances with a distinctive aroma (saponin) are thought to be toxic to subterranean termites [16,17].

Multiple feeding preferences within the colony showed that Merbau wood was the most unfavorable wood species for subterranean termites *C. curvignathus* and was not consumed at all. Wood with the highest level of feeding preference was Pine (536.76 mg), Mangium (386.94 mg), Keruing (334.64 mg), and Light red meranti (257.90

mg). for Teak the level of feeding preference was low (51.6 mg), while for Sengon (172.49 mg) and Sumatran camphor (127.21 mg) was quite high. Duncan's multiple range test showed that the feeding preference of subterranean termites *C. curvignathus* on Merbau and Teak wood species did not differ significantly, as well as between Sengon and Sumatran camphor; Keruing and Mangium. Light red meranti and Pine wood showed significant differences in feeding preferences with other wood species.

Sengon, Sumatran camphor, Keruing, Light red meranti, Mangium and Tusah wood species naturally belong to the durability class and low specific gravity (BJ). Sumatran camphor wood falls into durability class II - III with a BJ of 0.81. Keruing wood falls into durability class III with a BJ of 0.8. Light red meranti and Mangium wood are in the durability class III - IV with BJ 0.51. Pine wood is included in the durable class IV with BJ 0.55 while Sengon wood is included in the durable class IV - V with BJ 0.33. Weight loss in wood that belongs to the natural durability class and low specific gravity is due to the type of wood having low side hardness. The tendency of termite feeding activity will increase with decreasing wood hardness [6,7,18]. However, wood resistance to termite attack is not only influenced by wood hardness but also by the content of extractive substances that are toxic (repellent) to subterranean termites [19,20].

Based on the classification of wood resistance by reference [11], Merbau wood is highly resistant to *C. curvignathus* subterranean termite attack with 0% weight loss. Teak wood is classified as resistant with a percent weight loss of 3.71%. Sumatran camphor and Sengon wood are moderately resistant with a percent weight loss of 16.02% (Sumatran camphor) and 19.09% (Sengon), while the other four wood species are classified as vulnerable, with a percent weight loss of 41.21% (Keruing), 41.35% (Light red meranti), 43.21% (Mangium), and 54.38% (Pine).

3.1 Economic aspects of the relationship between wood price and natural resistance

The timber consumed by Indonesians is mostly used for construction timber which comes from sawn timber imported from outside Java. The price of sawn timber in Indonesia varies by type and size.

Table 3. Relationship between natural durability and timber price in the eight timber species under analysis

Species	Resistance Class	Weight Loss (%)	Relative Resistance	Price (IDR/m^3)	Price/Relative resistance	
					Value	Rank
I. bijuga	Very resistant	<1 *)	>100	18,100,000	<181,000.0	1
T. grandis	Resistant	3.71	26.95	16,000,000	593,692.0	4
D. aromatica	Moderately resistant	16.02	16.61	8,500,000	511,739.9	3

P. falcataria	Moderately resistant	19.09	5.24	1,000,000	190,839.7	2
D. borneensis	Poor	41.21	2.43	6,000,000	2,469,135.8	8
S. leprosula	Poor	41.35	2.42	5,700,000	2,355,371.9	7
A. mangium	Poor	43.21	2.31	3,000,000	1,298,701.3	6
P. merkusii	Poor	54.38	1.84	1,100,000	597,826.1	5

* indicates no weight loss observed during the 90-day study

In the context of the economic importance of wood use related to resistance to termite attack, it can be seen from the price figure (cost) of wood resistance to termites. Based on the percent weight loss can be calculated or compared to the relative resistance of wood, which is the inverse of the speed of percent weight loss. With the price of each type of wood known, the price is divided by the relative resistance to get the price per relative resistance. The lowest price per relative resistance indicates the most economical (good) use based on termite resistance (Table 3).

Merbau is the most economical timber use, followed by Sengon, Sumatran camphor, Teak, Pine, Acacia, Light red meranti and Keruing. The results of this analysis show that it is not always the case that the lower the resilience class or vulnerability, the less economical it is. For example, Sengon wood ranks second, while Teak wood ranks fourth economically.

The use of Sengon wood, which is more economical when compared to other types of wood other than Merbau wood, by being treated (preservation or impregnation) can make Sengon wood more economical, although it will increase production costs. This is true for Sumatran camphor and Pinus wood species. Using simple regression analysis, the relationship between relative resilience factors and timber prices resulted in the following model equation for estimating sawn timber prices:

$$Y = 157894x + 4E + 06, \; with\, r^2 = 0.6719 \quad (4)$$

where: Y = Estimated price of wood
X = Relative resistance value of wood

The relationship between the two factors shows a positive correlation, where any increase in relative resistance (increase in natural wood resistance class) will lead to an increase in the price of the wood. The model can be used to determine the price of wood based on its natural resistance class to subterranean termites *C. curvignathus*.

4 Conclusion and recommendations

The economic calculation of wood is important information for consumers where wood consumers on the island of Java consider that wood outside Java is superior in use as a building construction material. With economic value information, consumer decisions in using construction wood that is resistant to termite attack are not only based on the resistance class but can be seen from the relative resistance factor and the wood price factor, so that consumers can choose the most economical wood according to their purchasing power. Consumers can choose the most economical wood, namely Merbau wood which is very resistant to soil termite attack at a fairly expensive price because it is imported from outside Java or can choose to use Sengon wood which is quite resistant to termite attack at an affordable price and is no less economical than Merbau wood.

