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Effectiveness of Siwalan Fruit Rink and Corn Cob Waste Liquid Smoke in Preserving Sengon Wood Based on Density and Water Content

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Abstract

Background: Sengon is a fast-growing plant harvested 5-7 years after planting and is easily attacked by termites, so it needs to be preserved. Siwalan fruit husks and corn cobs are usually thrown away without being processed into useful products, even though these materials contain lignin, cellulose, and phenolics, which have the potential to act as anti-termite substances. To determine the potential of liquid smoke from siwalan husk and corn cob waste as a preservative for sengon wood (*Paraserianthes falcataria*). **Methods:** This research was conducted at the Biology Laboratory, Campus 3, PGRI University, Semarang, in September 2023. The research method was RAL (Completely Randomized Design) 9 treatments with three repetitions, namely: P0 (control), 5% liquid smoke from palm fruit husk waste (P1), 10% (P2), 15% (P3), and 20% (P4). Next, corn cob liquid smoke was 5% (P5), 10% (P6), 15% (P7), and 20% (P8). **Results:** The best increase in wood density was treatment P8, P1, P2, P5, P0, P3, P4, P6, and P7. The best increase in water content of sengon wood is in formulas P8, P4, P2, P6, P7, P1, P0, P5, and P3. The concentration of corncob liquid smoke contains the highest total Cr and dissolved Fe compounds compared to distilled water and liquid smoke from siwalan fruit peel waste, so it can potentially preserve sengon wood. **Conclusions:** liquid smoke from siwalan fruit peel and corn cob waste can be used as a preservative for sengon wood.

Keywords: corn cob waste; density; liquid smoke; sengon; siwalan fruit peel waste

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Introduction

Wood, as a forest product, plays a vital role in human life, and it is used for light and heavy construction, such as building materials, building houses, bridges, household equipment, and so on. Around 80-85% of the wood in Indonesia has low durability and is easily attacked by wood-destroying organisms such as termites, fungi, and other microorganisms. Sengon (*Paraserianthes falcataria* L.) is a fast-growing species that can be harvested 5-7 years after planting and is easy to manage so that it can increase wood demand in Indonesia (Aulia et al., 2020). Transgenic sengon seeds have 1.5x faster growth than regular sengon (Sudarmonowati, 2010; Astana et al., 2016).

Sengon can improve environmental quality, soil fertility, and water management (Nugroho & Salamah, 2015). Sengon wood contains lignin in sengon wood between 16.69392 - 23.77776%, holo cellulose 69.16934- 88.33281%, and α-cellulose 57.11835 - 74.21378% (Putra et al., 2018). Therefore, sengon can be used as a superior commodity to increase national income, so it needs to be balanced with the availability of raw materials and good quality wood (Purwanto, 2018). However, the specific gravity in sengon timber is 0.33 (0.24-0.49). It is strong class IV-V (low strength) and durable class IV, so it is susceptible to attack by fungi, insects, termites, and other microorganisms (Praptoyo & Puspitasari, 2013). Therefore, efforts to preserve sengon wood need to be made to increase its useful life and save on the use of sengon because the availability of timber in Indonesia is low. Also, sengon is not easily attacked by termites, fungi, and other microorganisms.

Generally, people use synthetic chemical compounds such as termiticides to preserve wood. However, using this chemical compound can cause damage to wood, both acute and chronic poisoning and environmental pollution (Yuliani et al., 2017). Based on survey results in the chemical shop market, chemical termiticides are expensive because, generally, 100 ml costs 30,000 - 50,000. Therefore, it is necessary to search for alternative wood preservatives that are environmentally friendly and economical. Efforts can be made with secondary metabolite compounds from plants, such as liquid smoke (Meidianto et al., 2019). Liquid smoke is a condensation result of steam from direct or indirect combustion of organic materials containing lots of lignin, cellulose, hemicellulose, and other carbon compounds (Anggraini, 2017).

