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The Antitermitic and Antifungal Activities and Composition of Vinegar from Durian Wood (*Durio* sp.)

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ABSTRACT

Chemical characterization of vinegars obtained from Durian wood (*Durio* sp.) and their termicidal activity against *Coptotermes curvignathus* and antifungal activity against *Schizophyllum commune* were evaluated. The process of pyrolysis produced wood vinegars at three distinct temperature: 350°C, 400°C, and 450°C. To determine their effectiveness against fungal growth, the vinegars were tested using a Petri dish with 1.0%, 2.0%, 3.0%, and 4.0% (v/v) against *S. commune*. In the experiment, termicidal activities were evaluated using a no-choice test for *C. curvignathus* with 3.0%, 6.0%, 9.0%, and 12.0% (v/v). The wood vinegar exhibited antitermitic activity to *C. curvignathus* workers in the no-choice experiment; For vinegar produced at 450°C, a 6% concentration was required to achieve 100% mortality against *C. curvignathus*. In addition, a 12% vinegar produced at 450°C resulted in the lowest mass loss of treated filter paper, which was 20.00%. Furthermore, all the wood vinegars exhibited antifungal activities against *S. commune* at concentration of 2.0%. The dominant chemical components of wood vinegar produced at temperature of 350°C, 400°C, and 450°C were 2-methoxy-phenol, 4-ethyl-2-methoxy-phenol, 4-ethyl-2-methoxy-phenol, 3.5-dimethoxy-4-hydroxytoluene, and creosol.

Keywords: *Coptotermes curvignathus*, Durian wood, antifungal activity, antitermitic activity, wood vinegar

1. INTRODUCTION

Biodegradation of wood caused by decay fungi and termites is recognized as one of the most serious problems, making it vulnerable to damage. To protect wood from this, synthetic chemicals have been utilized for a long time (Meyer, 2005; Theapparat *et al*., 2015; Verma *et al*., 2009). However, the use of these chemicals has resulted in environmental concerns and negative impacts (Bedmutha *et al*., 2011; Preston, 2000). Therefore, the development of alternative, environmentally-friendly wood preservatives is needed to reduce environmental pollution.

Adfa *et al*. (2023) observed that *Azadirachta indica* seed kernel showed termiticide against *Coptotermes curvignathus*. Nkogo *et al*. (2022) found an anti-termite activity in the bark of Guibourtia tessmannii from Gabon. Lee *et al*. (2020) reported that *Borneolum Syntheticum*, *Ephedra sinica*, and *Menthol*'s extracts inhibited the activity of termite intestinal enzymes. The utilization of compounds from plant extracts has recently been carried out to evaluate the synergism ability between compounds as antifungal agents (Na and Kim, 2022; Yoon and Kim, 2021).

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Recently, researchers have used wood vinegar as an antifungal and antitermitic agent. Wood vinegar has the potential for antimicrobial, antifungal and antitermitic activity, as well as insecticidal activity (Aly *et al*., 2022; Hashemi *et al*., 2014; Omulo *et al*., 2017; Shiny and Remadevi, 2014). For example, Desvita *et al*. (2021) reported that wood vinegar from cocoa pod shells at 300℃–380℃ showed antimicrobial activity against *Candida albicans* and *Aspergillus niger*. Teo (2022) reported that wood vinegar from *Rhizophora apiculate* exhibited antimicrobial activity against *Enterococcus faecalis, Escherichia coli, Proteus vulgaris* and *C. albicans*. Imaningsih *et al*. (2022) revealed that vinegar from Ulin wood (*Eusideroxylon zwager* Teijsm. & Binn) exhibited antifungal activity against *Pyricularia oryzae*. Gao *et al*. (2020) stated that the wood vinegar wheat straw exhibited antifungal activity against *Fusarium graminearum.* Wood vinegar from sunflower seed hulls was used to protect grains and products in storage against *Sitophilus oryzae, Lasioderma serricorne* and *Tribolium castaneum* (Urrutia *et al*., 2021).

