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Full Length Research Article

Anti-Termites Properties of Liquid Smoke from Bintangur Wood

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ABSTRACT

Wood and wood-based products are very vulnerable to termite attacks. One of the methods to control termite attacks is using chemical insecticide. However, the use of chemical insecticide is considered a negative effect on the environment. The aim of this research was to determine the anti-termite properties of liquid smoke against *Coptotermes curvignathus* Holmgren. The liquid smoke derived from bintangur wood pyrolysis at 370°C, 400°C, and 430°C was assessed as an anti-termite activity. Anti-termite activities against *C. curvignathus* were conducted by using liquid smoke with the concentration of 2%, 4%, 6%, and 8% (v/v). Simple linear regression was used to measure the effect of liquid smoke concentration against *C. curvignathus*. The results showed that the liquid smoke concentration of 6% and 8% at the three pyrolysis temperatures effectively controlled the subterranean termite's attack and resulted in 100% termites mortality. The chemical content of bintangur wood vinegar has contained phenol (1.23–1.65%) and acid (4.33–6.68%).

1. Introduction

Termites are destructive organisms that cause damage to both plantation crops and forest plants (Calderon and Constantino 2007; Jasmi and Ahmad 2011). Termites are also known as organisms that can cause damage to buildings and household furniture from wood (Ghaly and Edwards 2011). Jasmi and Ahmad (2011) stated that the *Coptotermes curvignathus* is the main species of termite attacking Araucaria plants with a damage rate of 74% compared to *Schedorhinotermes medioobscurus* and *Odontotermes sarawakensis* termites.

Termite control using chemicals has been conducted for a long time, but these chemicals can cause harm to the environment and human health. In addition, the death of non-target organisms is the result of synthetic chemical use. Termite control using natural ingredients is an alternative effort to reduce losses due to synthetic chemicals. One of the alternative materials that can be used for termite control is liquid smoke.

Liquid smoke is a product of burning wood or biomass using a pyrolysis device at high temperatures without air (Lee et al. 2011). As a raw material for liquid smoke production, wood is generally composed of main components, such as cellulose, hemicellulose, and lignin (Liu et al. 2017). Liquid smoke contains complex chemical components so that it can function as an anti-fungal (Gao et al. 2020) and anti-termite (Adfa et al. 2017). For example, liquid smoke obtained from wheat straw contains chemical components including m-cresol, 3,4-dihydroxy toluene, o-cresol, acetic acid, 4-ethyl phenol, 3-methyl catechol, propionic acid 2-ethyl phenol, and 4- ethyl phenol. This liquid smoke can inhibit the growth of the fungus *Fusarium graminearum* (Gao et al. 2020).

Adfa et al. (2017) stated that liquid smoke from surian wood (*Toona sinensis* A. Juss) contains dominant chemical components such as acetic acid. The results showed that the liquid smoke functioned as an anti-termite agent (Adfa et al. 2017). Another study conducted by Oramahi et al. (2018) stated that liquid smoke from palm oil stems has anti-termite activity. The anti-termite activity of liquid smoke is strongly influenced by the chemical components of liquid smoke, such as acids, phenols, and phenol derivatives. These chemical components are influenced by the pyrolysis temperature and the biomass source used.

This study aims to evaluate the efficacy of liquid smoke from bintangur wood (*Calophyllum inophyllum* Linnaeus) at pyrolysis temperatures of 370°C, 400°C, and 430°C against subterranean termites *C. curvignathus*. In addition, analysis of the constituent components of liquid smoke as phenol and acid contents at the three temperatures was also carried out.