The waste of siwalan fruit skins and corn cobs is generally thrown away or burned by the community without being processed into more valuable products, which can cause environmental pollution. Siwalan fruit skin contains anthocyanins and phenolic compounds, antioxidants as antifeedants to protect plants from attacks by pests, insects, and other organisms (Artiningsih & Purwaningtyas, 2016). Meanwhile, according to Sutoro et al. (1998); Martins et al. (2017), the chemical components of corn cob are 6.04% ash, high fibre, 15.70% lignin, 36.81% cellulose, 27.01% hemicellulose. Hence, it can potentially be used as raw material for smoke—liquid and wood preservatives. Corncob liquid smoke with a pyrolysis temperature of 300°C without redistillation causes termite mortality of around 20-40% (Pramasatya & Sunarta, 2018).

Research on liquid smoke using siwalan fruit skin waste and corn cobs to preserve sengon wood has never been conducted. Sengon wood preservation can be viewed based on the density and moisture content of sengon timber (Kusyanto, 2015). Based on the existing background and potential, it is necessary to research "The Potential of Liquid Smoke from Siwalan Fruit Peel and Corn Cob Waste as Preservation of Sengon Wood (*Paraserianthes falcataria*)." This research aims to determine the potential of liquid smoke from siwalan fruit husk and corn cob waste as a preservative for sengon wood based on increased wood density and water content in sengon timber.

Methods

Liquid smoke production and wood preservation tests were carried out at the Biology Laboratory, Campus 3, PGRI University Semarang, located on Jalan Pawiyatan Luhur III No.1, Bendan Duwur, Gajahmungkur Semarang. In addition, liquid smoke content tests were conducted at the Central Java Province Health Laboratory and Medical Device Testing Center. The research was carried out in September 2023. The materials used for the study included siwalan fruit skin waste, corn cobs, water, LPG gas, and sengon wood. The tools used for research are liquid smoke production tools (Figure 1), gas stoves, scales, wood moisture meters, liquid smoke storage buckets, sengon wood soaking containers, and jerry cans.

The research design used was a Completely Randomized Design (CRD) with nine treatments and three repetitions. The treatment design is as follows: P0 (control), P1 (liquid smoke from siwalan fruit rind waste 5% (P1), 10% (P2), 15% (P3), and 20% (P4). Next is liquid smoke from corncob waste: 5% (P5), 10% (P6), 15% (P7), and 20% (P8). The formula concentration refers to research by Panggabean (2014).

The research stages and procedures began with preparing materials and research equipment, making liquid smoke, making a formula or concentration of a liquid smoke solution, and cutting 27 samples of sengon wood measuring 4 cm x 5 cm x 6 cm. Next, the density and water content in sengon timber were measured, and the wood was soaked in liquid smoke. Twenty-seven samples were washed in each concentration of liquid smoke for three days and weighed so that the wood did not float (Panggabean, 2014). The following research procedure is to dry the sengon wood for 1 hour, then wash and air dry again at room temperature for 6 hours. The final stage is measuring the water content and density of the wood after soaking. The interpretation of the research results is in Table 1.

Figure 1. Liquid Smoke Production Equipment

Table 1. Interpretation of Research Data Analysis

Parameter	Data analysis and interpretation
Density of sengon wood	There are three densities of wood (Kusyanto, 2015), namely: 1. Specific gravity of high-density wood = 600 kg/m^3 or more. 2. Specific gravity of medium density wood = 400 – 599 kg/m^3. 3. Specific gravity of low-density wood = below 400 kg/m^3.
The water content of sengon wood	The high absorption capacity of wood for liquid smoke is due to the wood pores having a large percentage of cavities so that it can absorb optimally with different liquid smoke absorption levels (Prawira et al., 2013).
Test liquid smoke content.	Liquid smoke content testing needs to be carried out to determine the compounds contained in liquid smoke so that it has the potential to be used as a preservative for sengon wood.

Result

After carrying out the research, research results were obtained regarding the potential of distilled water, liquid smoke from siwalan shell waste, and corn cobs in preserving sengon wood. The research results are presented in Table 2.

