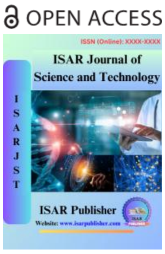

ISAR Journal of Science and Technology

Volume 4, Issue 1, 2026, Page: 53-61

Abbriviate Title- ISAR J Sci Tech

ISSN *(Online)*- 2584-2056

https://isarpublisher.com/journal/isarjst

Efficacy of *Eucalyptus camadulensis* (Dehnh.) Wood Vinegar as a Bio-Preservative against Subterranean termite attack on *Triplochyton scleroxylon* and *Terminalia superba* Wood Species

Abiodun Omonike Emeruwa[1], Josiah Thomas B. Riki[2]*, Abiodun Oluwafemi Oluwadare[1] and Adewunmi Omobolaji Adenaiya[1]

[1]Research Student, Professor and Lecturer, Department of Forest Production and Products, Faculty of Renewable Natural Resources, University of Ibadan, Ibadan, Oyo State

[2]Lecturer, Department of Forestry and Wildlife Management, Faculty of Agriculture and Life Sciences, Federal University Wukari, Nigeria.

***Corresponding Author**

Josiah Thomas B. Riki

Lecturer, Department of Forestry and Wildlife Management, Faculty of Agriculture and Life Sciences, Federal University Wukari, Nigeria.

Article History

Received: 18.10.2025
Accepted: 22.12.2025
Published: 17.01.2026

Abstract: This study examines wood vinegar extracted from *Eucalyptus camaldulensis* through the process of pyrolysis at various temperatures as an eco-friendly wood preservative, particularly against subterranean termite attacks on *Triplochyton scleroxylon* and *Terminalia superba*. Wood vinegar of *Eucalyptus camaldulensis* wood at the three temperatures (300°C, 400°C, and 500°C) were prepared into three concentration levels (50, 75 and 100%) and then tested for its preservative qualities. To assess its efficacy, treated wood samples were also incubated in a timber graveyard exposed to natural termite populations for 12 weeks. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$.The treated wood samples demonstrated enhanced resistance to termite damage; notably, those treated with wood vinegar from pyrolysis at 500°C showed no signs of termite activity or damage with weight loss of 0.4% and 1.8% for *Triplochyton scleroxylon* and *Terminalia superba* respectively, whereas samples treated with a 50% diluted solution from 300°C and 400°C exhibited only light termite attack with weight loss in the range of 0.8-5.7% , in stark contrast to the untreated controls which sustained significant damage with weight loss of 92%. This study not only underscores the benefits of using wood vinegar as an eco-friendly alternative but also encourages further exploration into its application across the wood preservation industry to promote environmental sustainability especially in Sub-Saharan Africa.

Keywords: Vinegar, Preservative, Temperature, Concentration.

Cite this article:

Emeruwa, A. O., Riki, J. T. B., Oluwadare, A. O., and Adenaiya, A. O., (2026). Efficacy of *Eucalyptus camadulensis* (Dehnh.) Wood Vinegar as a Bio-Preservative against Subterranean termite attack on *Triplochyton scleroxylon* and *Terminalia superba* Wood Species. *ISAR Journal of Science and Technology*, *4*(1), 53-61.

Introduction

One of the most important renewable natural resources that humans can still access is wood. It is a cellular, renewable, natural resource with outstanding strength-to-weight characteristics. It has distinctive structural and chemical properties that make it appealing to a wide range of end users, and it readily creates composite materials of botanical origin [1]. Wood can be used for a variety of purposes, such as building wooden buildings or furniture. However, the subject of wood's long-term resistance to natural deterioration processes is one of the main arguments against its usage for a variety of purposes [2].