2. Materials and Methods

2.1. Materials Preparation and Liquid Smoke Production

The preparation of bintangur wood (*Calophyllum inophyllum* Linnaeus) was carried out at the Wood Workshop Laboratory, Faculty of Forestry, Tanjungpura University, Pontianak. Bintangur wood raw material was obtained from sawmills in Pontianak. Bintangur wood was crushed into powder with a size of a 40 mesh sieve and retained by 60 mesh. The manufacture of liquid smoke was carried out by pyrolysis at the Engineering Laboratory of the Faculty of Agricultural Technology, Gadjah Mada University, Yogyakarta. Testing the efficacy of bintangur wood liquid smoke against subterranean termites *Coptotermes curvignathus* Holmgren was carried out at the Wood Technology Laboratory, Faculty of Forestry, Tanjungpura University. The production of liquid smoke applied the pyrolysis method following the previous studies (Darmadji and Triyudiana 2006; Oramahi et al. 2020a). The liquid smoke was manufactured through the following steps: bintangur wood powder was put into an aluminum reactor with a maximum capacity of 5 kg particle, then closed. A series of aluminum condensers was then installed, the heating furnace was turned on at a temperature of 370°C, 400°C, and 430°C with pyrolysis time for 120 minutes. The pyrolysis process is presented in **Fig. 1.**

2.2. Total Phenol Analysis

The total phenol analysis procedure was carried out based on Senter et al. (1989) as follows: (1) 1 ml of liquid smoke from bintangur wood was weighed and diluted with distilled water to reach a volume of 1,000 ml, (2) 1 ml of the solution is taken and then added as much as 5 ml of alkaline $NaCO_3$ (1 molar) solution, (3) The solution is left at 27°C for 10 minutes, (4) then added as much as 0.5 ml of Folin-ciocalteu reagent (commercial reagent: distilled water (1:1) v/v) and shaken using a vortex-shaker, (5) then left for 30 minutes, and the absorbance was read with a spectrophotometer (UV-Vis Shimadzu 1601, Japan) on a blank solution using a wavelength of 750 nm, and (6) the phenolic concentration of the sample solution was calculated based on the standard curve obtained from the pure phenol solution.

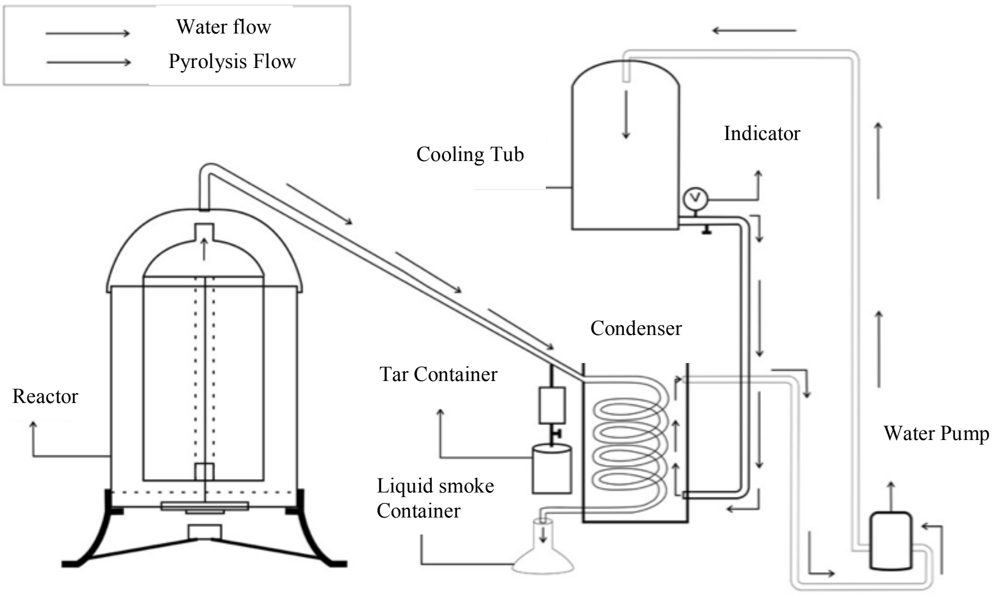

Fig. 1. Schematic of a tool for liquid smoke production through pyrolysis.

