Floresta Ambient., Rio de Janeiro, 2023; 30(3): e20230016
https://doi.org/10.1590/2179-8087-FLORAM-2023-0016
ISSN 2179-8087 (online)

Floram Floresta e Ambiente

ORIGINAL ARTICLE – Forest Products Science and Technology

# The Composition and Termicidal Activity of Vinegar from Medang Wood (*Cinnamomum sp.*) under Different Pyrolysis Temperature

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## Abstract

The degradation of wood caused by termite infestations is widely recognized as a substantial concern. Therefore, the development of alternative, environmentally-friendly preservation of wood is needed to reduce environmental pollution. The study aimed to analyze the chemical properties of vinegar from medang wood (*Cinnamomum* sp.) and assess its effectiveness as a termicidal activity against *Coptotermes curvignathus.* Wood vinegar is made by the pyrolysis method. Pyrolysis is carried out by inserting of air-dried medang wood particles into a pyrolysis reactor and was heated up to the desired temperature of 370, 400, 430°C with the pyrolysis time was 180 minutes. Wood vinegars were tested at various concentrations (2.0-10.0%, v/v) against *C. curvignathus* in a no-choice test. Result shows that an 8% concentration was required to achieve 100% mortality against *C. curvignathus* at a 430°C pyrolysis temperature. The lowest mass loss of treated filter paper, 11.99%, was obtained with a 430°C – 10.0% combination.

**Keywords:** Antifungal activity, *Coptotermes curvignathus,* medang wood, termicidal activity, wood vinegar.

## 1. INTRODUCTION AND OBJECTIVES

Wood is susceptible to organism degradation by termites. Synthetic chemicals have long been used to protect wood. Wood protective have been long using synthetic chemicals (Verma et al., 2009; Theapparat et al., 2015), however, the problems associated with their use include the negative effect to the environment (Preston, 2000; Bedmunntha et al., 2011). To decrease environmental pollution, it is important to create alternative wood preservatives that are eco-friendly. Wood vinegar is a potential alternative that has various properties such as for antimicrobial, antifungal and antitermitic activity, as well as insecticidal activity (Shiny and Remadevi, 2014; Hashemi et al. 2014; Omulo et al. 2017; Aly et al. 2022).

For example, de Souza et al. (2018) stated that wood vinegar from *Eucalyptus urograndis* and *Mimosa tenuiflora* at 450°C showed antimicrobial activity against *Escherichia coli*, *Pseudomonas aeruginosa* (ATCC 27853) and *Staphylococcus aureus* (ATCC 25923). They reported also that the wood vinegars exhibited antifungal activity against *Candida albicans* (ATCC 10231) and *Cryptococcus neoformans*. Rahmat et al. (2020) reported that vinegar from teak wood exhibited antifungal activity against *Sclerotium rolfsii*. Chen et al. (2020) revealed that vinegar from rubber tree (*Eucommia ulmoides*) exhibited antifungal activity against *Botrytis cinera*.

Permana et al. (2020) reoprted the vinegar from medang wood (*Cinnamomum* sp.) at 430 °C exhibited antifungal activity against *Schizophyllum commune*. They fungus about 98.57% at a concentration of 2.5% with wood vinegar pyrolysis temperature used is 430 °C. They revealed that wood vinegar was effective in inhibing *S. commune* fungus at a concentration of 2.5% with a 98.57% inhibition of fungal growth. Oramahi et al. (2023) reported that vinegar derived from durian wood (*Durio* sp.) demonstrated antitermitic against *Coptotermes formosanus* Holmgren in a no-choice experiment. Temiz et al. (2103) demonstrated that wood vinegar derived from gient cane at temperature of 450-525 °C exhibited antitermitic effect against *Reticultermes flavipes.* The primary chemical compounds found in the wood vinegar included acids, ketones, furans, benzene, phenols, sugars, and and guaiacols. Arsyad et al. (2020) stated that wood vinegar from bamboo pyrolyzed at 400°C contains phenols and acids that exhibited antitermitic activity. Recently, Oramahi et al. (2022a) stated that vinegar from nipah fruit shells and a mixture of shells and fiber, at temperature of 420 °C has antitermitic effect against *C. formosanus*.

However, wood vinegar from medang wood has not previously been assessed for antitermitic activity. The aim of this study was to evaluated the antitermitic activity against *Coptotermes curvignathus.* We also characterized of wood vinegar using gas chromatography-mass spectrometry (GC-MS).