The preservation of wood using synthetic chemicals has long been used to protect wood from destructive organisms. However, the use of synthetic chemicals has been restricted in many nations due to its toxicity, health hazards, and environmental effects [3]. Natural compounds derived from biorenewable resources should be developed as substitute protective agents, according to Grewal et al. [4]. When wood or other biomass burns at a high temperature, chemicals including wood vinegar, liquid smoke, and bio-oil are created. Furthermore, charcoal, tar, and other gaseous chemical components are byproducts of burning wood without oxygen. Wood vinegar is said to shield wood against termite and fungal attacks

The population's increasing need for wood for building projects has a detrimental impact on the forest. Termites degrade wood in service that is left unpreserved, increasing demand. Worldwide, a variety of chemicals are needed to protect wood and wood-based goods against biological agents. Some of these chemicals are dangerous to humans and animals, while others are considered to pollute the environment [5]. Synthetic chemicals harm numerous beneficial organisms and cause environmental issues.

Promising essential oils with pesticide and repellent properties are probably found in eucalyptus species [6]. From a toxicological and environmental perspective, using eucalyptus essential oil as a natural pesticide works better than using other pesticides sporadically, which helps solve the issue of insect resistance [7]. To the best of our knowledge, there are no reports on *Eucalyptus camadulensis* wood vinegar as a bio-preservative against termite attack in Nigeria. Termites are significant agents of wood and wood product biodegradation. Consequently, the creation of substitute bio-renewables is required to keep termites away from wood and wood products.

Materials and Methods

Study Area

The wood vinegar sample treatment was carried out at the Wood Laboratory of the Department of Forest Production and Products, University of Ibadan, Oyo state. The university is situated in the city of Ibadan with a geographical location of latitude 7°26'N and 7°28'N and longitude 3°52'E and 3°55'E. Ibadan has a geographical coordinate of latitude 7.2316°N and longitude 3.5347°E of the equator and 750m above the sea level. The study is characterised with two seasons- the wet season which is from the month of April to October and the dry season last from November to March [8]. The graveyard test was carried out in the termitarium at Forestry Research Institute of Nigeria (FRIN). The Forestry Research Institute of Nigeria is located between Ibadan North-west and Ibadan South-West with latitude ranging from 7.397975N to 7.385619444N and longitude ranging from 3.8634E to 3.8552E.

Sample Preparation

The plank of *Terminalia superba*, and *Triplochiton scleroxylon* procured from Sawmill within Ibadan city, Nigeria. The wood planks were subsequently cut into small pieces measuring 20 mm by 20 mm by 60 mm (breadth by width by length) using a circular saw machine, and the wood samples were smoothed using fine sandpaper to remove any rough edges. Meanwhile, there are 4 levels of concentration and three levels of Pyrolysis Temperature, with 10 replicates, a total of 120 test block was obtained from the plank of each species. The test blocks were marked for straightforward identification and differentiation. They were dried in an oven at 102 °C for 24 hours, and subsequently weighed as W1.

Preparation of the Preservative Treatment

Pure wood vinegar at the three temperatures were prepared into three concentration levels.

For 50% Concentration: 500 mL of 100% concentrated wood vinegar was measure using a measuring cylinder to a 1000ml volumetric flask. distilled water was added to the flask until the total volume reaches 1000 mL.

For 75% Concentration: 750 mL of 100% concentrated wood vinegar was measured using a measuring cylinder to a 1000ml volumetric flask. Distilled water was added to the flask until the total volume reaches 1000 mL. For 100% Concentration

For a 100% concentration, no dilution is required

Treatment Method

The wood samples were treated according to ANSI/ASTMD 1413 [9]. The wood samples oven dried at 102^{o}C until a constant weight is achieved, then weighed (W1). Subsequently, they were soaked in pre-prepared wood vinegar of varying concentrations for 24 hours (cold soaking), then removed and allowed to drain for some hours on a wire mesh to eliminate excess vinegar solution. The samples were then reweighed, recorded as W2, All the weighing was done by the use of the weighing balance. The test blocks were weighed then oven dried at 102^{0}C until a constant weight was attained then weighed again as W3.