2.3. Total Acid Analysis

The total acid analysis procedure was carried out based on AOAC (1990) as follows: (1) liquid smoke from bintangur wood was weighed about 1 mL, (2) then diluted with distilled water to reach a volume of 100 mL, (3) titrated with 0.1 N NaOH standard solution to pH reaches 8, and (4) the acid content is expressed in percent by weight of acetic acid.

2.4. Coptotermes curvignathus Termites Collection

Subterranean termites were obtained from infected tree stands in the area of the Ambawang River, Kubu Raya Regency, West Kalimantan, Indonesia. The termite used was *C. curvignathus* (worker and soldier castes). The characteristics of worker and soldier termites refer to procedures (Nandika et al. 2003). Maintenance of *C. curvignathus* was carried out in the laboratory with the following procedures (1) put the termites in a bucket that has been given rubberwood as a food source, (2) the bucket containing termites was covered with black plastic so that moisture is maintained, (3) this maintenance was carried out for 3 weeks before the study.

2.5. Testing of Liquid Smoke against Coptotermes curvignathus Termites In Vitro

Testing the efficacy of bintangur wood liquid smoke against *C. curvignathus* was carried out at the Wood Technology Laboratory, Faculty of Forestry, Tanjungpura University. The testing was referred to Kang et al. (1990) and Ganapaty et al. (2004). About 0.3 ml of liquid smoke from bintangur wood was dropped on filter paper media (Whatman number 1, diameter 55 mm). The filter paper was placed on a plastic cup with a diameter of 60 mm. The subterranean termites *C. curvignathus* (soldiers and workers) with a composition of 50 workers and 5 soldiers were placed on plastic plates and stored in the termite incubation room at a temperature of 27°C with a humidity of 70-80%.

Incubation was carried out for 21 days and observations were made every day to evaluate termite mortality. The filter paper as control was dripped with distilled water as much as 0.3 ml. The study used variations in the concentration of liquid smoke, such as 0%, 2%, 4%, 6%, and 8%, with four replications.

Percentage of termite mortality and filter paper weight loss as observation variables refers to Owoyemi et al. (2011) as follows:

$$Mortality\ (\%) = \frac{N_1 - N_2}{N_1} \times 100\% \quad (1)$$

where N_1 is the number of initial termites, and N_2 is the number of termites at the end of the test.

$$Filter\ paper\ weight\ loss\ in\ (\%) = \frac{B_1 - B_2}{B_1} \times 100\% \quad (2)$$

where B_1 is the weight of the initial filter paper (g), and $B2$ is the weight of the filter paper at the end of the test (g).

2.6. Experiment Design and Data Analysis

The experimental design was used to evaluate the effect of pyrolysis temperature in liquid smoke production of bintangur wood on the mortality of *C. curvignathus* and weight loss of filter paper using a factorial completely randomized design. The first factor was the pyrolysis temperature during the liquid smoke production from bintangur wood, consisting of 370°C, 400°C, and 430°C. The second factor was the concentration of liquid smoke from bintangur wood consisting of 0%, 2%, 4%, 6%, and 8%. Data on the mortality of *C. curvignathus* and weight loss of filter paper were analyzed using variance (ANOVA). An honestly significant difference test was carried out at 5% significance level to determine differences between treatments.

The use of simple linear regression analysis was to determine the effect of liquid smoke concentration of bintangur wood (x) on the mortality of *C. curvignathus,* and weight loss of filter paper (Y). The simple regression equation refers to Montgomery (1991):

$$Y = bo + bx \quad (3)$$

where bo is constant and b is regression coefficient.

Analysis of variance was conducted using SAS, and the simple linear regression analysis was conducted using the Statistical Package for Social Science (SPSS) program version 22 (SPSS Inc., USA).

