Vol. 9(2): 269-279, May 2021 DOI: https://doi.org/10.23960/jsl29269-279

P-ISSN: 2339-0913
E-ISSN: 2549-5747

Jurnal Sylva Lestari

Journal homepage: https://jurnal.fp.unila.ac.id/index.php/JHT

Full Length Research Article

Efficacy of Liquid Smoke Produced from Medang Wood (*Cinnamomum* sp.) against *Schizophyllum commune*

Rizka Diah Permana[1], Hasan Ashari Oramahi[2,*], Farah Diba[2]

[1] Master Program of Forest Science, Faculty of Forestry, Tanjungpura University. Jalan Daya Nasional, Pontianak, 78124, Kalimantan Barat, Indonesia
[2] Study Program of Forestry, Faculty of Forestry, Tanjungpura University. Jalan Daya Nasional, Pontianak, 78124, Kalimantan Barat, Indonesia
[*] Corresponding author. E-mail address: oramahi@fahutan.untan.ac.id

ARTICLE HISTORY:
Received: 4 February 2021
Peer review completed: 16 February 2021
Received in revised form: 3 March 2021
Accepted: 12 March 2021

KEYWORDS:
Efficacy
Inhibition of fungal growth
Liquid smoke
Medang wood
Schizophyllum commune

ABSTRACT

The efficacy of liquid smoke obtained from medang wood (*Cinnamomum* sp.) against *Schizophyllum commune* fungus was evaluated. This study aims to evaluate the antifungal properties of liquid smoke from medang against *S. commune* fungus. Potato Dextrose Agar (PDA) medium was used to determine the efficacy of the liquid smoke of medang wood on *S. commune* fungus growth. Three kinds of liquid smoke were obtained from the pyrolysis of medang wood at 370, 400, and 430°C. The efficacy of liquid smoke from medang wood for antifungal is a factorial 3 by 4 in a completely randomized design; the first factor was pyrolysis temperature of liquid smoke from medang (370, 400, and 430°C), and the second factor was the treatment of concentration of liquid smoke from medang wood (0, 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0%, v/v). The results showed that pyrolysis temperature affected liquid smoke from medang, and the concentration of liquid smoke was significantly different for inhibition of fungal growth. The results indicated that the pyrolysis temperature of liquid smoke production and the concentration of liquid smoke had a significant effect on *S. commune* fungus growth inhibition. Medang wood liquid smoke effectively inhibited the growth of *S. commune* fungus about 98.57% at a concentration of 2.5% with liquid smoke pyrolysis temperature used is 430°C.

1. Introduction

The community has currently begun to use the low durable class wood because of the limited types of wood with high-quality and durable class. Low durable wood is very susceptible to attack by destructive organisms such as subterranean termites and wood rot fungi. Residential buildings with wood structural components are generally very vulnerable to attack by wood-destroying organisms. Structural components in a building that uses wood include poles, roof truss, walls, and floors. The wood was used as a structural material at this time comes from wood with durability class III-V and strength class III-IV. Tropical climatic conditions have strongly supported the development of wood-destroying organisms. Wood damage can be caused by a group of microorganisms such as fungi. Wood rot fungi are fungi that can break down cellulose and lignin

so that wood becomes rotten and the strength of its elastic fibers descending rapidly (Herliyana et al. 2011). One of the wood-rot fungi is *Schizophyllum commune* that can cause wood damage.

One of the wood-destroying organisms is termites. In Indonesia, the termite that causes the most economic loss is the *Coptotermes* genus (Arinana 2007). One of the termite species causing the most damage is *Coptotermes curvignathus* Holmgren. Wood damage caused by destructive organisms such as fungi and termites can be prevented and controlled with a precautionary measure, namely preservation by providing preservatives, especially wood materials. Preservatives can be used as synthetic pesticides but have the potential to cause environmental and health problems for humans. Hence, a safer way to control wood-destroying organisms is by using natural pesticides such as liquid smoke.

Liquid smoke is a biopesticide used in the control of wood-destroying organisms. The use of liquid smoke for agricultural pest control has long been practiced in Thailand. Lee et al. (2011) stated that liquid smoke is a product of burning wood through pyrolysis at high temperatures without air). Raw materials such as wood or biomass to manufacture liquid smoke contain the main components as cellulose, hemicellulose, and lignin (Kan et al. 2016). Some researchers have reported that liquid smoke can be used as an anti-termite (Adfa et al. 2017; Indrayani et al. 2012; Oramahi et al. 2014), antifungal (Adfa et al. 2020; Oramahi and Yoshimura 2013; Subekti and Yoshimura 2020), and insect repellents (Prabowo et al. 2016; Sapindal et al. 2018).