Preservative Absorption Test

The wood samples were labeled with a waterproof marker and dried to a constant weight in an oven for 24 hours. They were weighed prior to the experiment to determine the initial weight (T1), indicative of the weight of the untreated wood samples. After treatment with preservatives wood vinegar, the samples were weighed again, noted as T2.

$$\text{Absorption \%} = 100\text{X}\,\frac{(T2-T1)}{T1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ eqn.1$$

Where: T2= Treated weight and T1= dry weight

Grave Yard Test

The graveyard was tidied and prepared; the wood samples were transported to the termitarium and buried completely underground for a period of 12 weeks. Bi-weekly checks were conducted for visual inspection of the wood samples in the field to assess the rate of termite attack. After 12 weeks, the wood samples were retrieved, oven-dried, and weighed, recorded as T4.

Extent of Attack and Evaluation

The rating scale used for the visual assessment of termite attacks was based on an adaptation of ASTM D 3345-22 [10]. As shown in Table 1.

Table 3.1. The rating scale used for the Visual Assessment of Termite Attack

RATING	Rating Description
4	**No attack**
3	**Light attack:** i. superficial erosion of insufficient depth to be measured on an unlimited area of the test specimen; or ii. attack to a depth of 0.5 mm provided that this is restricted to an area or areas not more than 30 mm2 in total; or iii. a combination of i and ii
2	**Moderate attack:** i. erosion of 1 mm in depth limited to not more than 1/10 of the surface area of the test specimen; or ii. single tunnelling to a depth of up to 3 mm; or iii. a combination of i and ii
1	**Heavy attack:** i. erosion of <1 mm in depth over more than 1/10 of the surface area of the tests specimen; or ii. erosion of >1 mm to <3 mm in depth limited to not more than 1/10 of the surface area of the test specimen; or iii. isolated tunnelling of a depth >3 mm not enlarging to form cavities; or iv. any combination of i, ii or iii
0	**Failure:** i. erosion of >1 mm to <3 mm in depth of more than 1/10 of the surface area of the test specimen, or ii. tunnelling penetrating to a depth >3 mm and enlarging to form a cavity in the body of the test specimen, or iii. a combination of i and ii

Source: ASTM D 3345-22

Calculation of Weight Loss of Wood Samples in Percentage

Weight loss due to termites' attack:

$$Weight\ loss\ (\%) = \frac{T3-T4}{T3}\ X\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn.\ 1$$

Where;

T3 = oven dried weight after treatment

T4 = weight of oven dried wood samples after exposure to termite's attack

Statistical Analysis

The experimental data generated was subjected to both descriptive and inferential analyses. Factorial analysis was used in analysing the results generated. Completely Randomized Design of 2x3x4 factorial was be used to determine the preservative efficacy of the wood vinegar. Where there were two levels of species (*T. superba* and *T. scleroxylon*), three levels of Pyrolysis Temperature and four levels of wood vinegar concentration. Analysis of Variance (factorial) was performed to determine the significant effect among the treatment groups. Post hoc (Fisher LSD) was carried out to separate significant means at $\alpha_{0.05}$.

Results and Discussion

Preservative Absorption

The absorption test results for the two species, *T. scleroxylon* and *T. superba*, across various combinations of temperature regimes (300°C, 400°C, 500°C) and concentration levels (50%, 75%, 100% and control), presented in Table 2 provide a comprehensive overview of how different treatments affect wood absorption. The preservative is represented through combinations of letters where the first letter corresponds to the pyrolysis temperature (A for 300°C, B for 400°C, and C for 500°C) and the second letter represents the concentration level (A for 0%, D for 50%, C for 75%, and B for 100%). For *T. scleroxylon*, the absorption rates varied significantly across the different treatments. The highest absorption rate was observed with the control group at 74.93%, indicating that untreated samples had the highest absorption. The lowest absorption rate was found at the 500°C temperature regime with 50% concentration (CD) at 33.51%. *T. superba* showed a similar trend where the highest absorption rate 61.75% for the control group, and the lowest was at the 500°C temperature regime with 75% concentration (CC) at 47.55%. Like *T. scleroxylon*, *T. superba* demonstrates a general decrease in absorption rates as temperature and concentration increase.