3. Results and Discussion

3.1. Chemical Components of Liquid Smoke from Bintangur Wood

The constituent components of liquid smoke as total phenol and total acid, are shown in **Table 1**. The total phenol component in the liquid smoke of bintangur wood was 1.23-1.42%, while the acid content was 4.33-6.68%. Adfa et al. (2020) stated that liquid smoke from *Cinnamomum parthenoxylon* contains chemical components such as acids and phenols as the dominant compounds. The acid compounds were acetic acid of 42.91% and phenolic compounds, such as 2-dimethoxy phenol of 5.51%. Meanwhile, the acid and phenol content in liquid smoke was obtained from a mixture of *Acacia mangium* Willd and *Vitex pubescens* Vahl wood sawdust were 6.05-8.73% and 2.13-6.70%, respectively (Oramahi et al. 2011). Alias et al. (2020) obtained the content of phenol, mequinol, 4-methyl phenol, 4-ethyl phenol, and acetic acid in bamboo liquid smoke were 11.57%, 14.87%, 2.85%, 11.46%, and 8.45%, respectively. The difference in phenol and acid content in this study was caused by differences in the raw materials for the liquid smoke production.

Table 1. The constituent components of liquid smoke from bintangur wood at various pyrolysis temperatures

Pyrolysis Temperature (°C)	Components	
	Phenol (%)	Acid (%)
370	1.42	4.33
400	1.23	6.13
430	1.65	6.68

Notes: The means are averages of 3 replicates.

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Table 1 shows that the increase in acid and phenol is influenced by pyrolysis temperature. The higher pyrolysis temperature indicated the increase of acid and phenol levels. However, the phenol content tends to decrease at 400°C. Wu et al. (2015) reported that the phenol content of liquid smoke at 450°C was higher than the phenol content at 350°C. The results of this study showed a tendency to increase the constituent content of liquid smoke with an increase in the pyrolysis temperature of liquid smoke production. The phenol content in liquid smoke from bamboo is formed from the pyrolysis of lignin, while acetic acid is formed from the pyrolysis of cellulose and hemicellulose (Theapparat et al. 2015).

3.2. Mortality of Coptotermes curvignathus Termites

The mortality percentage of *C. curvignathus* and weight loss of filter paper at different pyrolysis temperatures and concentrations of liquid smoke is presented in **Table 2**. The analysis showed that the treatment of liquid smoke concentration from bintangur wood and pyrolysis temperature of liquid smoke production (370°C, 400°C, and 430°C) had a significant effect on termite mortality and weight loss. The effect of liquid smoke on termite mortality at a liquid smoke concentration of 4% resulted in the highest mortality (90.91%) at a pyrolysis temperature of 430°C compared to that of termites at temperatures of 370°C and 400°C (**Table 2**). The difference in the ability of liquid acid anti-crawl activity is influenced by several factors, including the concentration of liquid smoke and the chemical components of liquid smoke (Adfa et al. 2017; Oramahi et al. 2020b). These results were in line with Oramahi et al. (2020b), stating that the liquid smoke from bengkirai wood and oil palm empty fruit bunches (OPEFB) has differences in its anti-termite properties. OPEFB liquid smoke has the highest anti-termite activity against *Coptotermes formosanus* termites at a temperature of 450°C compared to 350°C, with a concentration of 10%. Subekti and Yoshimura (2020) reported that liquid smoke from bamboo at a pyrolysis temperature of 450°C effectively controlled *C. formosanus* termites, with a mortality rate of 100% on day 14 with a concentration of 10%.