To date, there has been no investigation for antitermitic properties of woof vinegar produced from medang wood. Therefore, the objective of this study was to assess its effectiveness against *Coptotermes curvignathus* and to analyze its chemical compositon using gas chromatography-mass spectrometry (GC-MS).

## 2. MATERIALS AND METHODS

### 2.1. Materials

The raw material of medang wood (*Cinnamomum* sp.) was collected from Mempawah Regency, Indonesia. Its converted into particles with a disk mill in the Wood Workshop Laboratory, Faculty of Forestry, Universitas Tanjungpura, Pontianak, Indonesia).

### 2.2. Methods

#### 2.2.1. Preparation of raw material and pyrolysis of wood vinegar from medang wood (Cinnamomum sp.)

The medang wood was cut and made into particles with sizes of 2.38, mm. Wood particle pyrolysis was conducted following procedures described previously (Darmadji & Triyudiana, 2006; Oramahi et al. 2010; Oramahi et al. 2019; Oramahi et al. 2021). Pyrolysis was done by entering the particle wood into the pyrolysis reactor. The pyrolysis temperatures used were 370, 400, and 430°C, and the pyrolysis time was 180 minutes.

As much of 1,000 g of air-dried medang wood particles were put into a pyrolysis reactor with a capacity of 2000 g, and was heated up to the desired temperature of 370, 400, 430 °C with the heating rate of 5 °C/min. Smoke was channelled into a cooling column through a pipeline, and then cold water was flowed into the column through a pump to recover the condensed vinegar. All wood vinegars which were produced at temperature of 370, 400 and 430 °C for antitermite test.

#### 2.2.2. Chemical characterization of vinegar from medang wood

The chemical component of wood vinegar from medang wood were identified by GC–MS (Shimadzu, Japan, QP-210S). The GC–MS assay were as follows: capillary columns (DB-624); 30 m x 0.25 mm; the temperature of injection: 250 °C; column temperature program: 60–200 °C. Helium was used as carier gas at s flow rate of 40.0 mL/min. The electron ionization mode was set at 70 eV with temperature of interface (200 °C). The injection volume of sample was 1 ml. The temperature maintained at 60–200 °C with an increasing rate of 5 °C/min. Briefly, the chemical component of wood vinegar was identification by comparison with the standard library data (Mun and Ku, 2010) and calculated by the integrated peak areas.

#### 2.2.3. Antitermite test

Mature workers and soldiers of *Coptotermes curvignathus* were obtained from infected tree stands in the area of the Sungai Ambawang, Kubu Raya Regency, West Kalimantan, Indonesia. The no-choice bioassay method was accomplished as designated by Kang et al. (1990) and Ganapaty et al. (2004). Winegar from medang wood (0.3 mL) with 2.0, 4.0, 6.0, 8.0, and 10.0% concentrations (v/v) were pipetted onto filter papers (Whatman No. 1, 55-mm diameter). The treated filter paper was placed into a petri dish (60-mm diameter), and 30 workers and 3 soldiers were placed on each filter paper. Filter papers treated with distilled water were used as controls. Test dishes were then covered and placed in an incubator maintained at 27±3 °C and 80±2% RH in the dark for 21 days. Four replicates were made for each concentration. The mortalities of the termites and the weight loss of the filter paper were counted and the end of the test.

#### 2.2.4. Statistical analysis

The experimental design was used in evaluating the effect of the vinegar pyrolysis temperature on the termites mortality, *C. curvignathus*. The filter paper weight loss used a factorial completely randomized design. The first factor was the pyrolysis temperature (370, 400, and 430 °C). The second factor was the concentration of vinegar (0, 2.0 4.0, 6.0, 8.0 and 10.0 %). The means were separated using Uji Duncan Multiple Range Test (DMRT) at $p$ = 0.05. All data were calculated using SAS (version 8.2). Analysis of simple linear regression was used to determine the effect of the vinegar (X) on *C. curvignathus* mortality and the filter paper weight loss (Y). The pyrolysis temperatures were 370 °C, 400 °C, and 430 °C, and the concentrations were 0%, 2.0%, 4.0%, 6.0%, and 8.0%. Each treatment was repeated four times.