Generally, there is a trend where absorption decreases with the increase in temperature and concentration, the statistical analysis presented in Table 3 showed that temperature has significant effect on the absorption rate of the wood species, also there is a significant effect in the concentration levels when compared with the control group, whereas, there is no significant difference in among the concentration levels. The species absorption rate is not significantly different, also the interaction of temperature and concentration does not have a significant effect on the absorption rate of the species. However, there is no significant difference in the effect of species. The means of significant factors presented in Table 4.

The findings indicate a gain in the initial weight of the wood following cold soaking. The relative absorption test demonstrated that all cellulosic substances, such as wood, are capable of absorbing plant extracts, oils, and water-based preservatives like wood vinegar [11]. The Pyrolysis temperature has significant effect on the absorption percentage with temperature of 500^{o}C been significantly different from 300^{o}C and 400^{o}C, whereas there is no significant difference between temperature 300^{o}C and 400^{o}C, the concentration also has significant effect when compared with the control group (i.e the untreated samples soaked in water), however, there is no significant difference in the interaction between temperature and concentration levels as shown in tables 3 and 4. The is also no significant difference in the absorption percentage of the two wood species investigated, however, it was generally observed that absorption percentage decreased with increasing temperature which could possibly as the result of reducing moisture content with increasing temperature.

Table 2: Mean Preservative Absorption Percentage of the Selected Species

Treatment Groups (^{0}C)	**Concentration level (%)**	***T. scleroxylon***	***T. superba***
300	50%	48.24±2.5	47.02±2.4
300	75%	55.72±3.1	47.55±2.3
300	100%	60.89±2.8	48.69±2.1
400	50%	55.61±3.0	52.84±2.5
400	75%	52.73±2.9	50.12±2.0
400	100%	55.18±2.7	54.20±2.9
500	50%	33.51±1.8	48.89±2.7
500	75%	34.62±2.0	49.72±2.8
500	100%	38.38±2.2	52.49±2.6
Control	Untreated	74.93±3.5	61.75±3.0

Table 3: Univariate Tests of Significance for Absorption Percentage

Sources of variation	Degr. of	SS	MS	F-cal	P-value
TEMP	2	3629.8	1814.9	5.723	0.003785*
CONC	3	16940.3	5646.8	17.807	0.000000*
SPECIES	1	218.6	218.6	0.689	0.407287ns
TEMP*CONC	6	1704.3	284.0	0.896	0.498845ns
TEMP*SPECIES	2	2103.8	1051.9	3.317	0.038116*
CONC*SPECIES	3	2638.1	879.4	2.773	0.042401*
TEMP*CONC*SPECIES	6	813.8	135.6	0.428	0.860013ns
Error	216	68496.5	317.1		
Total	239	96545.3			

ns= not significant, * = significant

Table 4: Effect of Concentration and Temperature on the Absorption Percentage of *Triplochyton scleroxylon* and *Terminalia superba* Wood Species

Conc/Temp	Species	Absorption (%)
300^0C	*T. scleroxylon*	45.78[a]
	T. superba	49.58[a]
50%	*T. scleroxylon*	59.94[a]
	T. superba	52.74[abc]
400^0C	*T. scleroxylon*	51.48[a]
	T. superba	51.79[a]
75%	*T. scleroxylon*	54.72[a]
	T. superba	59.61[a]
500^0C	*T. scleroxylon*	47.68[a]
	T. superba	49.13[a]
100%	*T. scleroxylon*	59.61[a]
	T. superba	54.72[ac]
Untreated	*T. scleroxylon*	61.74[b]
	T. superba	74.93[c]

Conc= concentration level, temp = temperature

Preservative Efficacy of the Wood Vinegar

Extent of Termite attack on *Terminalia superba*

The visual rating for the two species assessed shows that the wood vinegar at different temperature and concentration levels has preservative effect of the treated test blocks (Table 5). Slight attack was observed in test blocks treated with weaker solutions (100%) of WV-300 and WV-400 from week six of incubation. The untreated test blocks however present no resistance to termite attack, it recorded attack from the week 2 to of the experiment and at week 10 all the test blocks have been eaten up by the termite.

