

The Effect of Burning Time on the Yield and Quality of Liquid Smoke from Sengon Wood Waste (*Falcataria moluccana*)

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Abstract

This study aims to determine the effect of burning time on the yield and quality of liquid smoke produced from sengon wood waste (*Falcataria moluccana*). The research method employed was an experimental design with a completely randomized design (CRD), consisting of three pyrolysis time treatments: 90 minutes, 120 minutes, and 150 minutes, each with three replicates. The parameters observed included yield, color, floating material, pH, phenol content, acetic acid content, and specific gravity. The results showed that the duration of combustion had a significant effect on the yield and acetic acid content of the liquid smoke, but no significant effect on pH, phenol content, and specific gravity. The highest yield was obtained at a combustion time of 150 minutes, with an average value of 23.07%, while the lowest yield was obtained at 90 minutes, with an average value of 15.90%. The pH value of the liquid smoke ranged from 3.07 to 3.16 and was classified as quality category II based on SNI 8985:2021. The phenol content exceeded the standard limit, while the acetic acid content and specific gravity mostly met the requirements of quality category II.

Keywords: Liquid smoke, sengon wood, burning time, yield, quality

Introduction

Indonesia is known as one of the world's largest forest product producers, especially in timber production. Currently, various wood processing industries have grown rapidly to meet the demand for building construction materials, furniture, paper manufacturing, and other products. According to Badan Pusat Statistik (2022), roundwood production in Indonesia in 2022 reached approximately 64.65 million m³ based on the results of the Quarterly Forestry Data collection. Until now, Indonesians have generally used sengon wood waste only as fuel (Pambudi 2018). This waste, in the form of sawdust, is usually left to rot or burned after drying. Sengon wood waste has not been optimally utilized. One alternative technology that can be applied to overcome this waste problem is to process wood waste into liquid smoke.

Liquid smoke is a black liquid produced from biomass, such as wood, bark, and other biomass waste, including forestry waste and industrial forest products, through a process called pyrolysis (Ridhuan *et al.* 2019). Pyrolysis is a thermochemical decomposition process that occurs in organic materials (biomass) through heating with little or no oxygen. In this process, the raw material undergoes chemical structure breakdown and becomes a gas phase (Ridhuan *et al.* 2019).

According to Fauzan and Ikhwanus (2017), the quality of liquid smoke is determined by its phenol content and acidity level because both play a major role as antibacterials. The higher the phenol content and acidity level, the higher the ability of liquid smoke to kill microorganisms. According to research by Putra *et al.* (2020), the phenol content of liquid smoke from sengon and avocado wood has the potential to inhibit bacterial growth. According to Arif *et al.* (2024), it was

reported that 75% grade 2 sengon wood liquid smoke has antimicrobial properties and is effective for use as an antiseptic.

Pyrolysis time affects the yield, pH, and density of the liquid smoke produced (Handayani and Sa'diyah 2022). Based on several previous studies, this study will use pyrolysis burning times of 90 minutes, 120 minutes, and 150 minutes. Although these studies provide preliminary information on changes in liquid smoke quality due to changes in pyrolysis duration, the time range used is relatively limited and only covers teak and mahogany. This time range is not sufficient to describe the characteristics of liquid smoke changes in other types of wood, such as sengon, which has a different chemical structure. Sengon wood has a different composition of lignin, cellulose, and hemicellulose compared to mahogany, so it has the potential to show different pyrolysis times. According to Shobib *et al.* (2023), sengon has a low lignin content of only 5%, with cellulose at 27% and hemicellulose at 41%. Meanwhile, teak has a high lignin content of 25%, cellulose of 32%, and hemicellulose of 8%. Mahogany wood has a lignin content of 21%, cellulose of 47%, and hemicellulose of 3%. Therefore, this study explores longer pyrolysis times. This study aims to determine the effect of pyrolysis burning time on the yield of liquid smoke produced from sengon wood powder. The results of this study are expected to provide information regarding the effective pyrolysis time for producing the yield and quality of liquid smoke from sengon wood powder.