Table 2. Termite mortality and filter paper weight loss at different pyrolysis temperatures and liquid smoke concentrations

Treatment		Termite Mortality (%)	Filter Paper Weight Loss (%)
Pyrolysis Temperature (°C)	Liquid Smoke Concentration (%)		
Control	0	17.00 (1.52)[a]	41.21 (1.73)[i]
370	2	64.40 (2.90)[b]	20.97 (0.52)[h]
	4	75.76 (2.47)[cd]	14.83 (2.68)[fg]
	6	100.00 (0.00)[f]	8.84 (1.07)[bcd]
	8	100.00 (0.00)[f]	6.86 (1.29)[bc]
400	2	69.70 (4.29)[bc]	18.30 (0.89)[gh]
	4	81.84 (2.47)[d]	12.60 (1.37)[def]
	6	100.00 (0.00)[f]	8.71 (1.17)[bcd]
	8	100.00 (0.00)[f]	6.12 (0.75)[ab]
430	2	81.06 (3.81)[d]	13.52 (1.55)[efg]
	4	90.91 (2.47)[e]	10.16 (0.80)[cde]
	6	100.00 (0.00)[f]	7.80 (1.62)[bcd]
	8	100.00 (0.00)[f]	5.06 (2.11)[abc]

Notes: Numbers in parenthesis are standard deviations. Means within a column followed by the same letter are not significantly different at 5% significance level using the LSD test.

The mortality of *C. curvignathus* due to treatment of liquid smoke from bintangur wood at various pyrolysis temperatures and concentrations of liquid smoke for 21 days is shown in **Fig. 2-4**.

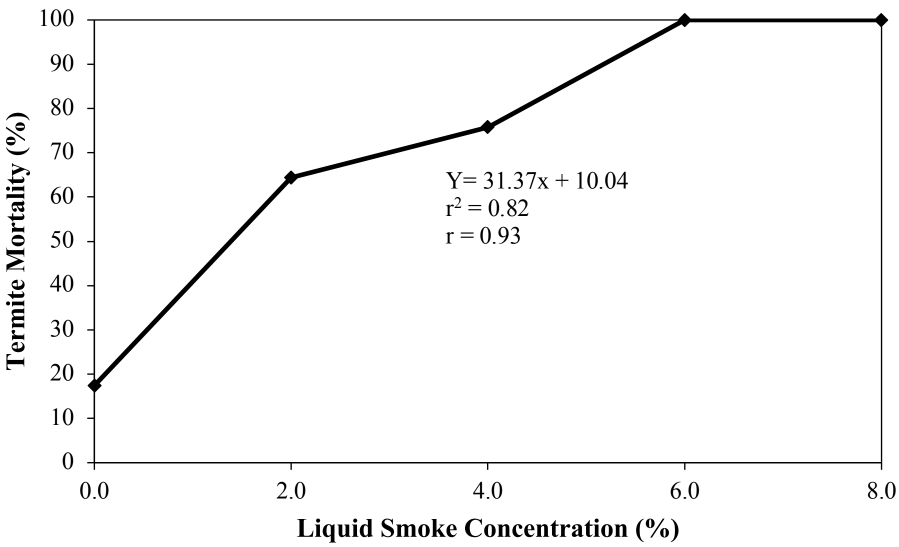

Fig. 2. Correlation between the concentration of bintangur wood liquid smoke at pyrolysis temperature of 370°C and mortality of *Coptotermes curvignathus*.