Table 5: Visual Rating of Termiticidal Effect of the Wood Vinegar on selected species

PRESERVATIVE	SPECIES	WEEK2	WEEK4	WEEK6	WEEK8	WEEK10	WEEK12
300^0C/50%	*T. scleroxylon*	4	4	4	4	4	4
	T. superba	4	4	4	4	4	4
300^0C/75%	*T. scleroxylon*	4	4	4	4	4	4
	T. superba	4	4	4	4	4	4
300^0C/100%	*T. scleroxylon*	4	4	3	3	3	3
	T. superba	4	4	4	3	3	3
400^0C/50%	*T. scleroxylon*	4	4	4	4	4	4
	T. superba	4	4	4	4	4	4
400^0C/75%	*T. scleroxylon*	4	4	4	4	4	4
	T. superba	4	4	4	4	4	4
400^0C/100%	*T. scleroxylon*	4	4	4	3	3	3
	T. superba	4	4	4	3	3	3
500^0C/50%	*T. scleroxylon*	4	4	4	4	4	4
	T. superba	4	4	4	4	4	4
500^0C/75%	*T. scleroxylon*	4	4	4	4	4	4
	T. superba	4	4	4	4	4	4
500^0C/100%	*T. scleroxylon*	4	4	4	4	4	4
	T. superba	4	4	4	4	4	4
Untreated	*T. scleroxylon*	2	2	2	0	0	0
	T. superba	2	3	2	0	0	0

Note: 4 – No attack, 3- Light Attack, 3- Moderate Attack, 1- Heavy Attack, 0- Failure.

Weight Loss Percentage

The data obtained from the percentage weight loss experiment corroborate the result of the visual assessment. The effect of termite exposure on treated and untreated wood samples is detailed in Table 6, the concentration levels, species and interaction between species and concentration level shows significant difference while temperature, interaction between temperature and concentration levels as well as interaction among temperature, concentration and species are not significantly different (Table 7). The follow up test reveal that *T. scleroxylon* generally exhibits lower resistance compare to *T. superba* across all the treatment groups (Plate 1 and Table 8). Pyrolysis temperature does not affect the termiticidal effect of the wood vinegar, however the concentration levels are significantly different with concentration level B (50%) exhibiting lowest termiticidal resistance with weight loss of 5.79% follow by C (75%) and D (100%) with weight loss of 1.13% and 0.41% respectively with no significant difference. Treated *T. superba* exhibited higher termiticidal effect across all the treatment groups with weight loss ranging from 0.82% to 1.08% which are not significantly different as shown **in Table 4.10a below**. Among all the concertation levels only B (50%) is significantly different with percentage mean weight loss of 3.32% whereas concentration D (100%) and C (75%) are not significantly different. All the treatment groups showed high termiticidal effect when compared to the control (untreated block samples) which showed total failure with weight loss of 92.04% and 92.37% for *T. scleroxylon* and *T. superba* respectively. The significant means are shown in table 7 and 8. Overall comparison of the two species shows that *T. superba* has higher resistance to termite attack. By the end of the 12 weeks exposure, all the untreated samples i.e the control for the two species were completely destroyed by the termite.

The preservative efficacy of wood vinegar against termite attack was investigated through the visual assessment ratings and percentage weight loss of treated and untreated test blocks of *T scleroxylon* and *T. superba* after 12 weeks of incubation. All combinations of temperature and concentration levels proved effective, highlighting the toxic nature of the wood vinegar due to its low pH and organic acid content, which renders the wood samples toxic to termite, one of the major properties of an effective wood preservative is its toxicity to bio deteriorating agents. These results align with findings by Oramahi and Yoshimura [12], who noted significant termite avoidance toward paper discs treated with wood vinegar at various concentrations.