The simple regression equation refers to Montgomery (1991):

$$Y = b_0 + bx \quad (1)$$

where Y is the dependent variable in the form of termite mortality in percent and the weight loss of filter paper in percent, $_0$ is the constant, $b$ is the regression coefficient, and X is the vinegar concentration in percent as independent variables. The simple linear regression analysis was performed using the Statistical Package for Social Science (SPSS) program version 25 (SPSS, Chicago, IL, USA).

## 3. RESULTS AND DISCUSSION

### *3.1. The chemical composition of wood vinegar from medang wood*

The GC-MS chemical analysis of the vinegar obtained from medang wood is shown in Table 1-3.

The results of the GC-MS analysis showed that the most abundant contents of wood vinegar at 370 °C were 2-methoxy- phenol (14.35%), phosphonic acid (16.53%), 5-methyl-2-furancarboxaldehyde, (7.60%), 2,6-dimethoxy-phenol (6.63%), creosol (5.53%), and 1-(2-furanyl)- ethanone (4.29%), meanwhile the main component of wood vinegar at 400 °C were 2-methoxy-phenol (15.94%), 5-methyl-2-furancarboxaldehyde (14.20%), phenol (11.23%), 1-(2-furanyl)-ethanone (5.35%), 2-methyl-2-Cyclopenten-1-one (3.45%), and creosol (3.26%). In addition, chemical compound of wood vinegar at 430 °C were phosphonic acid (37.06%), 2-methoxy-phenol (14.70), 2,6-dimethoxy-phenol (4.45%), 5-methyl-2-furancarboxaldehyde (4.25%), 1-(2-furanyl)-ethanone (2.74) and creosol (2.20%). Similarly, Recently, Kadir at al. (2021) reported wood vinegar derived from jelutung wood (*Dyera costulata*) and identified several main components, including benzyl alcohol, oGuaiacol, mCresol, dimethyl phenol, 2,6, cresol, 2-methyoxy-para-, phenol, 2,6-dimethoxy, catechol, 3-methyl- , vanillin, aceto vanillone and syringaldenyde.

The dominant components of wood vinegar were achieved on different retention times due to difference of pyrolysis temperatures. The pyrolysis temperature influenced the degradation of wood chemical component and resulted different amounts of each compound in wood vinegar. Similarly, Theapparat et al. (2015) reported the temperature of pyrolysis on wood made different retention times on GC–MS analysis. The wood vinegar chemical component is affected by temperature and various other factors, including amount of cellulose, hemicellulose, lignin) in the woods (Demiral and Ayan, 2011; Abnisa et al. 2013). However, for the sake of practicality, we focused only on temperature in this research.

**Table 1.** GC-MS analysis of vinegar from medang wood at 370 °C.

| No | RT | Wood vinegar compound | Area (%) |
|---|---|---|---|
| 1 | 3.96 | 2-Cyclopenten-1-one, 2-methyl- | 3.36 |
| 2 | 4.05 | Ethanone, 1-(2-furanyl)- | 4.29 |
| 3 | 5.13 | 2-Furancarboxaldehyde, 5-methyl- | 7.60 |
| 4 | 5.74 | Phosphonic acid, (p-hydroxyphenyl)- | 16.53 |
| 5 | 6.07 | 2-Furanone, 2,5-dihydro-3,5-dimethyl | 1.43 |
| 6 | 6.73 | 2-Cyclopenten-1-one, 2-hydroxy-3-methyl- | 1.98 |
| 7 | 8.36 | Phenol, 2-methoxy- | 14.35 |
| 8 | 11.20 | Creosol | 5.53 |
| 9 | 13.57 | Phenol, 4-ethyl-2-methoxy- | 2.19 |
| 10 | 15.57 | Phenol, 2,6-dimethoxy- | 6.63 |
| 11 | 15.90 | Benzenemethanol, a-ethyl-4-methoxy- | 1.03 |
| 12 | 21.91 | 2,4-Hexadienedioic acid | 1.20 |