The ability of liquid smoke to inhibit fungal growth is influenced by various factors, including the chemical components of liquid smoke (Kan et al. 2016). The chemical components of liquid smoke are influenced by wood chemical components and pyrolysis temperature (Wu et al. 2015). The pyrolysis temperature in liquid smoke production is an essential factor that causes changes in the chemical components of liquid smoke, especially phenol components and their derivatives and organic acids (Lee et al. 2011).

Medang wood, included in strength wood class II and durable wood class III, is used as a building material. Oramahi et al. (2020) stated that medang wood was processed into liquid smoke with the response surface method resulted in a liquid smoke yield of 22.90%. Medang wood liquid smoke has the potential as a biopesticide. This study evaluates the ability of liquid smoke from medang wood as an antifungal against *S. commune* fungus. The species is an important fungus causing the decline in wood quality, especially in tropical areas such as Indonesia.

2. Materials and Methods

2.1. Liquid Smoke Production

Liquid smoke was obtained from previous studies (Oramahi et al. 2020). The making process of liquid smoke is as follows: (1) medang wood powder measuring 3.36 mm (6 mesh) was inserted into the reactor, then the reactor and condenser circuit were adjusted, (2) the reactor then turned on, (3) the pyrolysis was carried out for 120 minutes at temperatures of 370, 400, and 430°C, (4) the smokes that appears through the reactor then flowed into the cooling column through the distribution pipe, and into this cooling column the water was channeled using a pump, and (5) the condensed vapor of liquid smoke was collected in Erlenmeyer; otherwise, the uncondensed smoke was streamed through the exhausted pipe as residual smoke. The production of liquid smoke was carried out at the Engineering Laboratory of the Faculty of Agricultural Technology, Gadjah Mada University.

2.2. Analysis of Total Phenol and Acid of Liquid Smoke

The total phenol analysis procedure is as follows (1) about 1 ml of liquid smoke from medang wood was weighed and diluted to a volume of 1,000 ml, (2) 1 ml of the solution was taken and then added as much as 5 ml of alkaline $NaCO_3$ solution, (3) the solution was left at 27°C for 10 minutes, (4) then added as much as 0.5 ml of Folin-Ciocalteu reagent (commercial reagent: 1: 1 v/v distilled water) and shaken using a vortex-shaker, (5) then the absorbance was left for 30 minutes in the 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 (Senter et al. 1989).

The acid analysis procedure was as follows: (1) liquid smoke from medang wood was weighed about 1 ml, (2) then it was diluted to reach a volume of 100 ml, (3) the solution was titrated with 0.1 N NaOH standard solution until reached pH 8 and the acid content was expressed in percent by weight of acetic acid (AOAC 1990).

2.3. Collection of Isolates and the Efficacy of Liquid Smoke from Medang Wood against Schizophyllum commune Fungus

S. commune (isolate) fungus was obtained from the Wood Technology Laboratory, Faculty of Forestry, Tanjungpura University, Pontianak. *S. commune* fungus was propagated using Potato Dextrose Agar (PDA) medium. Testing on fungi refers to the method of Suresh et al. (2019) and modified from Oramahi et al. (2018). Fungi growth media was used PDA in a petri dish with concentrations of liquid smoke from medang wood waste 0, 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0%, respectively.

The PDA medium was sterilized using autoclaved for 15 minutes at a temperature of 121°C and a pressure of 103.4 kPa (15 psi). Fungi isolate with 5 mm size was grown on the middle of a petri dish containing PDA media at the concentration and temperature of pyrolysis to make liquid smoke according to the treatment and control such as the petri dish contained PDA media.

Petri dishes (treatment and control) with fungi inoculated were incubated at room temperature (24–26°C). Treatment and control were repeated three times. The observation and calculation of the fungal diameter colony were carried out after a colony growing. The observation was at the end when the colony had covered all the Petri dishes for seven days of incubation. Measurement of antifungal activity using the formula Mori et al. (1997) as follows:

$$AFA = \frac{GC\text{-}GT}{GC\text{-}A} \; x \; 100\% \qquad (1)$$

where *AFA* is anti-fungal activity (%), *GC* is mycelium growth control (mm), *GT* is growth of mycelium in liquid smoke medium (mm), and *A* is initial incubation mycelium size (mm).

2.4. Experiment Design and Data Analysis

A completely randomized design with factorial type design was used to evaluate the effect of pyrolysis temperature and the concentration of liquid smoke from medang wood on *S. commune* fungus growth inhibition. The first factor is the pyrolysis temperature of the making of medang wood liquid smoke (370, 400, and 430°C). The second factor is the concentration of liquid smoke from medang wood (0, 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0%). Data of *S. commune* fungus was analyzed for variance (ANOVA) and presented in the form of the percentage of inhibition power of medang

wood liquid smoke against fungi. The effect between treatments was carried out by the Tukey's Honest Significant Difference (HSD) test at the 5% significant level. The SAS software was used for data analysis.