Table 2. Research Results

Treatment	Control	Concentration of liquid smoke from palm fruit skin	Concentration of liquid smoke from corn cob waste
Density of wood (before soaking)	$\bar{X}$ = 516 kg/m^3	$\bar{X}$ 5% = 491 kg/m^3 $\bar{X}$10% = 475 kg/m^3 $\bar{X}$15% = 491 kg/m^3 $\bar{X}$20% = 525 kg/m^3	$\bar{X}$ 5% = 500 kg/m^3 $\bar{X}$10% = 516 kg/m^3 $\bar{X}$15% = 508 kg/m^3 $\bar{X}$20% = 508 kg/m^3
Density of wood after drying after soaking	$\bar{X}$ = 563 kg/m^3	$\bar{X}$ 5% = 563 kg/m^3 $\bar{X}$10% = 538 kg/m^3 $\bar{X}$15% = 538 kg/m^3 $\bar{X}$20% = 569 kg/m^3	$\bar{X}$ 5% = 560 kg/m^3 $\bar{X}$10% = 552 kg/m^3 $\bar{X}$15% = 535 kg/m^3 $\bar{X}$20% = 588 kg/m^3
Increase in wood density (kg/m^3)	$\bar{X}$ = 9,10 %	$\bar{X}$ 5% = 14,6 % $\bar{X}$10% = 13,2 % $\bar{X}$15% =9,5 % $\bar{X}$20% = 8,3%	$\bar{X}$ 5% = 12% $\bar{X}$10% = 6,9 % $\bar{X}$15% =5% $\bar{X}$20% = 15,7 %
Wood moisture content (before soaking)	$\bar{X}$ = 40,1 %	$\bar{X}$5% = 29,9 % $\bar{X}$10% = 27,2 % $\bar{X}$ 15% = 38,3 % $\bar{X}$ 20% = 22,4 %	$\bar{X}$ 5% = 35,7 % $\bar{X}$ 10% = 29,3 % $\bar{X}$ 15% = 34,0 % $\bar{X}$ 20% = 15,6 %

Treatment	Control	Concentration of liquid smoke from palm fruit skin	Concentration of liquid smoke from corn cob waste
Wood moisture content (after drying after soaking)	$\bar{X}$ = 82,3 %	$\bar{X}$ 5% = 70,6 % $\bar{X}$ 10% = 73,4 % $\bar{X}$ 15% = 73,3 % $\bar{X}$ 20% = 78,9 %	$\bar{X}$ 5% = 71,8 % $\bar{X}$ 10% = 75,7 % $\bar{X}$ 15% = 81,3 % $\bar{X}$ 20% = 76,5 %
Increase in wood moisture content (%)	$\bar{X}$ = 105,2 %	$\bar{X}$ 5% = 136,1 % $\bar{X}$ 10% = 169,8 % $\bar{X}$ 15% = 91,3 % $\bar{X}$ 20% = 252,2 %	$\bar{X}$ 5% = 101,1 % $\bar{X}$ 10% = 158,3 % $\bar{X}$ 15% = 139,1 % $\bar{X}$ 20% = 390,3 %
		Liquid smoke content	
Fe terlarut	≤ 0,011 mg/L	≤ 0,331 mg/L	≤ 0,333 mg/L
Chromium total	0,004 mg/L	≤ 0,004 mg/L	0,006 mg/L
Timbal	≤ 0,008 mg/L	≤ 0,010 mg/L	≤ 0,010 mg/L
Fenol total	0,008 mg/L	0,006 mg/L	0,007 mg/L
Amonia	≤ 0,03 mg/L	2,05 mg/L	≤ 0,074 mg/L
Arsen	≤ 0,015 mg/L	≤ 0,015 mg/L	≤ 0,015 mg/L
Sianida	≤ 0,006 mg/L	≤ 0,006	≤ 0,006 mg/L

Discussion

The research results show that liquid smoke from siwalan fruit peel and corn cob waste can increase the preservation of sengon wood. This can be viewed based on the increase in density and water content of the wood. This increase is due to liquid smoke seeping into the wood structure. A high concentration of liquid smoke will be more abundant and easily absorbed by wood than a low concentration. The high absorption capacity of wood for liquid smoke is due to the wood pores having a large percentage of cavities so that it can absorb optimally with different liquid smoke absorption levels. Based on content tests on liquid smoke containing dissolved Fe, total chromium, dissolved lead, total Phenol, Ammonia, Arsenic, and Cyanide, it can potentially preserve sengon wood. It can also be seen that there is a significant increase in water content and wood density. Liquid smoke from corncob waste is more effective in preserving wood because the content of chemical compounds that have the potential to act as wood preservatives is higher than the content of liquid smoke from palm fruit husk waste or distilled water.