**Table 2.** GC-MS analysis of vinegar from medang wood at 400 °C.

| No | RT | Wood vinegar compound | Area (%) |
|---|---|---|---|
| 1 | 3.95 | 2-Cyclopenten-1-one, 2-methyl- | 3.45 |
| 2 | 4.05 | Ethanone, 1-(2-furanyl)- | 5.35 |
| 3 | 4.70 | 2-Cyclopenten-1-one, 3,4-dimethyl- | 1.23 |
| 4 | 5.13 | 2-Furancarboxaldehyde, 5-methyl- | 14.20 |
| 5 | 5.74 | Phenol | 11.23 |
| 6 | 5.88 | Phosphonic acid, (p-hydroxyphenyl)- | 2.22 |
| 7 | 6.00 | 2-Furanmethanol, 5-methyl- | 2.24 |
| 8 | 6.95 | 2-Cyclopenten-1-one, 2,3-dimethyl- | 2.40 |
| 9 | 8.34 | Phenol, 2-methoxy- | 15.94 |
| 10 | 11.20 | Creosol | 3.26 |
| 11 | 13.57 | Phenol, 4-ethyl-2-methoxy- | 1.13 |
| 12 | 15.60 | Phenol, 2,6-dimethoxy- | 2.33 |

**Table 3.** GC-MS analysis of vinegar from medang wood at 430 °C.

| No | RT | Wood vinegar compound | Area (%) |
|---|---|---|---|
| 1 | 3.96 | 2-Cyclopenten-1-one, 2-methyl- | 2.13 |
| 2 | 4.05 | Ethanone, 1-(2-furanyl)- | 2.74 |
| 3 | 5.14 | 2-Furancarboxaldehyde, 5-methyl- | 4.25 |
| 4 | 5.75 | Phosphonic acid, (p-hydroxyphenyl)- | 37.06 |
| 5 | 6.12 | 2-Furanone, 2,5-dihydro-3,5-dimethyl | 1.35 |
| 6 | 6.72 | 2-Cyclopenten-1-one, 2-hydroxy-3-methy\l- | 1.24 |
| 7 | 6.99 | 2-Cyclopenten-1-one, 2,3-dimethyl- | 1.13 |
| 8 | 7.68 | Phenol, 3-methyl- | 1.12 |
| 9 | 8.36 | Phenol, 2-methoxy- | 14.70 |
| 10 | 11.20 | Creosol | 2.20 |
| 11 | 13.66 | Phenol, 4-ethyl-2-methoxy- | 1.39 |
| 12 | 15.57 | Phenol, 2,6-dimethoxy- | 4.45 |

Adfa et al. (2020) characterized wood vinegar from *Cinnamomum parthenoxylon* contains primary chemical components such as acetic acid (42.91%), 3-butenoic acid (6.89%), 2-propenyl ester (2.26%), 1-hydroxy-2propanone (5.14%), and 3-methylcyclopentane-1,2-dione (2.23%). According to a previous study, phenolic compounds that were identified throung GC-MS analysis of wood vinegars included phenol, 2-methylphenol, 3-methylphenol, 2-methoxyphenol, 2,6-dimethylphenol, 2,4-dimethylphenol, 3-ethylphenol, 2,3-dimethylphenol, 2-methoxy-4-methyl phenol, 4-ethyl-2-methoxyphenol, 2,6-dimethoxyphenol, eugenol, 2-methoxy-4-propylphenol, and cis- and trans-isoeugenol (Hassan et al., 2016). Recenly, Oramahi et al. (2020) stated that the primary compounds of vinegar obtained from *bengkirai wood (Shorea laevis Ridl)* were 1,2-ethanediol, fluoromethane, formic acid, 2-propanone, acetic acid, acetol, furfural, 2,4-hexadecanoic acid and guaiacol. Whereas, the main compounds of vinegar obtained from mabang wood (*Shorea panchyphylla*) were 1,2-ethanediol, fluoromethane, formic acid, 2-propanone, acetic acid, acetol, furfural, 2,4-hexadecanoic acid, and guaiacol (Oramahi *et al.* 2022).

## 3.2. Antitermite performance

The daily mortality of *C. curvignathus* treated with wood vinegar at 370, 400, and 430 °C was determined for 21 days using a no-choice feeding test; the results are presented in Table 4.