Materials and Methods

Tools and Materials

The equipment used was a 10 kg capacity pyrolysis apparatus made of aluminum equipped with a thermometer,

an LPG stove as a heat source, weighing bottle, 50 mL burette, distiller, 250 mL Erlenmeyer flask, 250 mL, 500 mL, and 1000 mL beakers, 100 mL measuring cup, a stove, a spray flask, a 1000 mL measuring flask, a 10 mL micro burette, an analytical balance, a water bath, glass stirrer, pH meter, pycnometer, 25 mL pipette, 5 mL and 10 mL measuring pipettes, 1 mL, 5 mL, and 10 mL volumetric pipettes, spectrophotometer, 30 mL test tubes, thermometer, analytical balance.

The materials used were sengon wood powder (*Falcataria moluccana*), distilled water, phosphoric acid (H₃PO₄), hydrochloric acid (HCl), 0.1% phenolphthalein indicator, 5% methyl orange indicator, 0.025 N potassium dichromate (K₂Cr₂O₇), potassium iodide (KI) crystals, 4-aminoantipyrine solution, 0.5 N ammonium hydroxide (NH₄OH) solution, 1 N and 4 N sulfuric acid (H₂SO₄) solutions, 0.1 N bromate-bromide solution, 0.05% starch indicator solution, potassium ferricyanide solution (K₄Fe(CN)₆), 2.5 N sodium hydroxide solution (NaOH), buffer solution, phosphate buffer solution, 0.1 N sodium hydroxide standard solution (NaOH), anhydrous sodium sulfate (Na₂SO₄), sodium thiosulfate (Na₂S₂O₃) 0.025 N, potassium hydrogen phosphate powder (K₂HPO₄), potassium dihydrogen phosphate powder (KH₂PO₄).

Stages of Liquid Smoke Production

The liquid smoke production process begins with the preparation of raw materials in the form of sengon wood powder. The wood powder is cleaned to remove various impurities that can affect the final result. The raw materials are weighed to determine the exact amount used in each treatment. The drying stage is carried out for seven days under direct sunlight. During the drying period, the wood powder is weighed periodically to monitor the moisture content (Mariyamah *et al.* 2024). The pyrolysis process is carried out using 600 g of raw material for each time variation, namely W1 90 minutes, W2 120 minutes, and W3 150 minutes, with each temperature group undergoing the pyrolysis process three times. During the pyrolysis process, the temperature was maintained at 300 °C using a pyrolysis device equipped with a thermometer as a temperature controller, so that temperature stability could be monitored and controlled consistently throughout the combustion.



Figure 1. Pyrolysis Process

Liquid Smoke Quality Analysis

The liquid smoke from Sengon wood produced by pyrolysis was then tested for yield, color, floating matter, pH, phenol, acetic acid, and specific gravity.

Yield

According to Sahrum *et al.* (2021), yield is the ratio between the liquid smoke produced and the weight of the raw material used before combustion. Yield is determined by calculating the weight of the material used against the weight of the liquid smoke produced from each treatment and then calculating the average. This yield can be calculated using the following formula:

$$\text{Yield} = \frac{\text{Liquid smoke volume (mL)}}{\text{Sawdust volume (mL)}} \times 100\%$$

Color

A total of 25 mL of liquid smoke was placed in a test tube, and then the color of the sample was observed against a white background. Color testing was carried out by visually observing the sample using the sense of sight (SNI 8985:2021).

Floating Materials

The floating material test is conducted by adding 25 mL of liquid smoke to a test tube, then observing the presence or absence of floating material in the test sample using the sense of sight/eyes against a white test tube background (SNI 8985:2021).

pH

pH testing is carried out using a pH meter, which must first be calibrated using at least 2 buffer solutions. After the calibration process, the electrode is rinsed with mineral-free water and dried using a soft tissue paper. Next, the electrode is immersed in the test sample until the pH meter shows a stable reading. The reading that appears on the pH meter display is then recorded (SNI 8985:2021)

Phenol

This method is based on the principle of oxidation-reduction reactions, in which phenolic compounds in the sample undergo oxidation by the *Folin-Ciocalteu* reagent, which consists of phosphomolybdic acid and phosphotungstic acid in basic conditions, while the reagent undergoes reduction to form a blue complex. The intensity of the blue color formed is proportional to the total phenol concentration in the sample (Rotty *et al.* 2017). The total phenolic content is calculated using the formula quoted from (Susanty and Bachmid 2016):

$$\text{Phenol content} = \frac{c \times v}{m}$$

Explanation :

c = equivalent concentration of gallic acid (mg GAE/L)

v = volume of extract solution used (mL)

m = mass of extract used (g)