The level of cellulose and lignin in wood also affects the wood absorption of preservatives. According to Prawira et al. (2013), the concentration of the solution affects the durability (the penetrating power of the preservative into the wood) because the higher the concentration of the solution, the deeper the penetration and the more excellent the retention of the preservative. Wood density is directly related to porosity or the proportion of empty cavity volume (Haygreen et al., 2003) in Prawira et al. (2013). The smaller the density value of the wood, the greater the volume of the cell wall cavities, making it easier for liquid smoke to penetrate deep into the wood.

The test results for liquid smoke content showed that corncob liquid smoke's dissolved Fe and total chromium were higher than liquid smoke from palm fruit peel waste and distilled water. Therefore, sengon wood soaked in liquid smoke from corncob waste is more durable than wood soaked in liquid smoke from siwalan fruit peel waste or distilled water. The dark colour of liquid smoke can come from the high content of the materials used, namely corn cobs, palm fruit husk waste, and iron (Fe). When water with a high iron content comes into contact with air, it will become cloudy and smelly (Bidayatun, 2021). Iron levels can irritate the skin and eyes Febriana & Ayuna (2015). Due to the dissolved iron content, it can be used as a wood preservative and anti-termite agent and even cause termite mortality.

The results of the Cr content in liquid smoke from corncob waste were higher than in liquid smoke from palm fruit peel waste and the control (distilled water). Therefore, corncob waste liquid smoke has more potential as a sengon wood preservative. Chromium plays a role in preserving wood, metal plating, metal alloys, magnetic tape, paint pigments, rubber cement, paper, leather tanning, and metal plating (Haryani, 2023). Chromium is not found naturally in water, but chromium ions can be found in hexavalent, trivalent, and quaternary forms in liquid media, where the hexavalent and trivalent types are more stable (Ehsanpour et al., 2022).

Another compound contained in liquid smoke is lead (Pb). Lead can preserve wood and make paper resistant to insects (termites). According to Hadi (2008), the tradition of making insect-proof (termite) paper in China and New York uses red lead. Lead is a compound whose toxicity is very high, causing termite mortality. Therefore, it can protect sengon wood from termite attacks and preserve sengon wood.

Another compound contained in liquid smoke is phenol. Phenol compounds have a role in forming colour in smoked products. Therefore, sengon wood soaked using liquid smoke changes colour to dark brown-black. Phenol has antioxidant activity, which can extend its shelf life or preserve Sengon wood. According to Muzdalifah et al. (2020), liquid smoke containing phenol, benzene, and acid compounds is one option that can be used as a preservative because it has an antioxidant effect. Phenol (C6H5OH) has a molecular weight (BM) of around 94.11 with a boiling point of 181.2 ^{0}C.

Another vital compound contained in liquid smoke as a preservative for sengon wood is ammonia. The ammonia in liquid smoke evaporates across the surface of the wood and is absorbed by the sengon wood. The ammonia content allows a bond between extractive substances and ammonia, which produces a toxic compound for dry wood termites to preserve sengon wood. According to Nurmawan (2011), wood is composed of dead cells, forming a cavity in the middle of the cells. The cell walls also connect cavities (notches), so the wood is porous, and ammonia gas enters the wood. Ammonia is one of the materials that can be used as a wood preservation fumigant, and it is environmentally friendly and easy for people to apply (Taqiyudin, 2011). The chemical compound ammonia (NH3) has a distinctive sharp odour.

During the test, after 96 hours, you could still smell ammonia in the wood. This allows the smell of ammonia to be still inhaled by the test termite samples. According to Oka (2005), ammonia evaporates quickly and enters the bodies of insect pests in gas form through their respiratory system (Oka, 2005; Taqiyudin, 2011). Taqiyudin's (2011) test results showed that the ammonia fumigant gas was able to penetrate up to the maximum distance of the test sample (5 cm) on each type of wood and at each level of ammonia used (Taqiyudin, 2011). The longer the termite feeding time, the more ammonia will accumulate and be inhaled by the termites, which can cause high mortality. Ammonia can improve wood's physical, mechanical, and durability properties (Cahyo, 2013).