3. Results and Discussion

3.1. Components of Liquid Smoke from Medang Wood (Cinnamomum sp.*)*

The constituent components of liquid smoke from medang wood at various pyrolysis temperatures are presented in **Table 1**. The comparison of liquid smoke constituent components at pyrolysis temperatures of 370, 400, and 430°C showed differences in acid content between the three temperatures. The higher temperature indicates the higher the acid content. In comparison, the phenol content between the three pyrolysis temperatures has almost a similar content. **Table 1** shows that the highest acid content at the pyrolysis temperature of 430°C is 6.44%. According to a previous study, Subekti and Yoshimura (2020), the highest acid content in wulung bamboo (*Gigantochloa atroviolacea*) liquid smoke at 300°C pyrolysis temperature was 4.47%, and the highest phenol content at 450°C was 8.03%.

Table 1. The constituent components of medang wood *(Cinnamomum* sp.*)* liquid smoke at various pyrolysis temperatures

Pyrolysis temperatures (°C)	Constituent components of medang wood liquid smoke	
	Phenol (%)	Acid (%)
370	1.04	4.60
400	1.09	6.02
430	1.06	6.44

Wu et al. (2015) stated that liquid smoke from Chinese fir powder had the highest acid content at 250°C pyrolysis temperature, while the highest phenol content was obtained at 350-450°C. The results showed a decrease in acid levels and an increase in phenol with the increase of pyrolysis temperature. Hagner et al. (2020) reported that the phenol content and total acid in liquid smoke from birch wood (*Betula* sp.) were 2.4 and 11.2%, respectively. The difference in the constituent components of liquid smoke can occur due to differences in wood species and pyrolysis temperatures. The results are in line with the previous study from Abnisa et al. (2013), stating that pyrolysis temperature has an effect on compounds that can be extracted at the time of making liquid smoke. Oramahi et al. (2020) examined the production of liquid smoke from *Shorea leavis* and concluded that different pyrolysis temperatures produce different liquid smoke constituents.

3.2. The Inhibition of Liquid Smoke from Medang Wood (Cinnamomum sp.*) against Schizophyllum commune Fungus*

Liquid smoke inhibition of *Cinnamomum* sp. against *S. commune* at various temperatures of liquid smoke pyrolysis is presented in **Table 2**. The HSD test results show that the concentration of 3.0% at the three temperatures (370, 400, and 430°C) has the highest inhibition value of fungal growth, about 100%. **Table 2** shows that the temperature of liquid smoke pyrolysis which effectively inhibited the growth of *S. commune* fungus was at a temperature of 430°C with a concentration of 2.5%, which could inhibit the fungus growth by 98.57%.

Table 2. The inhibition of liquid smoke from medang wood *(Cinnamomum* sp.) against *Schizophyllum commune* fungus

Treatment		Inhibition of *S. commune* fungus growth (%)
Pyrolysis temperature (°C)	**Liquid smoke concentration (%)**	
Control	0	0 ± 0 a
370	0.5	0 ± 0 a
	1.0	24.57 ± 0.61 c
	1.5	40.34 ± 0.03 e
	2.0	72.95 ± 0.08 g
	2.5	92.51±0.03 i
	3.0	100 ± 0 l
400	0.5	0 ± 0 a
	1.0	25.11± 0.15 c
	1.5	38.67± 0.39 d
	2.0	81.53 ± 0.22 h
	2.5	93.39±0.11 j
	3.0	100 ± 0 l
430	0.5	18.18± 0.03 b
	1.0	38.31± 0.005 d
	1.5	69.06± 0.13 f
	2.0	81.01 ± 0.16 h
	2.5	98.57± 0.43 k
	3.0	100 ± 0 l

Notes: The mean followed by the same letter is not significantly different at 5% significant level based on the HSD test.

Fig. 1-3 show the inhibition of fungal growth on media given liquid smoke with different pyrolysis temperatures and concentrations. Pyrolysis temperatures of 370 and 400°C with liquid smoke concentrations of 0, 0.5, 1.0, and 3.0% and pyrolysis temperatures of 430°C with a concentration of 3.0% had no significance different fungus sizes. Pyrolysis temperatures at 370 and 400°C at concentrations of 1.5%, 2.0%, and 2.5% showed different sizes. The pyrolysis temperature at 430°C is significantly different in size than the pyrolysis temperature of 370 and 400°C at concentrations of 0.5, 1.0, 1.5, 2.0, and 2.5%. The difference in the size of the fungus growth indicated smaller with the greater the concentration of liquid smoke given to the fungi growth medium. The control treatment had the full size of the fungus around the Petri dish plate, then the greater the concentration of liquid smoke from the medang wood indicated the smaller the size of the fungus.