Acetic Acid

Acetic acid testing using the ditritsi test. Titration is an analytical method used to determine the amount of dissolved substances quantitatively. This technique involves a complete chemical reaction between the analyte (titrant) and the reagent (titrant). A titrant with a known concentration will react with the titrant to measure the concentration of the substance (Indrajaya *et al.* 2021). The data obtained will then be calculated using the following formula:

$$\text{Total Acidity (\%)} = \frac{(V \text{ NaOH} \times N \text{ NaOH} \times \text{Acetic Acid BM}) \times \text{FP}}{\text{Sample weight} \times 1000} \times 100\%$$

Explanation :

V NaOH : volume used (mL)
 N NaOH : normality (0,01N)
 FP : dilution factor

Acetic Acid BM : 60 g/mol

Density

Based on (SNI 8985:2021), density testing using a pycnometer involves weighing equal volumes of liquid smoke and water at 20 °C sequentially in the pycnometer. The results are then converted into relative density d_{20}^{20} using the following equation:

$$d_{20}^{20} = \frac{m_2 - m_0}{m_1 - m_2}$$

Explanation :

m₀ : mass, in grams, of the empty pycnometer
 m₁ : mass, in grams, of the pycnometer filled with water
 m₃ : mass, in grams, of the pycnometer filled with liquid smoke

Table 1. Quality of Liquid Smoke from SNI 8985:2021

No	Characteristics	Unit	Requirements	
			Grade 1	Grade 2
1	Color	-	Yellow to brown	Yellow to brown
2	Floating Material	-	None	None
3	pH	-	1,50 - 2,75	2,76 - 4,50
4	Density	-	1,0050 - 1,0500	1,0050 - 1,0500
5	Acetic Acid	%	8,00 - 15,00	1,10 - 7,99
6	Phenol	%	Maximum 2,0	Maximum 2,0

Data Analysis

This study used a one-way analysis of variance (ANOVA) method at a significance level of 5%. One-way ANOVA is a statistical technique that aims to compare the means of three or more independent groups influenced by one independent variable (factor). This method is used to evaluate whether there are statistically significant differences between these groups (Montgomery 2017).

Yield

The liquid smoke yield is the percentage of results obtained from the pyrolysis process in each treatment, namely W1 90 minutes, W2 120 minutes, and W3 150 minutes. The percentage yield was obtained by comparing the volume of liquid smoke (mL) produced with the volume of sawdust (mL) used, then multiplying the result by 100%. The effect of pyrolysis time on liquid smoke yield in this study is shown in Table 2.

Results and Discussion

Table 2. Liquid Smoke Yield Results

Treatment	Repetition			Average (%)
	1	2	3	
W1	16,6	14,9	16,2	15,90 ± 0,73
W2	19,3	19,7	20,6	19,87 ± 0,54
W3	24,4	22,4	22,4	23,07 ± 0,94

Table 2 shows that treatment W1 had an average yield of 15.90%, W2 had 19.87%, and W3 had 23.07%. These results indicate that the highest or best yield was obtained in treatment W3, which was 150 minutes, while the lowest yield was found in treatment W1, which was 90 minutes. Next, a

variance analysis was conducted at a level of 0.05 using the SPSS application on each repetition to determine the effect of the burning time tested on the yield produced. The test results can be seen in Table 3.

Table 3. Results of Analysis of Variance (ANOVA) for Liquid Smoke Yield

Source of variance	Sum of Squares	df	Mean Square	F	Sig.
Treatment	77,34	2	38,67	45,2	0,000241
Error	5,13	6	0,86		
Total	82,47	8			

Note : Sig \leq 0,05 : Values are significantly different (*Significant*), Sig \geq 0,05 : Values are not significantly different (*Non-Significant*)

Based on the ANOVA test results in Table 3, the significance value of 0.000241 is smaller than 0.05, so the analysis results show that the treatment has a significant effect on liquid smoke yield. Thus, there is a very significant difference between the time treatments on liquid smoke yield.