The greater the compound content in liquid smoke that enters and binds to the wood cell walls, the more toxic the wood will be to wood-destroying organisms such as termites. Factors that influence the entry of preservatives into the wood are the type of wood, the anatomical structure of the wood, the permeability of the wood, the density of the wood, the condition of the wood, the preservation method, and the nature of the preservative used (Sinuhaji, 2012). Ammonia allows a bond between extractive substances and ammonia, producing a toxic compound for wood termites. The more ammonia used, the more poisonous compounds will stick to the wood, causing individual termites to die and reducing weight loss in the wood (Sunihaji, 2012). Ammonia at certain levels can attack insect exoskeletons and cause insect death over a long period (Cahyo, 2013).

Ammonia can be converted into nitrites and nitrates by bacteria in the soil, so ammonia acts as a soil fertilizer. The greater the specific gravity value of wood, the smaller the mortality value. The particular gravity of wood is directly related to porosity or the volume proportion of empty voids. The greater the value of the specific gravity of the wood, the smaller the cavity volume, so it will be more difficult for ammonia vapour to penetrate deep into the wood. Ammonia vapour entering the wood's pores can produce anti-termite substances, resulting in termite mortality. The higher the ammonia content, the greater the steam produced in an airtight space, so penetration into the wood is better. Saturated ammonia vapour conditions cause termites to not survive for long (Nurmawan, 2011).

Ammonia residue is also still effective in increasing the durability of wood or preventing termite attacks. The effectiveness of this residue in preventing dry wood termite attacks on a laboratory scale has been proven to be effective. Ammonia residue is still toxic to wood-destroying organisms (after 48 hours) (Sinuhaji, 2012). Fumigant residues can harm commodities and have low toxicity to plants, humans, and other non-target organisms. So, finishing is necessary to apply to the wood material after it has been fumigated. Finishing applications like paint can remove the residual odour from ammonia on wood. Another way is to dry the wood in the air or with a fan; heat treatment can be given after the wood has been fumigated. Airing and heat treatment can remove the remaining ammonia odour in fumigated wood (Taqiyudin, 2011).

The arsenic content in liquid smoke is also an anti-termite agent and preserves sengon wood. According to Munandar (2013), arsenic can protect wood, pigments, firecrackers/pyrotechnics, eradicate weeds, melt glass, dyes, and chemicals. Therefore, this liquid smoke can potentially be a preservative for sengon wood because it contains arsenic. Wood preservation can be done using copper arsenate, sodium arsenate, and zinc arsenate, which are added with chromate compounds (Munandar, 2013). These compounds are used under pressure, react with wood, and produce compounds that are insoluble in water. Preserving wood logs is resistant to attacks by fungi and insecticides, so the use of arsenic in the field of wood preservation is increasing from year to year (Munandar, 2013).

Alkaloid, a cyanide poison, can be used as an insecticide to eradicate plant pests such as insects and termites. The cyanide content can be an anti-food agent for wood-destroying organisms. Cyanide can enter the pores of Sengon wood to increase its strength. The cyanide content has the potential to cause metabolic disorders such as anti-eating and even poisoning, and cyanide poison is a poison that causes seizures, which can cause respiratory and nervous disorders and result in imperfect cell development (Sari, 2019). Cyanide inhibits the action of the ferric cytochrome oxidase enzyme in taking oxygen for respiration. The cyanide content is beneficial as a wood preservative because it contains alkaloid poisons, which can prevent attacks by wood-destroying insects.

Conclusions

Based on the research that has been carried out, it can be concluded that liquid smoke from siwalan fruit husk and corn cob waste is effective in preserving sengon wood (*Paraserianthes falcataria*). Based on the increase in density and water content of sengon timber, the best concentration is corncob liquid smoke, with a concentration of 20% (P8).