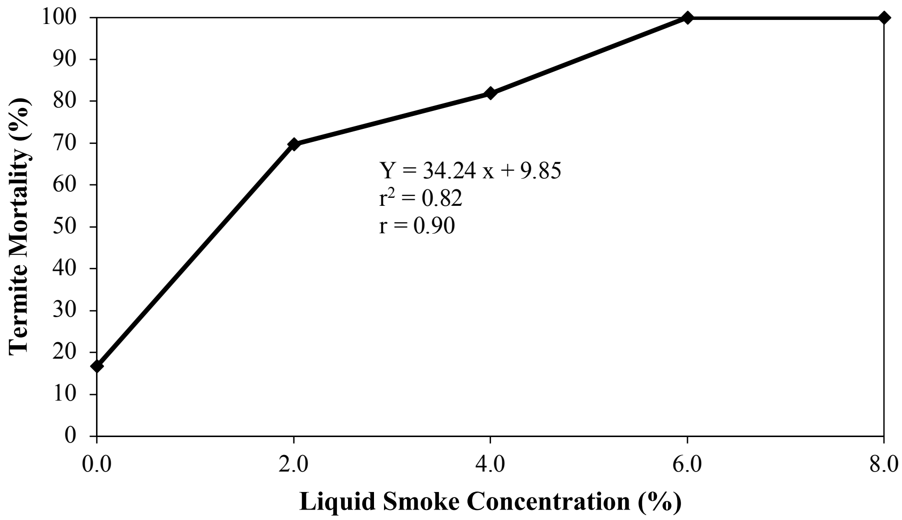

Fig. 3. Correlation between the concentration of bintangur wood liquid smoke at pyrolysis temperature of 400°C and mortality of *Coptotermes curvignathus*.

The correlation value between the concentration of bintangur wood liquid smoke and termite mortality at pyrolysis temperatures of 370°C, 400°C, and 430°C were 0.93, 0.90, and 0.84, respectively, indicating a positive and strong correlation ($p < 0.05$). The simple regression equation and the coefficient determination in the treatment of bintangur wood liquid smoke concentration on the mortality of *C. curvignathus* at pyrolysis temperatures of 370°C, 400°C, and 430°C are Y = 31.37x + 10.04 and 0.87, Y = 34.24x + 9.85 and 0.82, and Y = 40.15x + 9.36 and 0.70, respectively. This equation shows that the higher the concentration of liquid smoke from bintangur wood is followed by the high mortality of *C. curvignathus*. This result shows that the higher concentration of liquid smoke indicated the higher levels of the components in the liquid smoke, which have anti-termite properties. The results of this study are in line with the results of research by Adfa et al. (2020), stating that increasing the concentration of liquid smoke from cinnamon (*Cinnamomum parthenoxylon*) significantly led to an increase in the mortality of *C. curvignathus*.

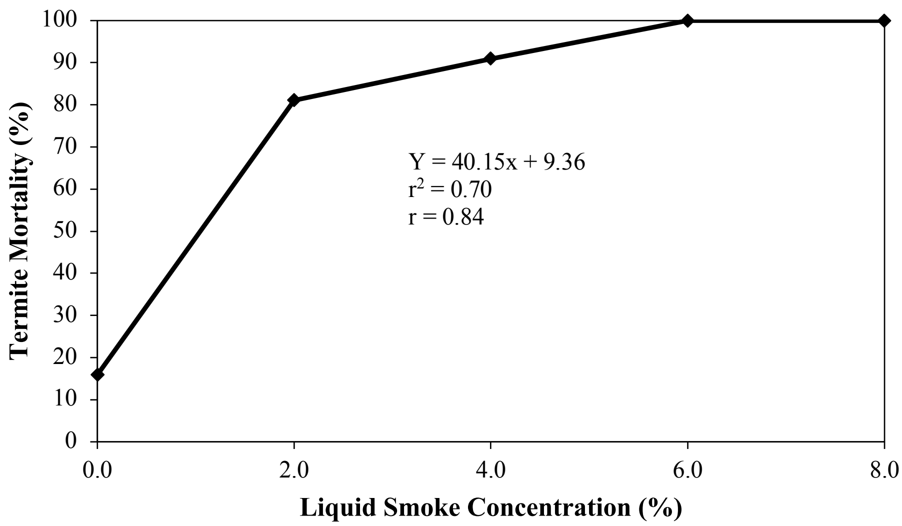

Fig. 4. Correlation between the concentration of bintangur wood liquid smoke at pyrolysis temperature of 430°C and *Coptotermes curvignathus* mortality.