The effective inhibition of the *S. commune* fungus growth is at a pyrolysis temperature of 430°C with a concentration of 2.5%. This is based on the regression analysis results of the inhibition value of fungal growth obtained at each pyrolysis temperature and different concentrations of liquid smoke. Liquid smoke produced from pyrolysis temperature of 430°C had the highest average value of *S. commune* fungus growth inhibition compared to the pyrolysis temperatures of 370 and 400°C. The higher concentration of liquid smoke indicated a higher antifungal index. According to previous studies, liquid smoke can function as an antifungal (Lee et al. 2011; Oramahi and Yoshimura 2013; Yatagai et al. 2002). Zabka and Pavela (2013) stated that liquid smoke from wheat straw contained 2-ethyl phenol and 4-ethyl phenol and effectively controlled fungi of the *Fusarium*, *Penicillium*, and *Aspergillus* genus. In addition, Dambolena et al. (2012) stated that m-cresol and o-cresol act as antifungals against *Fusarium verticilliodes.*

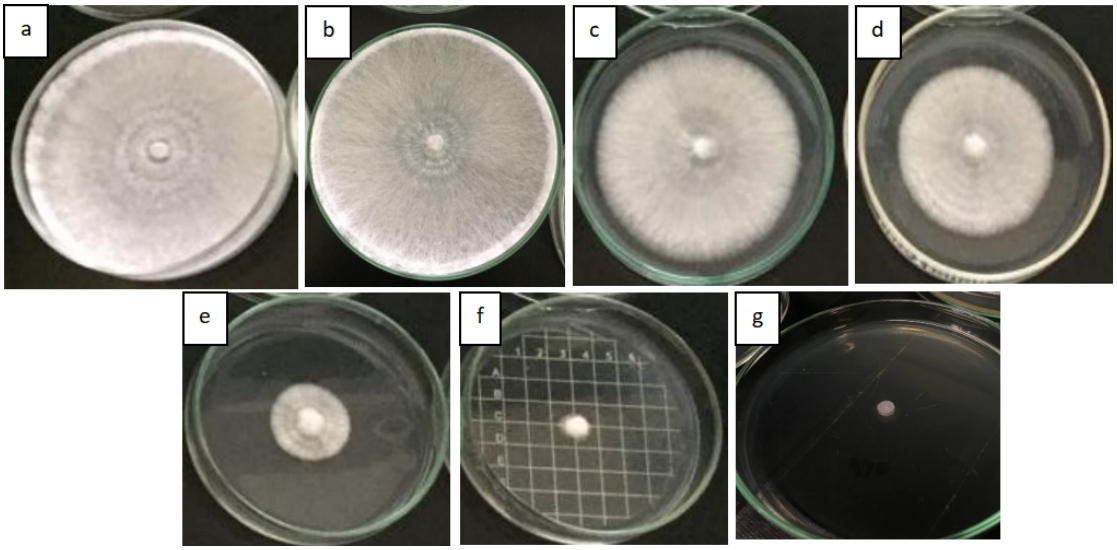

Fig. 1. The growth of *Schizophyllum commune* fungus colonies with a pyrolysis temperature of 370ºC at 0% control (a), liquid smoke concentration of 0.5% (b), 1.0% (c), 1.5% (d), 2.0% (e) , 2.5% (f), and (g) 3.0%.