The effectiveness of wood vinegar is largely due to the presence of principal organic compounds which act against bio-deteriorating agents. Organic acids such as acetic acid, and phenolic compounds including 2-methoxy-phenol and creosol, play a crucial role in this effect. Gama *et al.* [13], observed high amounts of these compounds in Eucalyptus wood vinegar, similar to findings from other studies on its termiticidal and fungicidal properties. Research by Wititsiri [14], and subsequent investigations have highlighted the significant contribution of these active ingredients to the termiticidal and pesticidal properties of wood vinegar. For instance, the wood vinegar obtained from coconut shells and a mixture of coconut shell and coir vinegars achieved termite mortality rates of 81.71% and 95.12%, respectively. Similarly, Suprianto *et al.* (2023), identified that the efficacy of Durian wood vinegar increases with the concentration of active components like 2-methoxy-phenol and creosol.

It was observed that treatments with weaker solutions (50%) of WV-300 and WV-400 exhibited slight termite attacks around week six of the experiment, a similar trend reported by previous studies that the termiticidal properties of wood vinegar is enhance with increasing pyrolysis temperature and concentration. Vinegar pyrolyzed at 400°C and above was found to be more effective, likely due to the presence of phosphonic acid and phenol derivatives [15]. This is also supported by the observed patterns in termite mortality, which significantly rise with higher concentrations of wood vinegar, a finding corroborated by Oramahi *et al.* [16]. This finding is further supported by studies on wood vinegar derived from various sources, including *Toona Sinensis*, which showed a high percentage of acetic acid significantly contributes to its termiticidal properties [17]. Likewise, wood vinegars rich in phenolic and acetic acid from Cryptomeria japonica and other mixed sources have been reported effective against *R. speratus* [18].

Overall, the compiled evidence from various studies supports the significant potential of wood vinegar as a natural termiticide, indicating that its application could be a sustainable approach to managing termite populations.

Plate 1: Effects of Termite attack on the wood specie. A: Sound samples of *Terminalia superba* after exposure to Termite Attack for 12 weeks, B: Slightly attacked samples of *Triplochyton sleroylon* after exposure to termite attack for 12 weeks

Table 6: ANOVA for Weight Loss after Exposure to Termite Attack

Sources of Variation	Degr. of freedom	SS	MS	F-cal	P-value
TEMP	2	51.3	25.6	2.33	0.100174ns
CONC	3	368979.8	122993.3	11160.85	0.000001*
SPECIES	1	67.3	67.3	6.11	0.014205*
TEMP*CONC	6	86.7	14.5	1.31	0.252990ns
TEMP*SPECIES	2	25.7	12.9	1.17	0.313309ns
CONC*SPECIES	3	307.9	102.6	9.31	0.000008*
TEMP*CONC*SPECIES	6	54.2	9.0	0.82	0.555680ns
Error	216	2380.3	11.0		
Total	239	371953.3			

ns= not significant, *= significant

Table 7: Fishers LSD Test Showing Significant Difference among Concentration levels and between Species after exposure to termite attack

CONC	SPECIES	WEIGHT LOSS%
50%	*T. scleroxylon*	0.41086a
	T. superba	1.08613a
75%	*T. scleroxylon*	1.13581a
	T. superba	0.82811a
100%	*T. scleroxylon*	5.79635c
	T. superba	0.86102a
Untreated	*T. scleroxylon*	92.04279b
	T. superba	92.37273b

Table 8: Fishers LSD Test Showing Significant Difference among the Concentration levels