Shiny and Remadewi (2014) examined the ability of liquid smoke from coconut shells against the subterranean termites *Odontotermes horni* (Wasmann), *O. obesus* (Rambur), *O. redamanni* (Wasmann), and *Microtermes obesi* (Holmgren). The results showed that the higher the concentration of coconut shell liquid smoke caused an increase in termite mortality. This is because the active ingredients in liquid smoke, mainly phenols and phenol derivatives, are more at higher concentrations. Oramahi et al. (2018) stated that the mortality of *Coptotermes formosanus* subterranean termites significantly increased with an increase in the concentration of liquid smoke from oil palm stems. The two previous studies are in line with the results obtained, such as the highest termite mortality value was obtained at a concentration of 6% and 8% in the three pyrolysis temperatures.

3.3. Filter Paper Weight Loss

The effect of the liquid smoke of bintangur wood on the weight loss of filter paper by *C. curvignathus* at various pyrolysis temperatures and concentrations of bintangur wood liquid smoke is shown in **Fig. 5-7**. The simple regression equation and the coefficient determination on the treatment of bintangur wood liquid smoke concentration on the weight loss of filter paper at pyrolysis temperatures of 370°C, 400°C, and 430°C are Y = 34.71x - 4.04 and 0.84, Y = 33.34x - 3.99 and 0.80, and Y = 31.15x - 3.90 and 0.70, respectively. This equation shows that the higher the concentration of liquid smoke from bintangur wood indicated the lower weight loss of filter paper due to *C. curvignathus*. This is related to the eating activity of termites in consuming filter paper as food. The correlation between the pyrolysis temperature during liquid smoke production and the decrease in filter paper weight due to termites was influenced by termite mortality. This is because the surviving termites still consume filter paper, resulting in a high reduction in weight. **Fig. 5-7** explains that the treatment of bintangur wood liquid smoke concentration (2–8%) against *C. curvignathus* resulted in a decrease in filter paper weight by 5.06–20.97%. The results of this study support the results of the research of Oramahi and Yoshimura (2013), stating that the application of liquid smoke from laban wood (*Vitex pubescens* Vahl) at a liquid smoke concentration of 1–5% against *Reticulitermes speratus* termites causes a decrease in filter paper weight by 6.70–23.70%.

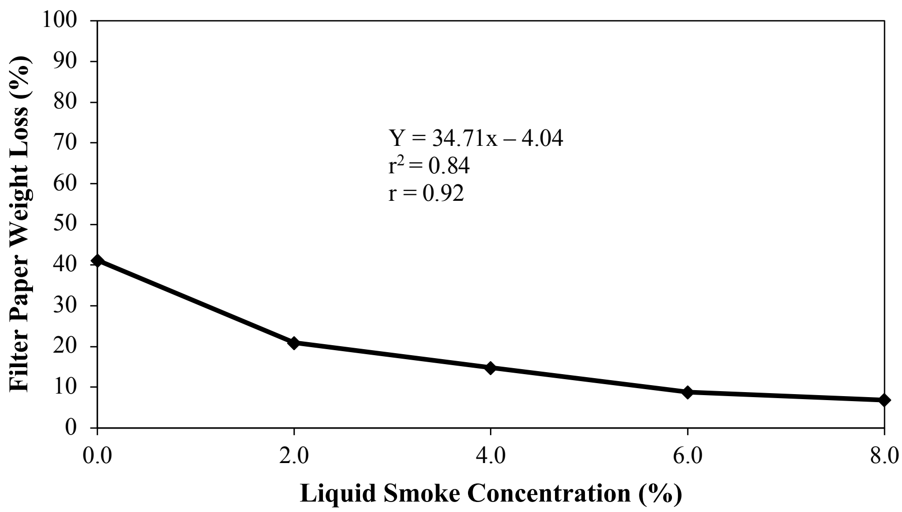

Fig. 5. Correlation between the concentration of bintangur wood liquid smoke at pyrolysis temperature of 370°C and the weight loss of filter paper.