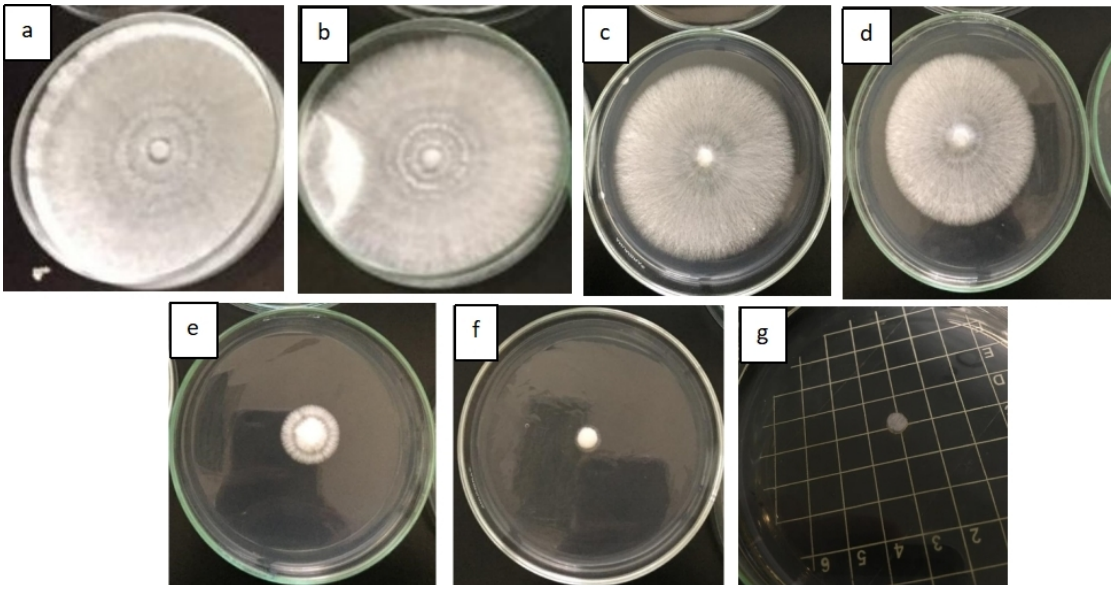

Fig. 2. The growth of *Schizophyllum commune* fungus colonies with a 400ºC pyrolysis temperature at 0% (a) control, liquid smoke concentration of 0.5% (b), 1.0% (c), 1.5% (d), 2.0% (e), 2.5% (f), and (g) 3.0%.

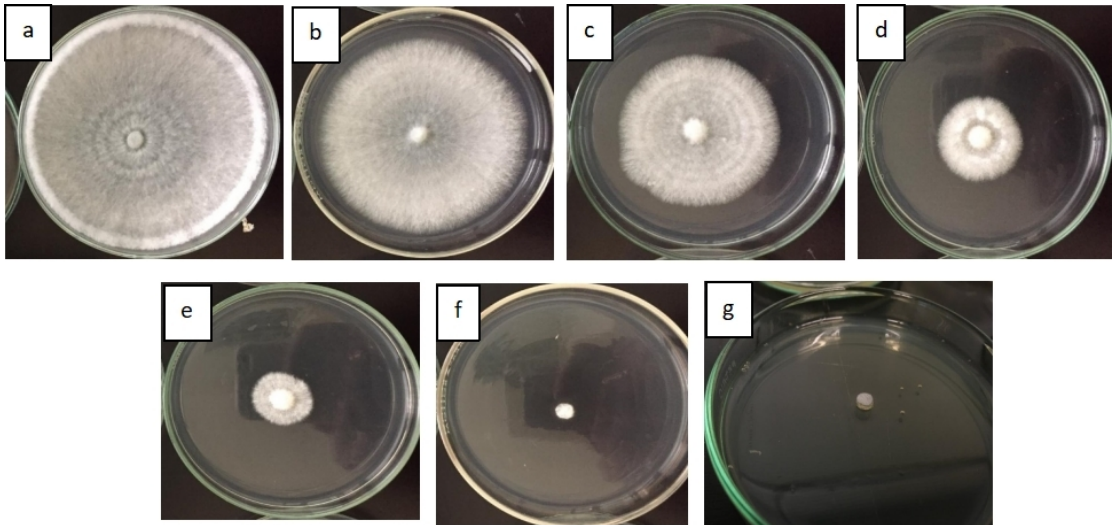

Fig. 3. The growth of *Schizophyllum commune* fungus colonies with a pyrolysis temperature of 430ºC at 0% control (a), liquid smoke concentration 0.5% (b), 1.0% (c), 1.5% (d), 2.0% (e), 2.5% (f), and (g) 3.0%.

According to Uysal et al. (2014), liquid smoke from peach stone can inhibit the fungus *Coriolus versicolor* growth. Baharom et al. (2020) stated that the liquid smoke from *Averrhoa carambola*, *Cocos nucifera*, and *Mangifera indica* could inhibit plant disease-causing pathogens such as *Fusarium oxysporum, Colletotrichum gloeosporioides, Pestalotiopsis microspora,* and *Ralstonia solanacearum* bacteria. Based on Adfa et al. (2020), the acids and phenols from *Cinnamomum parthenoxylon* liquid smoke were suspected of causing antifungal activity. *Cinnamomum parthenoxylon* liquid smoke has the potential to prevent the growth of *S. commune* and *Fomitopsis palustris*. The results of research on liquid smoke from *Gigantochloa atroviolacea* can also be used as an inhibitor of the growth of wood rot fungi (Subekti and Yoshimura 2020).

Based on Dediwanto et al. (2020), liquid smoke from bengkirai wood (*Shorea leavis* Ridl) at 350 and 450°C has the ability as an antifungal in inhibiting the growth of the *S. commune* fungus. Oramahi et al. (2018) stated that liquid smoke from bengkirai wood at a pyrolysis temperature of 450°C and a concentration of 1.5% liquid smoke could inhibit the growth of *Phytophthora citrophthora* by 100%. Oramahi et al. (2020) stated that the chemical content of liquid smoke from bengkirai wood at a pyrolysis temperature of 400°C produces acetic acid, 1- hydroxy-2-propanone, furfural, benzene sulfonic acid, mequinol, 4-methyl phenol, and 2-methoxy- 4-methyl phenol.