Increasing concentrations of wood vinegar were associated with significantly increased mortality of *Coptotermes curvignathus* and decreased weight loss of the filter paper (Table 4), the highest termite mortality was at the highest concentration (8.0%) of wood vinegar at 430 °C. Statistically significant differences in filter paper consumption were observed for diluted wood vinegar between the control and treated samples. This trend is similar to that found by Oramahi et al. (2023) wherein *Coptotermes curvignathus* died after 21 days of exposure. Termicidal activity in the present study was consistent with the acetic acid and phenol contents in wood vinegars (Table 1), which is in agreement with previous results. This result is similar with Yatagai et al. (2002) who reported that acetic acid was responsible for the high mortality of termites. Furthermore, Oramahi and Yoshimura (2013) state that acid and phenol compounds contained in *Vitex pubescens*-wood vinegar cause significant termite mortality and mass loss at concentration of 5%. Oramahi et al (2018) also reported that acid and phenol compounds in wood vinegar from oil palm trunk affect highest termite mortality and mass loss at concentration of 10%. Similar result also reported by Adfa et al (2017) who state that the two largest components in *Toona sinensis* wood vinegar are acid and phenol components, whereas these two components cause the highest mortality of termite at concentration of 8%. Suprianto et al. (2023) investigated wood vinegar from durian wood (*Durio* sp.) and found that it exhibited termicidal activity and the main components of durian vinegar that contributed to high termicidal activity were 2-methoxy-phenol, 4-ethyl-2-methoxy-phenol, 4-ethyl-2-methoxy-phenol, 3.5-dimethoxy-4-hydroxytoluene, and creosol. The wood vinegar contributed significantly to termite

**Table 4.** Termite mortality and filter paper weight loss at different pyrolysis temperatures and wood vinegar concentrations.

| Pyrolysis temperature (°C) | Wood vinegar concentration (%) | Termite mortality (%) | Filter paper weight loss (%) |
|---|---|---|---|
| Control | 0 | 15.90 ± 4.78 a | 80.99 ± 4.40 a |
| 370 | 2 | 37.72 ± 5.22 b | 64.73 ± 2.71 b |
| | 4 | 54.54 ± 3.31 c | 56.52 ± 2.39 c |
| | 6 | 75.45 ± 4.32 ef | 45.33 ± 4.45 d |
| | 8 | 91.36 ± 3.10 g | 33.34 ± 6.55 gf |
| | 10 | 100 ± 0 h | 21.61 ± 3.58 h |
| 400 | 2 | 54.54 ± 2.56 c | 56.45 ± 4.55 c |
| | 4 | 71.81 ± 4.32 e | 47.09 ± 3.41 d |
| | 6 | 90.91 ± 2.57 g | 41.50 ± 2.01 de |
| | 8 | 99.09 ± 1.05 h | 29.49 ± 5.08 g |
| | 10 | 100 ± 0 h | 15.29 ± 2.87 i |
| 430 | 2 | 62.72 ± 3.48 d | 57.94 ± 5.21 c |
| | 4 | 79.09 ± 3.15 f | 36.88 ± 4.30 ef |
| | 6 | 95.90 ± 2.28 h | 23.12 ± 4.72 h |
| | 8 | 100 ± 0 h | 14.92 ± 2.68 i |
| | 10 | 100 ± 0 h | 11.99 ± 1.43 i |

Means in the same column with the same letters (a-i) are not significantly at the level of P <0.05 by DMRT.

mortality, and the effectiveness of wood vinegar against *C. curvignathus* increased with the vinegar concentration. The vinegar pyrolyzed at 430 °C lost more filter paper mass than wood vinegar at 370 and 400 °C (10.0% concentration). We hypothesize that the chemical components found in the mabang vinegar at 430 °C, including phosphonic acid, together with its characteristic phenol and phenol derivatives, may cause this antitermitic activity. Similarly, Subekti et al. (2020) concluded that wood vinegar from wulung bamboo (*Gigantochloa atroviolacea*) was effective against *C.y curvignathus* Holmgren. Moreover, Oramahi et al. (2014) reported that wood vinegars from laban wood (*Vitex pubescens*) had the potential to prevent attacks by *C. curvignathus*.

The effects of wood vinegar on the mortality of *C. curvignathus* termites at numerous pyrolysis temperatures and concentrations of wood vinegar are shown in Figs. 1-3.

The correlation values between the concentration of medang vinegar and termite mortality at pyrolysis temperatures of 370, 400, and 430 °C were 0.99, 0.93, and 0.90, respectively, which indicated a positive and strong correlation ($p < 0.05$). Similarly, the highest correlation was studied by Oramahi et al (2023).