Rosalina *et al*. (2016) revealed that vinegar from Bintaro wood (*Cerbera odollam* Gaertn) exhibited antitermitic activity against *C. curvignathus* Holmgren in a no-choice experiment. Temiz *et al*. (2013) reported that wood vinegar from giant cane at 450℃–525℃ showed antitermitic activity against *Reticultermes flavipes*. The wood vinegar contains primary chemical components such as acids, ketones, furans, benzene, phenols, sugars, and guaiacols. Arsyad *et al*. (2020) reported that wood vinegar obtained from bamboo pyrolyzed at 400℃ contains phenols and acids that exhibit antitermitic activity. Recently, Adfa *et al*. (2017) reported that wood vinegar from *Cinnamomum parthenoxylon* contains primary chemical components such as carboxylic acids, phenols, furan derivatives, amines, and a few hydrocarbon aromatics and that it had the potential to prevent attacks by *C. curvignathus*. Oramahi *et al*. (2021a) stated that vinegar from Bintangur wood has antitermitic activity against *C. curvignathus*.

However, vinegar from Durian wood has not previously been assessed for antitermitic and antifungal activity. The aim of this study was to evaluate the antitermitic activity against *C. curvignathus* and antifungal activity against *Schizophyllum commune*. We also characterized wood vinegar using gas chromatography–mass spectrometry (GC-MS).

2. MATERIALS and METHODS

2.1. Materials

The Durian wood (*Durio* sp.) was collected from Kubu Raya Regency, West Kalimantan, Indonesia, and converted into particles with a disk mill in the Wood Workshop Laboratory (Forestry Faculty of Tanjungpura University, Pontianak, West Kalimantan, Indonesia).

2.2. Methods

2.2.1. Wood vinegar production

The material was collected from Pontianak, West Kalimantan, Indonesia. The raw material was converted into wood meals using a Willey mill with 8–12 mesh screens, and air dried to about 12% of moisture content in Wood Workshop Laboratory, Forestry Faculty, Tanjungpura University, Pontianak, West Kalimantan, Indonesia. The different main components of wood vinegar were obtained due to different pyrolysis temperature treatment. The dried meal was pyrolyzed in a laboratory furnace, following Darmadji and Triyudiana (2006), Oramahi *et al*. (2019, 2021b). This air-dried material (900 g) was placed in a closed reactor. The reactor was heated up to the desired temperature of 350℃, 400℃, 450℃ with reaction time 3 hours respectively. The resulting smoke was directed into a cooling column through a pipeline, and cold water was circulated through the column using a pump to condense the vinegar.

2.2.2. Chemical characterization of vinegar from Durian wood

The chemical composition of wood vinegar obtained from Durian wood was determined using GC–MS (QP-210S, Shimadzu, Kyoto, Japan). The GC–MS analysis involved the use of capillary columns (DB-624) measuring 30 m × 0.25 mm, with injection temperature of 250℃ and a column temperature program ranging 60℃–200℃. Helium gas was used as the carrier gas at a flow rate of 40.0 mL/min. The electron ionization mode was set at 70 eV with interface temperature of 200℃. The injection volume of the sample was 1 mL, and the temperature was maintained at 60℃–200℃ with a gradual increase of 5℃/min. Briefly, the chemical component of wood vinegar was identified by comparing it to the standard library data (Mun and Ku, 2010) and calculated by the integrated peak areas.

2.2.3. Antitermitic test

Mature workers and soldiers of *C. curvignathus* were obtained from infected tree stands in the area of the Ambawang River, Kubu Raya Regency, West Kalimantan, Indonesia. The no-choice bioassay technique was conducted in accordance with the procedures specified by Ganapaty *et al*. (2004) and Kang *et al*. (1990). Filter papers (50-mm diameter) were treated with 0.3 mL of wood vinegar dilution from Durian at concentrations of 3.0%, 6.0%, 9.0%, and 12.0% (v/v) and 50 workers and 5 soldiers were placed on each filter papers. Treated filter papers were then placed in a Petri dish (50-mm diameter), while filter papers treated with distilled water served as a control. The Petri dishes were sealed and kept in an incubator maintained at temperature of 27 ± 3℃ and a relative humidity of 80 ± 2% in the dark. Four replicates were performed for each concentration, and the number of dead termites was counted for 21 days.

2.2.4. Fungal inhibition bioassay

The bio-assay to inhibit fungal growth was carried out following the method described by Kartal *et al.* (2011). To prepare the inoculate, *S. commune* was cultured for seven days on potato dextrose agar (PDA) plates at 27℃. Four different concentrations (1.0%, 2.0%, 3.0%, and 4.0% v/v) of Durian wood vinegar were added into PDA media, which was then autoclaved for 15 min at 121℃ and 103.4 kPa (15 psi). The sterilized PDA media was then poured into 90-mm diameter Petri dishes, and a single 5-mm diameter plug was taken from the pre-cultured PDA plates and placed in the center of each Petri dish. Uninoculated PDA dishes were used as untreated (controls).