This occurs due to the components of liquid smoke, especially the levels of acid and phenol (**Table 1**), which can act as an antifungal. According to research by Oramahi et al. (2011), the acid and phenol content of liquid smoke from Acacia sawdust (*Acacia mangium* Willd) and Laban wood (*Vitex pubescens* Vahl) act as an antifungal. Acid content is a compound as an antimicrobial. This is confirmed by the research of Lou et al. (2011) proved that the mechanism of chlorogenic acid as an antimicrobial disrupts the intracellular membrane and releases cytoplasmic macromolecules, leading to cell death. Based on the results of this study, it can be concluded that chlorogenic acid kills pathogenic bacterial strains by triggering irreversible permeability of changes in cell membranes. This causes cells to lose their ability to maintain membranes and including nucleotide cytoplasmic macromolecules. Medang wood liquid smoke that effectively inhibited the growth of *S. commune* fungus was at a concentration of 2.5%, and the pyrolysis

temperature was at 430°C. Correlation between the concentration of liquid smoke and the pyrolysis temperature of 430°C with the inhibition of fungal growth is presented in **Fig. 4**.

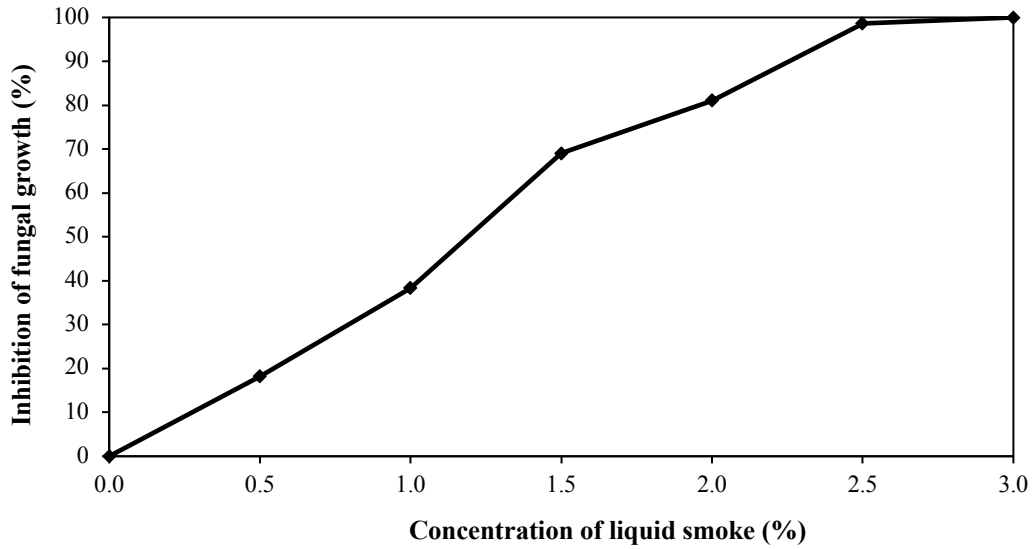

Fig. 4. The correlation between the concentration of liquid smoke at a pyrolysis temperature of 430°C to the growth inhibition of *S. commune* fungus.

The concentration enhancement of liquid smoke was increased the growth inhibitory of *S. commune* fungus growth. This is shown by the regression equation $Y = 3.98 + 35.96x$, which has a coefficient of determination (R^2) of about 0.96. This indicates that the higher liquid smoke concentration shows the higher inhibition of *S. commune* fungus growth.

Fig. 1-3 and **Table 1** showed that the higher the liquid smoke concentration of medang wood indicates the higher growth inhibition of the *S. commune* fungus. The pyrolysis temperature and the concentration of liquid smoke had a very significant effect on the growth of the *S. commune* fungus. Hou et al. (2018) stated that the components of liquid smoke from *Eucommia ulmoides* consist of phenols, ketones, aldehydes, alcohols, organic acids, and benzene. The liquid smoke obtained has potential as an antifungal agent against Penicillium, Aspergillus, and Rhizopus fungi.

4. Conclusions

Liquid smoke obtained from the pyrolysis of medang wood *(Cinnamomum* sp.) at temperatures of 370, 400, and 430°C has the ability as an antifungal agent to inhibit the growth of the *Schizophyllum commune* fungus. The pyrolysis temperature and concentration of liquid smoke concentration had a significant effect on inhibiting the growth of the *S. commune* fungus. The ability of liquid smoke to inhibit *S. commune* fungal growth was effectively obtained at a liquid smoke concentration of 2.5% with a temperature of 430°C. The ability of liquid smoke to inhibit *S. commune* fungal growth shows the potential of liquid smoke as a biopesticide.

Acknowledgments

The authors are grateful for the funding from the Indonesian Ministry of Research and Technology (Ristek/BRIN) through Master Thesis Research Scheme, with a grant number of SP DIPA-042.06.1.401516/2020.