Acknowledgements. Thanks to IPB for the Forest Products Pest and Disease Laboratory, Inter-University Research Center - Life Sciences facility that used during the research, and Lembaga Pengelola Dana Pedidikan (LPDP).

Novelty Statement. The economic calculation of wood is important information that can be seen from the relative resistance factor and the price factor of wood, to determine the most economical wood against subterranean termites' attack.

Conflict of Interest. The author(s) declare(s) that there is no conflict of interests regarding the publication of this article.

References

1. Rakhmawati, D.: Prakiraan kerugian ekonomis akibat serangan rayap pada bangunan perumahan di Indonesia. [Undergraduate Thesis]. Institut Pertanian Bogor, Indonesia (1996)
2. Ditjen Cipta Karya.: Masalah serangan rayap pada bangunan. Ditjen Cipta Karya, Departemen Pekerjaan Umum (1983)
3. Nandika, D., Rismayadi, D., Diba, F.: Rayap: Biologi dan pengendaliannya. Muhammadiyah University Press, Surakarta (2003)
4. Nandika, D., Husaeni, E.A., Surjokusumo, S., Ngilly, D.: A survey on termite problems in the low-cost housing compound of Jakarta and its vicinity. In: Proceedings of the Symposium of Pest Ecology and Pest Management, pp.229. Southeast Asian Regional Center for Tropical Biology, Bogor (1985)
5. Subekti, N., Widiyaningrum, P., Nandika, D., Solihin, D.D.: Colony Composition and Biomass of *Macrotermes gilvus* Hagen (blattodea: termitidae) in Indonesia. IIUM Engineering Journal **20**(1), 24–28 (2019)
6. Supriana, N.: Feeding behaviour of termites (Insecta: Isoptera) on tropical timber and treated materials. [Doctoral Thesis]. University of Southampton, England (1983)
7. Swoboda, L.E., Miller, D.M.: Laboratory Assays Evaluate the Influence of Physical Guidelines on Subterranean Termite (Isoptera: Rhinotermitidae) Tunneling, Bait Discovery, and Consumption. Journal of Economic Entomology **97**(4), 1404–1412 (2004)
8. Judd, T.M.: Cues Used by Subterranean Termites During Foraging and Food Assessment. In: Khan, M., Ahmad, W. (eds) Termites and Sustainable Management. Sustainability in Plant and Crop Protection. Springer, Cham (2018)
9. Iwanaga, S., Masuda, M.: Shift in raw materials for the wood processing industry in Java Island, Indonesia: A perspective from the post natural forest era. TROPICS **22**(3) (2013)
10. Sornnuwat, Y., Vongkaluang, C., Yoshimura, T., Tsunoda, K., Takahashi, M.: Wood Consumption and Survival of the Subterranean Termite, *Coptotermes gestroi* Wasmann using the Japanese Standardized Testing Method and the Modified Wood Block Test in

Bottle. Wood Research: Bulletin of the Wood Research Institute Kyoto University **82**, 8–13 (1995)
11. Sornnuwat, Y.: Resistance of commercial timbers and fast growing timber of Thailand for building construction to *Coptotermes gestroi* Wasman. In: Proc. The 1996 Annual Meeting of The International Research Group on Wood Preservation, Stockholm (1996)
12. Qiu, H., Liu, R., Long, L.: Analysis of chemical composition of extractives by acetone and the chromatic aberration of teak (*Tectona Grandis* LF) from China. Molecules **24**(10), 1989 (2019)
13. Rosamah, E., Ferliyanti, F., Kuspradini, H., Dungani, R., Aditiawati, P.: Chemical content in two teak woods (*Tectona grandis* Linn. F.) that has been used for 2 and 60 years. J. Biol. Sci. Technol. Manag **2**, 15–19 (2020)
14. Hillis, W.E., Yazaki, Y.: Polyphenols of Intsia heartwoods. Phytochemistry **12**(10), 2491–2495 (1973)
15. Becker, G.: Physical, chemical and biological factors influencing the damage of wood and other materials by termites. In: Proc. Internat. Biodegrad. Symp. ONR.NBS, pp. 259–271 (1975)
16. Atmosuseno, B.S.: Budidaya, Kegunaan dan Prospek Sengon. Penerbit Swadaya, Jakarta (1994)
17. Azizah, A., Adnan, M.R., Su'udi, M.: Potensi serbuk gergaji kayu sengon sebagai insektisida botani. JBIO: Jurnal Biosains (The Journal of Biosciences) **4**(2), 113–119 (2018)
18. Rasib, K.Z., Ashraf, H.: Feeding preferences of *Coptotermes heimi* (Isoptera: Termitidae) under laboratory and field conditions for different commercial and non-commercial woods. International Journal of Tropical Insect Science **34**, 115–126 (2014)
19. Bakaruddin, N.H., Dieng, H., Sulaiman, S.F., Ab Majid, A.H.: Evaluation of the toxicity and repellency of tropical plant extract against subterranean termites, *Globitermes sulphureus* and *Coptotermes gestroi*. Information Processing in Agriculture **5**(3), 298–307 (2018)
20. Kadir, R., Hassan, B.: Toxicity and repellent effects of wood extractives of five Malaysian wood species on Asian subterranean termite *Coptotermes gestroi* Wasmann. European Journal of Wood and Wood Products **78**(6), 1249–1262 (2020)