Based on the results of the study, the yield produced in treatment W1 had an average yield of 15.90%, W2 was 19.87%, and W3 was 23.07%, indicating that the duration of pyrolysis combustion affects the amount of yield produced. In line with the research conducted by Handayani and Sa'diyah (2022), it states that the yield of liquid smoke tends to increase with the increase in pyrolysis time. The amount of liquid smoke condensation is also influenced by the duration of combustion, because the longer the pyrolysis process

lasts, the more the conversion of liquid smoke will increase. According to Komarayanti *et al.* (2018), the longer the pyrolysis time, the more raw materials are decomposed due to the longer contact time with heat. This is because the higher the pyrolysis temperature, the more liquid smoke is produced, as higher temperatures increase the speed of the pyrolysis reaction, thereby increasing the ability to decompose organic compounds (Ridhuan *et al.* 2019).

Liquid Smoke Quality Analysis

The average values of the liquid smoke quality analysis results are presented in Table 4, and the results of the analysis of variance (ANOVA) are presented in Table 5.

Table 4. Results of liquid smoke quality analysis

Parameter	Treatment (Average)			Description
	W1	W2	W3	
Color	Brown	Brown	Brown	Meets Standards
Floating Material	Yes	Yes	Yes	Does Not Meet Standards
pH	3,16 \pm 0,04	3,15 \pm 0,06	3,07 \pm 0,07	Meets Standards
Phenol (%)	3,2 \pm 0,10	2,85 \pm 0,06	3,42 \pm 0,37	Does Not Meet Standards
Acetic Acid (%)	6,07 \pm 0,13	5,91 \pm 0,33	7,48 \pm 0,72	Meets Standards
Density (g/cm ³)	1,026 \pm 0,0016	1,0273 \pm 0,0012	0,9903 \pm 0,0009	Meets Standards

Table 5. Calculated F values of the variance analysis.

Parameter	F calculated	Sig.
Yield	45,2	0,00024
pH	1,553	0,286
Phenol	3,407	0,103
Acetic Acid	6,99	0,0271
Density	0.002	0.998

Note : Sig \leq 0,05 : Values are significantly different (*Significant*), Sig \geq 0,05 : Values are not significantly different (*Non-Significant*)

Color

Based on Table 4, it is evident that all treatments, W1, W2, and W3, produced relatively uniform colors, namely brown. These results indicate that even though there were variations in treatment times of 90, 120, and 150 minutes, the changes that occurred did not affect the color. Thus, it can be concluded that the color of the product in all treatments meets SNI quality standards, which is in the yellow to brown category.

The color of the sengon wood liquid smoke produced in this study is darker than the results of the study conducted by Arif *et al.* (2024), which found that sengon wood liquid smoke has a clear yellow color because the study involved a distillation process. According to Izza *et al.* (2022), the dark color of liquid smoke is caused by the presence of tar compounds in the liquid smoke. Tar is a compound that is basically black in color, toxic, and has a high molecular weight. Therefore, to obtain liquid smoke that is free of tar content, further distillation is needed to produce liquid smoke with a clearer color.

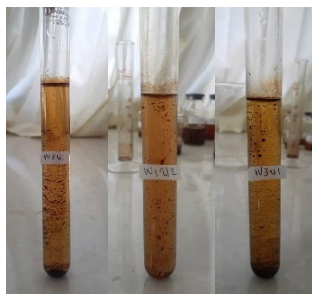


Figure 2. Color of liquid smoke

Floating Materials

Table 4 shows that in all treatments W1, W2, and W3, floating materials were found, indicating that increasing the time from 90 to 150 minutes did not eliminate the presence of floating materials. The floating materials detected in the pyrolysis results are generally tar or heavy hydrocarbon compounds that are not completely degraded. Further purification processes, such as distillation, are needed to reduce the tar and floating material content so that the quality of the liquid smoke produced is better. Therefore, all treatments in this floating material are declared not to meet the SNI 8985:2021 quality standard.