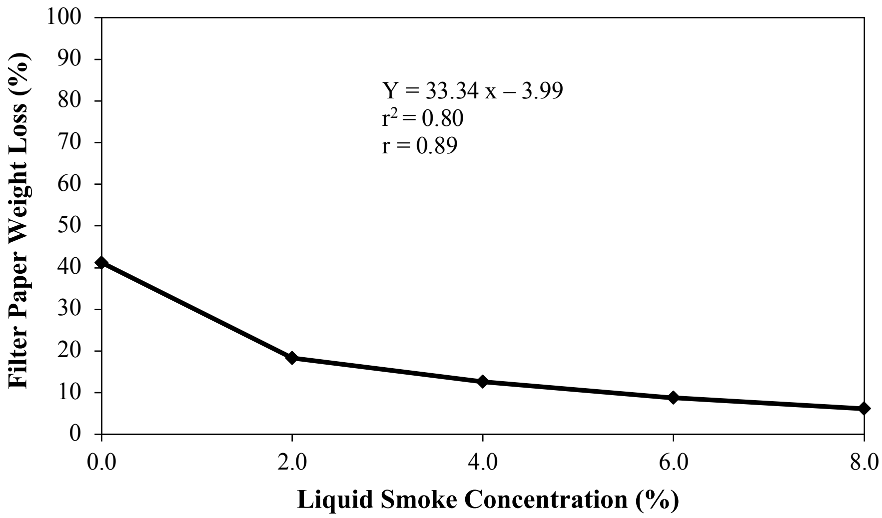

Fig. 6. Correlation between the concentration of bintangur wood liquid smoke at pyrolysis temperature of 400°C and the weight loss of filter paper.

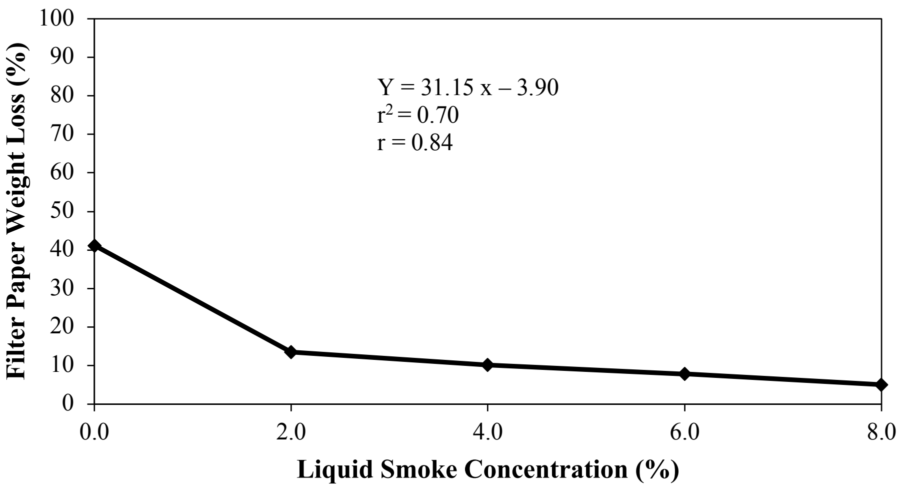

Fig. 7. Correlation between the concentration of bintangur wood liquid smoke at pyrolysis temperature of 430°C and the weight loss of filter paper.

4. Conclusions

Bintangur wood liquid smoke (*Calophyllum inophylum* Linnaeus) has the ability to act as an anti-termites agent against *Coptotermes curvignathus* Holmgren subterranean termites. Bintangur wood liquid smoke concentrations of 6% and 8% at three pyrolysis temperatures (370°C, 400°C, and 430°C) resulted in a subterranean termite mortality value of 100%. The lower the percentage of weight loss value of filter paper indicated the higher concentration of liquid smoke. The chemical components in bintangur wood liquid smoke contained phenol (1.23-1.65%) and acids (4.33-6.68%). The optimal concentration of bintangur wood liquid smoke in inhibiting termite attack is 6% at pyrolysis temperatures of 370°C, 400°C, and 430°C.

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