The experiment was conducted in four replicates for each condition. The Petri dishes with the treated and untreated samples were placed in a conditioning room at 27℃. The treatment ended when the fungal growth in the control sample reached the edge of the Petri dish. The diameter of fungal colony was measured daily, and the percentage of inhibition rate was calculated using the following formula:

$$I = [(C - T) / C] \times 100, \quad (1)$$

where I = inhibition, as a percentage; C = colony diameter of mycelium from control Petri dishes, in millimeters; and T = colony diameter of mycelium from the Petri dishes containing the wood vinegar (mm).

2.3. Statistical analysis

A 3 × 5 and 3 × 5 factorial completely randomized design was used for antitermitic and antifungal activities, respectively. The first factor was temperature of pyrolysis (350℃, 400℃, and 450℃) for both antitermitic and antifungal activities. The second factor in the antitermitic activity design was the concentration of wood vinegar, with five different concentrations of 0%, 1.0%, 2.0%, 3.0%, and 4.0% (v/v). In the antifungal activity design, the second factor was the concentration of wood vinegar, with five different concentrations of 0%, 3.0%, 6.0%, 9.0%, and 12.0% (v/v). The means were separated using Duncan Multiple Range Test at $p = 0.05$ for antitermitic and antifungal activities. All data were processed using the SAS software (version 8.2, SAS Institute, Cary, NC, USA).

3. RESULTS and DISCUSSION

3.1. The chemical composition of vinegar from Durian wood

The GC-MS chemical analysis of the vinegar obtained from Durian wood at 350℃, 400℃, and 450℃ is shown in Tables 1–3.

Table 1 showed that from GC-MS analysis at 350℃ the major component of vinegar from Durian wood were phenol, 2-methoxy-; phenol, 2,6-dimethoxy-; creosol; 3,5-dimethoxy-4-hydroxytoluene; and phenol, 4-ethyl-2-methoxy-. The areas of each component were 24.69%; 12.81%; 8.63%; 5.98% and 5.48% respectively. Meanwhile, the result from GC-MS analysis at 400℃ showed the major components of vinegar from Durian wood were phenol, 2-methoxy-; phenol, 4-ethyl-2-methoxy-; creosol; ethanone, 1-(2-furanyl)-; and 2-cyclopenten-1-one, 2-methyl-. The areas of each component were 24.74%; 13.54%; 8.10%; 5.28% and 4.24% respectively. Table 3 showed that from GC-MS analysis at 450℃, the major components of vinegar from Durian wood were Phenol, 2-methoxy-; creosol; phenol, 2,6-dimethoxy-; phenol, 4-ethyl-2-methoxy- and 3,5-dimethoxy-4-hydroxytoluene. The areas of each component were 24.49%; 9.00%; 8.16%; 4.58% and 3.09% respectively.

The results of the GC-MS analysis showed that the most abundant contents were 2-methoxy-phenol, 4-ethyl-2-methoxy-phenol, 4-ethyl-2-methoxy-phenol, 3,5-dimethoxy-4-hydroxytoluene, and creosol (Tables 1–3). Similarly, Akkuş *et al*. (2022) investigated that the chemical components of wood vinegar from oak (*Quercus petraea* L) were 2-methoxy-phenol, 2-cresol, 4-methyl-

Table 1. GC-MS analysis of vinegar from Durian wood at 350℃

No	RT (min)	Wood vinegar compound	Area (%)
1	3.94	2-Cyclopenten-1-one, 2-methyl-	3.76
2	4.04	Ethanone, 1-(2-furanyl)-	4.93
3	5.13	2-Furancarboxaldehyde, 5-methyl-3	4.40
4	6.66	Methylcyclopentane-1,2-dione	2.34
5	6.91	2-Cyclopenten-1-one, 2,3-dimethyl-Phenol, 3-methyl-	1.56
6	7.66	Phenol, 2-methyl-	0.09
7	8.32	Phenol, 2-methoxy-	24.69
8	11.20	Creosol	8.63
9	12.50	2-Isopropoxyphenol	4.17
10	13.61	Phenol, 4-ethyl-2-methoxy-	5.48
11	15.57	Phenol, 2,6-dimethoxy-	12.81
12	18.02	3,5-Dimethoxy-4-hydroxytoluene	5.98
13	21.93	2,4-Hexadienedioic acid	1.79

GC-MS: gas chromatography–mass spectrometry, RT: retention time.