References

Abnisa, F., Arami-Niya, A., Wan Daud, W. M. A., Sahu, J. N., and Noor, I. M. 2013. Utilization of Oil Palm Tree Residues to Produce Bio-Oil and Bio-Char via Pyrolysis. *Energy Conversion and Management* 76: 1073-1082. DOI: 10.1016/j.enconman.2013.08.038

Adfa, M., Kusnanda, A. J., Saputra, W. D., Banon, C., Efdi, M., and Koketsu, M. 2017. Termiticidal Activity of *Toona sinensis* Liquid smoke against *Coptotermes curvignathus* Holmgren. *RASĀYAN Journal of Chemistry* 10: 1088-1093. DOI: 10.7324/RJC.2017.1041866

Adfa, M., Romayasa, A., Kusnanda, A. J., Avidlyandi, Yudha, S. S., Banon, C., and 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. DOI: 10.5658/WOOD.2020.48.1.107

AOAC. 1990. *Association of Analytical Chemist (AOAC), Official Method of Analysis*. 18th edition. Benyamin Franklin. Washington DC.

Arinana. 2007. Teknologi Umpan Berbahan Aktif Kitosan untuk Pengelolaan Rayap Tanah *Coptotermes curvignathus* Holmgren (Isoptera: Rhinotermitidae). *Jurnal Ilmu Pertanian Indonesia* 12(1): 1-16.

Baharom, N. A., Rahman, M. H. A., Shahrun, M. S., Suherman, F. H. S., and Masdar, S. N. H. 2020. Chemical Composition and Antimicrobial Activities of Liquid Smoke from Carambola, Coconut Shells and Mango against Selected Plant Pathogenic Microorganisms. *Malaysian Journal of Microbiology* 16(6): 438-445.

Dambolena, J. S., López, A. G., Meriles, J. M., Rubinstein, H. R., and Zygadlo, J. A. 2012. Inhibitory Effect of 10 Natural Phenolic Compounds on *Fusarium verticillioides*. A Structure-Property–Activity Relationship Study. *Food Control* 28(1): 163-170. DOI: 10.1016/j.foodcont.2012.05.008

Dediwanto, Y., Oramahi, H. A., and Nurhaida, N. 2020. Potensi Asap Cair dari Kayu Bengkirai dalam Menghambat Pertumbuhan Jamur *Schizophyllum commune* secara In Vitro. *Jurnal Galung Tropika* 9(1): 1-9. DOI: 10.31850/jgt.v9i1.518

Hagner, M., Lindqvist, B., Vepsäläinen, J., Samorì, C., Keskinen, R., Rasa, K., and Hyvönen, T. 2020. Potential of Pyrolysis Liquids to Control the Environmental Weed *Heracleum mantegazzianum*. *Environmental Technology and Innovation* 20: 101154. DOI: 10.1016/j.eti.2020.101154

Herliyana, E. N., Maryam, L. F. and Hadi, Y. S., 2011. *Schizophyllum commune* Fr. Sebagai Jamur Uji Ketahanan Kayu Standar Nasional Indonesia pada Empat Jenis Kayu Rakyat: Sengon (*P. falcataria*), Karet (*H. brasiliensis*), Tusam (*P. merkusii*), Mangium (*A. mangium*). *Jurnal Silvikultur Tropika* 2(3): 176-180.

Hou, X., Qiu, L., Luo, S., Kang, K., Zhu, M., and Yao, Y. 2018. Chemical Constituents and Antimicrobial Activity of Wood Vinegars at Different Pyrolysis Temperature Ranges Obtained from *Eucommia ulmoides* Olivers Branches. *RSC Advances* 8: 40941-40949. DOI: 10.1039/C8RA07491G

Indrayani, Y., Oramahi, H. A., and Nurhaida. 2012. Evaluation of Liquid Smoke as Bio-Pesticide to Control Subterranean Termites *Coptotermes* sp.. *Jurnal Tengkawang* 1: 87-96. DOI: 10.26418/jt.v1i2.126

Kan, T., Strezov, V., and Evans, T. J. 2016. Lignocellulosic Biomass Pyrolysis: A Review of Product Properties and Effects of Pyrolysis Parameters. *Renewable and Sustainable Energy Reviews* 57: 1126-1140. DOI: 10.1016/j.rser.2015.12.185

Lee, S. H., H'ng, P. S., Cow, M. J., Sajap, A. S., Tey, B. T., Salmiah, U., and Sun, Y. L. 2011. Effectiveness of Pyroligeneous Acid from Vapour Released in Charcoal Industry against Biological Attacks under Laboratory Condition. *Journal of Applied Sciences* 11: 3848-3853. DOI: 10.3923/jas.2011.3848.3853