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Declaration statement

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References

Anggraini, S.P.A. 2017. Teknologi Asap Cair dari Tempurung Kelapa, Tongkol Jagung, dan Bambu sebagai Penyempurna Struktur Kayu. *Seniati: Seminar Nasional Inovasi dan Aplikasi Teknologi Di Industri.* 3(2):D18.1-D18.6. https://doi.org/10.36040/seniati.v3i2.1992

Artiningsih, N. A., & Purwaningtyas, E. F. 2016. Pengembangan Optimalisasi Ekstraksi Antosianin Kulit Buah Siwalan Warna Ungu dan Diimplementasikan Sebagai Pewarna Alami Pada Kain Katun Secara Pre-Mordanting. *Prosiding Seminar Nasional Sains dan Teknologi*. 1(1):44-49

Aulia, N. *et al*. (2020). Evaluasi Pertumbuhan Tanaman Sengon Laut (*Paraserianthes falcataria* (L) Nielsen) pada Tanah Rawa. *Jurnal Sylva Scienteae* , 3(6):1072-1077. https://doi.org/10.20527/jss.v3i6.4724

Cahyo, A.D. (2013). Pengaruh Fumigasi Amonia terhadap Sifat Fisis, Mekanis dan Keawetan Tiga Jenis Kayu Hasil Tanaman. *Skripsi.* Bogor: Institut Pertanian Bogor.

Diatmika, I.G.N.A.Y.A., P.K.D Kencana., & G. Arda. 2019. Karakteristik Asap Cair Batang Bambu Tabah (*Gigantochloa nigrociliata* Buse-Kurz) yang Dipirolisis pada Suhu yang Berbeda. *Jurnal Beta(Biosistem dan Teknik Pertanian),* 7(2):278-285 https://doi.org/10.24843/JBETA.2019.v07.i02.p07

Ehsanpour, S., Riahi Samani, M., & Toghraie, D. (2022). Chromium (VI) removal from aqueous solution using Eggshell/ poly pyrole composite, *Alexandria Engineering Journal*, 1-9. https://doi.org/10.1016/j.aej.2022.09.018

Febriana, L. dan A. Ayuna (2015). Studi Penurunan Kadar Besi (Fe) dan Mangan (Mn) dalam Air Tanah menggunakan Saringan Keramik. *Jurnal Teknologi,* 7(1). https://doi.org/10.24853/jurtek.7.1.35-44

Hadi, M. (2008). Pembuatan Kertas Anti Rayap Ramah Lingkungan dengan Memanfaatkan Ekstrak Daun Kirinyuh (Eupatorium odoratum). *Bioma*, 6(2):12-18. https://doi.org/10.14710/bioma.10.1.12-18

Hanifarianty,S. & A.Vachlepi. 2019. Pengawetan Kayu Karet Menggunakan Asap Cair dan Ekstrak Kunyit dengan Teknik Perendaman Dingin. *Widyariset*, 5(2):65-74. http://dx.doi.org/10.14203/widyariset.5.2.2019.65-74

Haryani, T. (2023). Penyediaan Bahan Uji Profisiensi untuk Analisis Logam Kromium (Cr) dalam Air Mineral. *Skripsi*, Yogyakarta: Universitas Islam Indonesia.

Isa, I., Musa, W.J.A., dan Rahman, S.W. (2019). Pemanfaatan Asap Cair Tempurung Kelapa Sebagai Pestisida Organik Terhadap Mortalitas Ulat Grayak (*Spodoptera litura F.*). *Jamb.J.Chem.,* 01 (1), 15-20. https://doi.org/10.34312/jambchem.v1i1.2102

Kusyanto, M. 2015. Kajian Material Kayu Glugu Sebagai Bahan Bangunan. *Jurnal Teknik Unisfat,* 10(1), 33–37

Lessy, I., S. Ohorella., dan S. Karepesina. (2018). Sifat Fisis Kayu Sengon (*Paraserianthes falcataria L. Nielsen*) pada Lahan Agroforestry di Ambon, Maluku. *Jurnal Agrohut,* 9(1):1-11. https://doi.org/10.51135/agh.v9i1.13

Martins, O.D., S.P.A Anggraini, & S. Yuniningsih. 2017. Pemanfaatan Tongkol Jagung Menjadi Asap Cair Menggunakan Proses Pirolisis. *eUREKA : Jurnal Penelitian Teknik Sipil dan Teknik Kimia*, 1(1):1-5.