CONC	WEIGHT LOSS%
50%	0.74850a
75%	0.98196a
100%	3.32868b
Untreated	92.20776c

Conclusion and Recommendations

The study confirmed the efficacy of wood vinegar, showing that treated wood blocks resisted termite attacks over 12 weeks, even under natural conditions. This aligns with laboratory findings and underscores the robustness of wood vinegar as a bio-preservative. Its natural components act as repellents and toxicants to termites, offering a sustainable and eco-friendly alternative to synthetic chemicals. Using wood vinegar supports sustainable wood preservation practices, crucial for protecting tropical wood species like *Triplochyton scleroxylon* and *Terminalia superba* from decay and pests. This contributes to the conservation of tropical forests and promotes the durability and sustainable management of these invaluable wood species.

The use of wood vinegar for wood preservative and other application should be further investigated especially in Sub-Saharan Africa. Other wood species should also be investigated for their suitability in terms of colour for wood vinegar production.

Conflicts of Interest

The authors declared that there is no conflict of interest regarding the publication of this paper.

Funding

The author declared that no funding was received for this research.

Acknowledgement

The author acknowledged the support provided by the Wood Laboratory of the Department of Forest Production and Products, Faculty of Renewable Natural Resources, University of Ibadan, Ibadan Nigeria.

Declaration

The authors declared that the manuscript titled "Efficacy of *Eucalyptus camadulensis* (Dehnh.) Wood Vinegar as a Bio-Preservative against Subterranean termite attack on *Triplochyton scleroxylon* and *Terminalia superba* Wood species)" is the original work carried out by Abiodun Omonike Emeruwa, Josiah Thomas B. Riki, Abiodun Oluwafemi Oluwadare and Adewunmi Omobolaji Adenaiya

Authors Contribution

Professor Abiodun Oluwafemi Oluwadare provided the idea and problem formulation for the study while Mrs Abiodun Omonike Emeruwa, Drs. Josiah Thomas B. Riki and Adewunmi Omobolaji Adenaiya carried out the research and did the analysis. Both the authors were involved in writing the article.

References

1. Przybek, A. (2025). The role of natural fibers in the Building Industry—The perspective of sustainable development. *Materials*, *18*(16), 3803. https://doi.org/10.3390/ma18163803 **https://doi 10.15376/biores.20.3.Laleicke**
2. Laleicke, P. F. and Hubbe, M. A. (2025). Outdoor Wood Finishing: A Review on Making Wood Resistant to Moisture, Ultraviolet Light, and Degradation. *BioResources*, *20*(3). **https://doi 10.15376/biores.20.3.Laleicke**
3. Oramahi, H. A., Tindaon, M. J., Nurhaida, N., Diba, F. and Yanti, H. (2022). Termicidal activity and chemical components of wood vinegar from nipah fruit against Coptotermes curvignathus. *Journal of the Korean Wood Science and Technology*, *50*(5), 315-324. https://doi.org/10.5658/WOOD.2022.50.5.315
4. Grewal, A., Abbey, L., Gunupuru, L.R. 2018. Production, prospects and potential application of pyroligneous acid in agriculture. *Journal of Analytical and Applied Pyrolysis* 135: 152-159. https://doi.org/10.1016/j.jaap.2018.09.008
5. Kalleshwaraswamy, C. M., Shanbhag, R. R., & Sundararaj, R. (2022). Wood degradation by termites: Ecology, economics and protection. In *Science of Wood Degradation and its Protection* (pp. 147-170). Singapore: Springer Singapore. https://link.springer.com/chapter/10.1007/978-981-16-8797-6_5
6. Nerio, L. S., Olivero-Verbel, J. and Stashenko, E. (2010). Repellent activity of essential oils: a review. *Bioresource technology*, *101*(1), 372-378. https://doi.org/10.1016/j.biortech.2009.07.048
7. Batish, D. R., Singh, H. P., Kohli, R. K., & Kaur, S. (2008). Eucalyptus essential oil as a natural pesticide. *Forest ecology and management*, *256*(12), 2166-2174. https://doi.org/10.1016/j.foreco.2008.08.008
8. Olayanu, C. M., Omole, A. O., Adeyemo, S. M., Majekobaje, A. R., & Areo, O. S. (2022). Evaluation of selected physical properties of Blighia sapida K. Koenig wood. *European Journal of Agriculture and Food Sciences*, *4*(2), 58-66. https://eu-opensci.org/index.php/ejfood/article/view/20477
9. American Society for Testing and Materials (ASTM) D1413 (1976). Standard Test Method for Wood Preservatives by Laboratory Soil-Block Cultures. This standard has been withdrawn and is no longer an active standard. West Conshohocken, PA, USA, Volume 4.1. https://www.google.com/search?q=ASTMD+1413-1976&oq=ASTMD+1413-1976
10. American Society for Testing and Materials (ASTM) D3345-22. (2022). Standard Test Method for Laboratory Evaluation of Wood for Resistance to Subterranean Termites. American Society of Testing and Materials: West Conshohocken, PA, USA, Volume 4.1. https://www.google.com/search?q=ASTMD+1413-1976&oq=ASTMD+1413-1976
11. Adeduntan, S. A. (2015). The termicidal effect of some plant material on some selected wood species. *International Journal of Biological and Chemical Sciences*, *9*(2), 986-995. https://www.10.4314/ijbcs.v9i2.34
12. Oramahi, H. A., Yoshimura, T. 2013. Antifungal and antitermitic activities of wood vinegar from *Vitex pubescens* Vahl. *Journal of Wood Science* 59.4: 344–350. https://link.springer.com/article/10.1007/s10086-013-1340-8
13. Gama, G. S. P., Pimenta, A. S., Feijó, F. M. C., Santos, C. S., Fernandes, B. C. C., de Oliveira, M. F., de Souza, E. C., Monteiro, T. V. C., Fasciotti, M., de Azevedo, T. K. B., de Melo, R. R. and Júnior, A. F. D. (2023). Antimicrobial