Lou, Z., Wang, H., Zhu, S., Ma, C., and Wang, Z. 2011. Antibacterial Activity and Mechanism of Action of Chlorogenic Acid. *Journal of Food Science* 76(6): M398-M403. DOI: 10.1111/j.1750-3841.2011.02213.x

Mori, M., Aoyama., M., Doi, S., Kanetoshi, A., and Hayashi, T. 1997. Antifungal Activity of Bark Extracts of Deciduous Trees. *Holz als Roh- und Werkstoff* 55: 130-132. DOI: 10.1007/BF02990531

Oramahi, H. A., Diba, F., and Wahdina, W. 2011. Aktivitas Antijamur Asap Cair dari Sebuk Gergaji Kayu Akasia *(Acacia mangium* Willd*)* dan Kayu Laban *(Vitex pubescens* Vahl*)*. *Bionatura* 13(1): 79-84.

Oramahi, H.A. and Yoshimura, T. 2013. Antifungal and Antitermitic Activities of Liquid smoke from *Vitex pubescens* Vahl. *Journal of Wood Science* 59: 344-350. DOI: 10.1007/s10086-013-1340-8

Oramahi, H. A. and Diba, F. 2014. New Bio Preservatives from Lignocelluloses Biomass Bio-oil for Anti Termites *Coptotermes curvignathus* Holmgren. *Procedia Environmental Sciences* 20: 778-784. DOI: 10.1016/j.proenv.2014.03.094

Oramahi, H. A., Wardoyo, E. R. P., and Kustiati. 2018. Efficacy of Liquid Smoke Produced from Bengkirai Wood against on *Phytophthora citrophthora*. *Jurnal Perlindungan Tanaman Indonesia* 22(2): 160-166. DOI: 10.22146/jpti.33113

Oramahi, H. A, Yoshimura, T., Rusmiyanto, E., and Kustiati. 2020. Antifungal and Antitermitic Activities of Vinegars from Two Biomass Resources at Different Pyrolytic Temperatures. *Journal of Applied Biological Sciences* 14(1): 26-38.

Prabowo, H., Martono, E., and Witjaksono. 2016. Activity of Liquid Smoke of Tobacco Stem Waste as An Insecticide on *Spodoptera litura* Fabricius Larvae. *Jurnal Perlindungan Tanaman Indonesia* 20: 22-27. DOI: 10.22146/jpti.16620

Sapindal, E., Ong, K. H., and King, P. J. H. 2018. Efficacy of *Azadirachta excelsa* Vinegar against *Plutella xylostella*. *International Journal of Pest Management* 64(1): 39-44. DOI: 10.1080/09670874.2017.1293866

Senter, S. D., Robertson, J. A., and Meredith, F. I. 1989. Phenolic Compound of the Mesocarp of Creathaven Peaches during Storage and Ripening. *Journal of Food Science* 54(5): 1259-1268. DOI: 10.1111/j.1365-2621.1989.tb05968.x

Subekti, N., and Yoshimura, T. 2020. Activity of Bamboo Wulung's Smoke *Gigantochloa atroviolacea* against Subterranean Termites and Fungi Attack. *AGRIVITA Journal of Agricultural Science* 42(3): 543-549. DOI: 10.17503/agrivita.v42i3.2761

Suresh, G., Pakdel, H., Rouissi, T., Brar, S. K., Fliss, I., and Roy, C. 2019. In Vitro Evaluation of Antimicrobial Efficacy of Pyroligneous Acid from Softwood Mixture. *Biotechnology Research and Innovation* 3(1): 47-53. DOI: 10.1016/j.biori.2019.02.004

Uysal, T., Duman, G., Onal, Y., Yasa, I., and Yanik, J. 2014. Production of Activated Carbon and Fungicidal Oil from Peach Stone by Two-Stage Process. *Journal of Analytical and Applied Pyrolysis* 108: 47-55. DOI: 10.1016/j.jaap.2014.05.017

Wu, Q., Zhang, S., Hou, B., Zheng, H., Deng, W., Liu, D., and Tang, W. 2015. Study on the Preparation of Liquid smoke from Biomass Residues by Carbonization Process. *Bioresource Technology* 179: 98-103. DOI: 10.1016/j.biortech.2014.12.026

Yatagai, M., Nishimoto, M., Hori, K., Ohira, T. and Shibata, A., 2002. Termiticidal Activity of Liquid Smoke, Its Components and Their Homologues. *Journal of Wood Science* 48(4): 338-342. DOI: 10.1007/BF00831357

Zabka, M., dan Pavela, R. 2013. Antifungal Efficacy of Some Natural Phenolic Compounds against Significant Pathogenic and Toxinogenic Filamentous Fungi. *Chemosphere* 93(6): 1051-1056. DOI: 10.1016/j.chemosphere.2013.05.076