Meidianto,A., A. Jayuska., & M.A Wibowo. 2019. Bioaktivitas Antirayap Ekstrak Kayu Gaharu Buaya (Aetoxylon sympetalum) Terhadap Rayap Tanah (Coptotermes sp). *Jurnal Kimia Khatulistiwa,* 8(1):11-16.

Munandar, S. (2013). Faktor yang Berhubungan dengan Kadar Arsen (As) dalam Urin Masyarakat Kelurahan Kawatuna Kecamatan Mantikulore Sulawesi Tengah. *Tesis. Makassar*: Universitas Hasanuddin.

Munif, N.A. (2020). Perbandingan Hasil Analisa Pengawetan Kayu Glugu dengan Boraks & Ekstrak Kulit Singkong Melalui Rendaman Dingin Ditinjau terhadap Uji Fisis dan Uji Mekanik. *Skripsi*. Semarang: UNNES

Muzdalifah., T. Syarif., A. Aladin. (2020). Potensi Pemanfaatan Limbah Biomassa Serbuk Gergaji Kayu Besi (*Eusideroxylon zwageri*) Menjadi Asap Cair melalui Proses Pirolisis. *ILTEK : Jurnal Teknologi*, 15(2):78-81. https://doi.org/10.47398/iltek.v15i02.28

Nugroho,T.A. & Z.Salamah. (2015). Pengaruh Lama Perendaman & Konsentrasi Biji Sengon (*Paraserianthes falcataria L.*). *Jupemasi-Pbio,* 9 (3)

Nurmawan, D. (2011). Potensi Fumigasi Berbahan Aktif Amonia terhadap Kayu Nangka, Angsana, Dan Petai dari Serangan Rayap Tanah Coptotermes curvignathus Holmgren. *Skripsi.* Bogor: Institut Pertanian Bogor.

Pramasatya, P.M. & S. Sunarta. 2018. Pengaruh Suhu Pirolisis dan Proses Redistilasi Terhadap Sifat Fisiko-Kimia Asap Cair Tongkol Jagung. *Skripsi.* Yogyakarta: Universitas Gadjah Mada.

Praptoyo, H., & Puspitasari, R. (2013). Variasi sifat anatomi kayu sengon (*Paraserianthes falcataria* (L) Nielsen) dari dua jenis pemudaan yang berbeda. *Seminar Nasional Mapeki XV* (pp. 33–41). Makasar.

Prawira, H., Oramahi, H.A., Setyawati, Dina, Diba, Farah. (2013). Aplikasi Asap Cair dari Kayu Laban (*Vitex Pubescens Vahl*) untuk Pengawetan Kayu Karet. *Jurnal Hutan Lestari*, 1(1):16-22. https://dx.doi.org/10.26418/jhl.v1i1.874

Purwanto, F. (2018) Omset petani pohon sengon di desa pangkoh kabupaten pulang pisau. *Skripsi.* Palangka Raya: IAIN Palangka Raya.

Sari, N.M. (2019). Analisis Uji Fisis dan Uji Mekanis Kayu Sengon yang Diawetkan dengan Rendaman Dingin Ekstrak Umbi Gadung. *Skripsi.* Semarang: Universitas Negeri Semarang.

Sinuhaji, H.J. (2012). Efektifitas Pengawetan Kayu dengan Rendaman Dingin dan Fumigasi Amonia Pada Sepuluh Jenis Kayu Rakyat Terhadap Rayap Kayu Kering. *Skripsi.* Bogor: Institut Pertanian Bogor.

Taqiyudin, M. (2011). Pengaruh Residu Amonia Akibat Fumigasi terhadap Mortalitas Rayap Tanah (Coptotermes curvignathus Holmgren) Pada Beberapa Jenis Kayu Rakyat. *Skripsi*. Bogor: Institut Pertanian Bogor.

Yuliani, T.S., H. Triwidodo, dan K. Mudikdjo. (2017). Pestisida Rumah Tangga Untuk Pengendalian Hama Permukiman Pada Rumah Tangga (Home Pesticides for Urban Pest Control In Households). *JPSL*, 1(2):73–83.