Table 2. GC-MS analysis of vinegar from Durian wood at 400℃

No	RT (min)	Wood vinegar compound	Area (%)
1	3.94	2-Cyclopenten-1-one, 2-methyl-	4.24
2	4.04	Ethanone, 1-(2-furanyl)-	5.28
3	5.13	2-Cyclohexen-1-one, 4-ethyl-4-methyl-	3.55
4	5.77	Phosphonic acid	0.46
5	6.08	1,6-Heptadien-4-ol	1.43
6	6.67	2-Cyclopenten-1-one, 2-hydroxy-3-methyl-	1.84
7	6.91	2-Cyclopenten-1-one, 2,3-dimethyl-	1.77
8	7.62	Phenol, 2-methyl-	0.07
9	8.32	Phenol, 2-methoxy-	24.74
10	9.13	2-Cyclopenten-1-one, 3-ethyl-2-hydroxy-	0.98
11	11.19	Creosol	8.10
12	12.52	2-Isopropoxyphenol	1.12
13	15.57	Phenol, 4-ethyl-2-methoxy-	13.54
14	15.85	Formic acid	0.16
15	21.91	2,4-Hexadienedioic acid	1.26

GC-MS: gas chromatography–mass spectrometry, RT: retention time.

phenol, 4-methoxy-3-methylbenzyl alcohol, 2-methoxy-4-methylphenol, 2,6-dimethoxy-phenol, 2,3-dimethylphenol, and phenol. Liu *et al*. (2021) reported that wood vinegar from apple tree branches were acids, alcohols, carbohydrate, esters, ketones, phenols, and nitrides. The main component was acetic acid.

Kadir *et al.* (2021) characterized wood vinegar from Jelutung wood (*Dyera costulata*) contained principal components of benzyl alcohol, *o*-Guaiacol, *m*-Cresol, dimethyl phenol, 2,6, cresol, 2-methyoxy-para-, phenol, 2,6-dimethoxy, catechol, 3-methyl-, vanillin, aceto vanillone and syringaldenyde. Laougé *et al*. (2020) characterized wood vinegar from Pearl Millet (PM) and Sida cordifolia (SC) using GC-MS. PM vinegar contained phenolic and acidic compounds. The phenolic compounds were 2,6-dimethoxyphenol while acidic compounds were acetic and propanoic acids. The other compounds include benzene, furfural, guaiacol, 2-dyclopenten-1-one, and 2-hydroxy-3-methyl-, trimethylamine. In addition, the SC vinegar detected similar compounds compared to that of obtained from PM. Faisal *et al*. (2018) characterized wood vinegar from Durian peel (Durio zibethinus) of containing more than fifteen chemical components such as phenolic acid, carbonyl, carboxylate, furan, and acid compounds. Ariyanti *et al*. (2017) characterized wood vinegar from ebony wood, contained phenol, 2,6-dimethoxy-4- (2-propenyl) (CAS) 4-Allyl-2,6-dimethoxyphenol, hexanoic acid, 1-methylethyl ester (CAS) isopropyl hexanoate, pentanoic acid, 4-oxo, ethyl ester (CAS) ethyl levulinate, acetaldehyde (CAS) ethanal, and 4-Methoxy-3-(methoxymethyl) phenol. Oramahi *et al*. (2020) have recently communicated that the main components found in vinegar produced from Bengkirai wood *Shorea laevis* Ridl) were guaiacol, 2,4-hexadecanoic acid, 1,2-ethane-