The simple regression equation and the determination of coefficient in the treatment of wood vinegar concentration on the mortality of *C. curvignathus* termites at pyrolysis temperatures of 370, 400, and 430 °C are Y = 19.48 x + 8.61 and 0.98, Y = 30.63 x + 8.25 and 0.87, and Y = 36.89 x + 7.78 and 0.81, respectively. This equation shows that the higher the concentration of wood vinegar is, the higher the mortality of *C. curvignathus* termites. This result shows that higher concentrations of wood vinegar components such as phosphonic acid and phenol indicated higher levels of anti-termite properties. The results of this study are in line with the results of study by Oramahi et al. (2023), who reported that increasing the concentration of wood vinegar from wood (*Durio* sp.) significantly increased the mortality of termites (*C. curvignathus*).

## 3.3. Filter paper weight loss

The effects of wood vinegar on the weight loss of filter paper by *C. curvignathus* termites at numerous pyrolysis temperatures and concentrations of wood vinegar are shown in Figs. 4-6. The simple regression equation and the determination of coefficient on the effect of wood vinegar concentration on the weight loss of filter paper at pyrolysis temperatures of 370, 400, and 430 °C are Y = 79.16 x – 5.75 and 0.96, Y = 74.37 x – 5.52 and 0.92, and Y = 74.06 x – 7.18 and 0.95, respectively.

This equation shows that the higher the concentration of wood vinegar was, the lower the weight loss of filter paper due to subterranean *C. curvignathus* termites, indicating decreased consumption of filter paper as food. Termite mortality

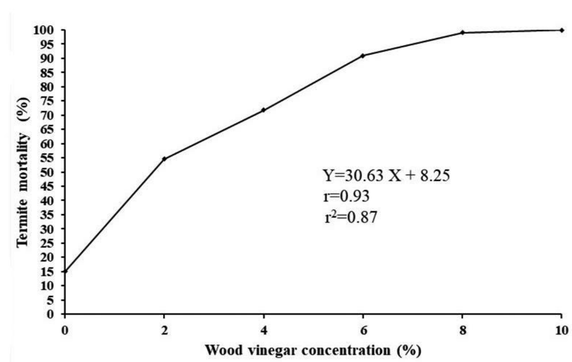


**Figure 2.** Simple regression and correlation between the concentration of vinegar from medang wood (%) and mortality of *Coptotermes curvignathus* at 400°C pyrolysis temperature.

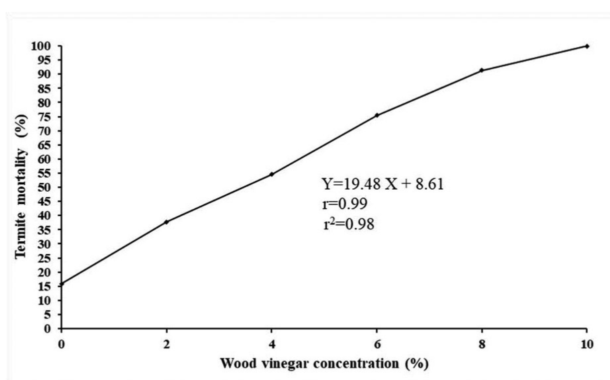


**Figure 1.** Simple regression and correlation between the concentration of vinegar from medang wood (%) and mortality of *Coptotermes curvignathus* at 370 °C pyrolysis temperature.

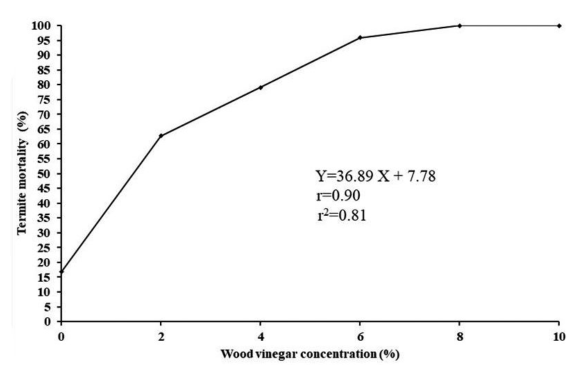


**Figure 3.** Simple regression and correlation between the concentration of vinegar from medang wood (%) and mortality of *Coptotermes curvignathus* at 430 °C pyrolysis temperature.

influenced the correlation between the pyrolysis temperature of vinegar and the decrease in filter paper weight. This is because the surviving termites still consumed filter paper, resulting in a high reduction in weight. Figures 4-6 show that treatment with vinegar at concentrations of 2.0-8.0% against *C. curvignathus* resulted in 11.99-64.73% decreases in filter paper weight. The results of this study are in line with the results of the research by Oramahi et al. (2018), in which the application of wood vinegar from oil palm trunk at concentrations of 2.50-10.0 % against *C. formosanus* termites caused 11.75-38.88 % decreases in filter paper weight.