activity and chemical profile of wood vinegar from Eucalyptus (*Eucalyptus urophylla* x *Eucalyptus grandis* - clone I144) and bamboo (*Bambusa vulgaris*). *World Journal of Microbiology and Biotechnology* 39.7. https://link.springer.com/article/10.1007/s11274-023-03628-x

14. Wititsiri, S. (2011). Production of wood vinegars from coconut shells and additional materials for control of termite workers, Odontotermes sp. and striped mealy bugs, *Ferrisia virgata*. Songklanakarin. *Journal of Science and Technology.* 33. 349-354. https://www.thaiscience.info/journals/Article/SONG/10891343.pdf
15. Subekti, N., Yoshimura, T. 2020. Activity of bamboo wulung's smoke gigantochloa atroviolace against subterranean termites and fungi attack. AGRIVITA Journal of Agricultural Science 42(3): 541-547. https://scholar.google.com/scholar
16. Oramahi, H. A., Permana, R. D., Diba, F. And Indrayani, Y. (2023). The composition and Termicidal Activity of Vinegar from Medang Wood (Cinnamomum sp.) under different pyrolysis temperature. *Floresta e Ambiente*, *30*, e20230016. https://doi.org/10.1590/2179-8087-FLORAM-2023-0016
17. Adfa, M., Romayasa, A., Kusnanda, A.J., Avidlyandi, A., Yudha, S.S., Banon, C., Gustian, I. 2020. Chemical components, antitermite and antifungal activities of *Cinnamomum parthenoxylon* wood vinegar. *Journal of the Korean Wood Science and Technology* 48(1): 107-116. https://doi.org/10.5658/WOOD.2020.48.1.107
18. Yatagai, M., Nishimoto, M., Hori, K., Ohira, T. & Shibata, A. 2002. Termiticidal activity of wood vinegar, its components and their homologues. *Journal of Wood Science* 48.4: 338-342. https://link.springer.com/article/10.1007/BF00831357