Table 3. GC-MS analysis of vinegar from Durian wood at 450℃

No	RT (min)	Wood vinegar compound	Area (%)
1	3.95	2-Cyclopenten-1-one, 2-methyl-	2.36
2	4.04	Ethanone, 1-(2-furanyl)-	3.76
3	5.13	2-Furancarboxaldehyde, 5-methyl-	2.96
4	5.63	Pentanoic acid	0.31
5	5.77	Phosphonic acid	1.58
6	5.89	2-Cyclopenten-1-one, 2,3-dimethyl-	1.66
7	5.98	2-Furanmethanol, 5-methyl-	0.75
8	6.70	1,2-Cyclopentanedione, 3-methyl-	1.77
9	7.69	Phenol, 3-methyl-	0.73
10	7.93	Acetic acid	1.16
11	8.38	Phenol, 2-methoxy-	24.49
12	8.59	Formic acid	0.54
13	11.20	Creosol	9.00
14	12.44	2-Isopropoxyphenol	1.49
15	13.57	Phenol, 4-ethyl-2-methoxy-	4.58
16	15.56	Phenol, 2,6-dimethoxy-	8.16
17	18.01	3,5-Dimethoxy-4-hydroxytoluene	3.09

GC-MS: gas chromatography–mass spectrometry.

diol, fluoromethane, formic acid, 2-propanone, acetic acid, acetol, and furfural.

3.2. Antitermic performance

The daily mortality of *C. curvignathus* treated with vinegar from Durian wood at 350℃, 400℃, and 450℃ was determined for 21 days using a no-choice feeding test; the results are presented in Table 4.

Table 4 shows that there was a significant increase in mortality of *C. curvignathus* and decrease in filter paper mass loss as the concentration of wood vinegar increased. The highest termite mortality was observed at the highest concentration (6%) of wood vinegar produced at 450℃. The consumption of filter paper was significantly different between the control and treated samples when diluted wood vinegar was used. These findings are consistent with Oramahi *et al*. (2020) study, where *C. curvignathus* also died after exposure for 21 days. The presence of acetic acid, phenol, and phenol derivatives in wood vinegar, as shown in Table 4, is responsible for their termicidal activity, which is consistent with previous research. Yatagai *et al*. (2002) stated that the content of wood vinegar organic fraction and acetic acid might be responsible for the differences in termicidal activities.

Oramahi *et al*. (2022a) studied wood vinegar made from the shells of Nipah fruit and a mixture of shells and fibers, which have shown potential for use as an antitermitic agent against *C. curvignathus*. The use of

Table 4. Toxic effect of the vinegar from Durian wood and mass losses of the filter papers in a no-choice test against *Coptotermes curvignathus*

Treatment		Termite mortality (%)[1)]	Mass loss after 21 days (%)
Wood vinegar	Conc. of treating solutions (%)		
Untreated control	0	16.67 ± 3.03[a]	57.68 ± 2.99[a]
350℃	3.0	65.91 ± 5.17[b]	44.17 ± 1.29[b]
	6.0	92.68 ± 4.31[e]	40.43 ± 2.60[bc]
	9.0	99.24 ± 1.52[f]	35.01 ± 4.44[d]
	12.0	100 ± 0[f]	27.03 ± 0.61[e]
400℃	3.0	73.49 ± 5.55[c]	40.44 ± 1.35[bc]
	6.0	98.49 ± 1.75	34.70 ± 2.86[d]
	9.0	100 ± 0[f]	27.65 ± 2.18[e]
	12.0	100 ± 0[f]	21.75 ± 2.68[f]
450℃	3.0	84.85 ± 5.53[d]	37.45 ± 2.27[cd]
	6.0	100 ± 0[f]	30.76 ± 1.90[e]
	9.0	100 ± 0[f]	23.10 ± 2.99[f]
	12.0	100 ± 0[f]	20.00 ± 3.07[f]

[1)] Means (n = 4) ± SD using 55 termites per replicate.
[a–f] Duncan's multiple range test indicated significance (p < 0.05) between groups denoted by numbers followed by letters.

wood vinegar was found to be effective against termites and effectiveness increased with higher concentration of vinegar. When compared to wood vinegar produced at lower temperatures, wood vinegar produced at 450℃ resulted in more filter paper mass loss. The antitermitic activity of wood vinegar may be attributed to its chemical components, including acetic acid, propanoic acid, phenol and phenol derivatives. Previous studies have also shown that wood vinegar from other sources, such as Wulung bamboo and Nipah fuit shells, can prevent termite attacks (Subekti and Yoshimura, 2020). Lee *et al*. (2022) found that wood vinegar from rubberwood and oil palm trunk contained various chemical compounds, including acids, alcohols, furfural and furan derivatives, as well as phenol and methoxyphenol derivatives, which could potentially be used as antitermite against *C. curvignathus*. The main chemical components of wood vinegar obtained from *Syzygium polyanthum* were acetic acid, phenol, ketone, benzene, and aldehyde (Hadi *et al*., 2020).