## 4. CONCLUSIONS

The vinegars from mabang wood have antitermite potential, especially wood vinegar pyrolyzed at 430 °C against *C. curvignathus* termites. Increasing concentrations of mabang vinegar were associated with significantly increased mortality of *Coptotermes curvignathus* ternites and decreased mass loss of the filter paper, as well as the highest termite mortality was at the highest concentration of wood vinegar at 430 °C. The predominant compounds in the wood vinegar were phenol, 2-methoxy-phenol, phosphonic acid and 1-(2-furanyl) ethanone.

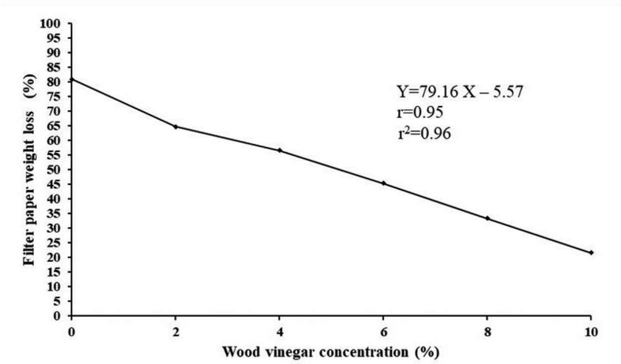


**Figure 4.** Simple regression and correlation between the concentration of vinegar from medang wood (%) and the weight loss of filter paper at 370 °C pyrolysis temperature.

## SUBMISSION STATUS

Received: 17 May 2023
Accepted: 23 Sep. 2023
Associate editor: Fernando Gomes

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Farah Diba: conceptualization (equal), data curation (equal), investigation (supporting), resources (equal), validation (supporting), writing – original draft (supporting), writing – review and editing (lead).
Rizka Diah Permana: data curation (equal), formal analysis (lead), investigation (lead), methodology (lead), project administration (equal), validation (lead), visualization (lead), writing – original draft (lead), writing – review and editing (supporting).
Yuliati Indrayani: conceptualization (equal), writing – review & editing (supporting).

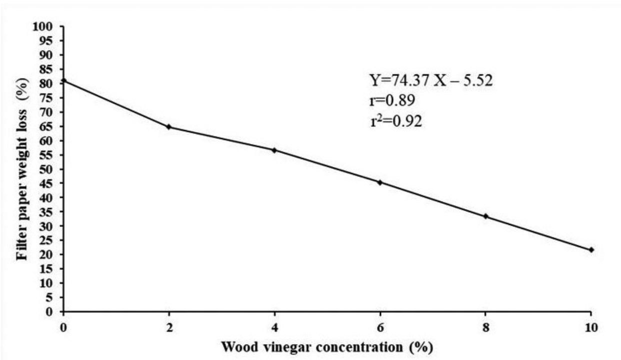


**Figure 5.** Simple regression and correlation between the concentration of vinegar from medang wood (%) and the weight loss of filter paper at 400 °C pyrolysis temperature.

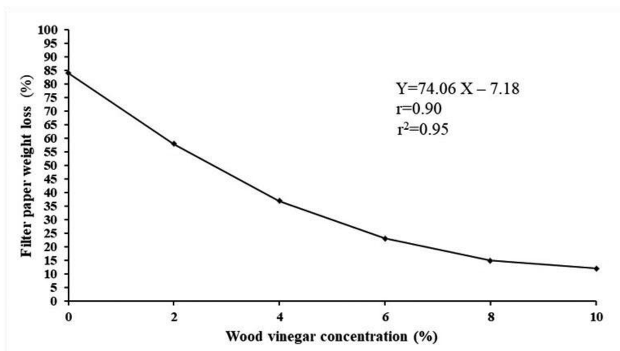


**Figure 6.** Simple regression and correlation between the concentration of vinegar from medang wood (%) and the weight loss of filter paper at 430 °C pyrolysis temperature.

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