3.3. Growth inhibition performance against decay fungi

S. commune as saprobic wood decay fungi, mainly consumes lignin in wood. Therefore, efforts to control it are necessary. The fungus *S. commune* has the ability to decay wood in a moderate category, but it still needs to be a concern because the resulting loss of wood reaches 9.87% (Djarwanto *et al*., 2018).

Table 5 summarizes the effects of increasing concentrations of Durian wood vinegar on the growth of *S. commune*.

Overall, the wood vinegars showed antifungal proper-

Table 5. Growth inhibition performance of vinegar from Durian wood against *Schizophyllum commune* on the PDA media

Treatment		
Wood vinegar	Concentrations of wood vinegar in PDA media (%)	Inhibition (%)[1)]
Untreated /control	0	0.00 ± 0.00[a]
350℃	1.0	3.52 ± 0.92[b]
	2.0	100 ± 0.00[e]
	3.0	100 ± 0.00[e]
	4.0	100 ± 0.00[e]
400℃	1.0	7.61 ± 1.64[c]
	2.0	100 ± 0.00[e]
	3.0	100 ± 0.00[e]
	4.0	100 ± 0.00[e]
450℃	1.0	13.06 ± 2.54[d]
	2.0	100 ± 0.00[e]
	3.0	100 ± 0.00[e]
	4.0	100 ± 0.00[e]

[1)] Means (n = 4) ± SD.
[a–e] Duncan's multiple range test indicated significance (p < 0.05) between groups denoted by numbers followed by letters.
PDA: potato dextrose agar.

ties, with the effectiveness increasing as the concentration of wood vinegar increased. The wood vinegar was found to be significant inhibition against *S. commune* at a concentration of 2.0%. This high antifungal activity may be attributed to the higher levels of 2-methoxy-phenol, 4-ethyl-2-methoxy-phenol, 4-ethyl-2-methoxy-phenol, 3,5-dimethoxy-4-hydroxytoluene, and creosol (Tables 1–3). Similar findings have been reported by Oramahi *et al*. (2022b) and Theapparat *et al*. (2015). Oramahi *et al*. (2018) investigated the antifungal properties of wood vinegar from oil palm trunk against decay fungi at concentrations ranging 0.5 to 1.5 (v/v). The results showed that all three wood vinegars produced at 350℃, 400℃, and 450℃ exhibited antifungal activity against *T. versicolor* and *F. palustris* with performance increasing with concentration. The wood produced at 350℃ demonstrated the highest performance with 100% inhibition against *T. versicolor* at concentrations of 1.0% and 1.5%.

Li *et al*. (2022) found that the total of acids and phenols in wood vinegar produced at temperature ranging from 380℃–550℃ contributed to its antifungal activity against *Fusarium oxysporum.* Anggraini *et al*. (2021) identified several chemical compounds in wood vinegar produced from *Fafraea fragrans* and *Gluta renghas,* including acetic acid, ethylic acid, 2-propanone, 1-hydroxyacetol, phenol, 2-methoxyguaiacol, and phenol, which exhibited antifungal activity. Adfa *et al*. (2020) found that the phenolic compounds of wood vinegar from *C. parthenoxylon* contributed to its antifungal activity. Oramahi *et al*. (2010) stated that wood vinegar from oil palm empty fruit bunch exhibited antifungal activity against *A. niger*. Lee *et al*. (2022) also reported that wood vinegar produced from rubberwood and oil palm trunk demonstrated antifungal activity against white rot fungi, *Pycnoporus sanguines*, and could be used as a wood preservative.

4. CONCLUSIONS

Durian wood vinegar was found to exhibit antitermitic activity against *C. curvignathus.* Increasing concentrations of the vinegar led to a significant increase in termitic mortality and a decrease in the mass loss of filter paper. The highest mortality rate was observed at the highest concentrations of wood vinegar, obtained at 450℃. All vinegar from Durian wood completely inhibited the growth of the *S. commune* at 2.0% concentrations. The predominant compounds in the wood vinegar were 2-methoxy-phenol, 4-ethyl-2-methoxy-phenol, 4-ethyl-2-methoxy-phenol, 3,5-dimethoxy-4-hydroxytoluene, and creosol.

CONFLICT of INTEREST

No potential conflict of interest relevant to this article was reported.

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