Figure 3. Floating material in liquid smoke

pH

Based on the results of the study, the pH values produced in Table 4 for treatment W1 had an average pH value of 3.16, W2 of 3.15, and W3 of 3.07, which means that the values were below 7, indicating that the solution was acidic. The pH value decreases as the temperature and pyrolysis time increase (Handayani and Sa'diyah, 2022). A low pH value indicates that liquid smoke has antimicrobial and sterilizing properties (Swastawati *et al.* 2022). This is because a low pH value affects the shelf life and storage capacity of products, as at low pH, microbes or bacteria that interfere with the preservation process tend to be unable to live and multiply well (Izza *et al.* 2022).

The pH value of sengon wood liquid smoke produced in this study is higher than the results of a study conducted by Arif *et al.* (2024), which found that sengon wood liquid smoke has a pH value of 3.1, 3.0, and 2.9. When compared to the quality standards set by SNI 8985:2021, all treatments fall into quality category 2. Thus, all treatments, W1, W2, and W3, meet the SNI standard in Quality Category II, with relatively stable pH values between treatments.

Based on Table 5, the significance value is greater than 0.05, specifically 0.286. Therefore, it can be concluded that the treatments applied do not have a significant effect on the tested parameters.

Phenol

Based on the data in Table 5 it shows that the average phenol content exceeds the maximum limit set in the SNI standard. The highest value is found in treatment W3 with an average of 3.42%, and the lowest is found in treatment W2 with an average of 2.85%. When compared to the quality standards set by SNI 8985:2021, none of the treatments met the SNI quality requirements.

According to Seri Maulina *et al.* (2018), the longer the combustion or pyrolysis process is carried out, the higher the phenol content in the liquid smoke. The temperature in the pyrolysis process is one of the factors that can increase the content of phenolic compounds, as explained by Seri Maulina *et al.* (2018). However, the duration of heating also has a significant effect on pyrolysis results. The longer the raw material is heated, the longer it is exposed to heat, causing more components in the raw material, such as lignin, to decompose. According to Swastawati (2022), this causes the phenol content to be higher because more lignin decomposes. According to Rigling *et al.* (2023), phenolic compounds are important compounds in smoke products. The importance of phenolic compounds in liquid smoke is that phenolic compounds function as aroma and flavor enhancers specific to smoked products. Liquid smoke contains phenolic chemicals that can form hydrogen bonds with bacterial proteins and damage their structure, thereby inhibiting bacterial growth (Ribeiro *et al.* 2015).

According to Sahrum *et al.* (2021), the phenol content, when associated with pH and total titratable acid in liquid smoke in each treatment, obtained a relationship whereby the

higher the phenol content in liquid smoke, the lower the pH value produced, meaning that the total titratable acid in liquid smoke will be higher. and vice versa, when the phenol content is low, the pH becomes high, and the titratable acidity becomes low. This relationship was proven in this study, where the liquid smoke from sengon wood had high phenol and acid content but produced low pH. This is because sengon wood sawdust has components such as hemicellulose and cellulose, which, when decomposed, will produce organic acid compounds such as acetic acid.

The results of the ANOVA test for phenol content in Table 5 show that the significance value is greater than 0.05, namely 0.103. Therefore, it can be concluded that the treatment given has no significant effect on the parameters tested.

Acetic Acid

Based on the data in Table 4, it can be seen that the highest acid content was found in treatment W3, with an average of 7.48%, and the lowest was found in treatment W2, with an average of 5.91%. According to Fadillah and Alfiarty (2015), an increase in combustion time tends to increase the acetic acid content in liquid smoke. This occurs because the longer the process takes, the more biomass is decomposed and produces organic acid compounds. Based on the SNI 8985:2021 standard, the acetic acid contained in the liquid smoke from this study meets the quality requirements for liquid smoke, namely quality 2.

The results of the ANOVA test for acid content, shown in Table 5, indicate that the significance value is less than 0.05, specifically 0.0271. Therefore, it can be concluded that the duration of combustion has a significant effect on the acid content being tested.

Density

Table 4 shows that the highest specific gravity value was in treatment W2, with an average value of 1.0273, while the lowest specific gravity value was in treatment W3, with an average value of 0.9903. The results of this study are in line with the research by Handayani and Sa'diyah (2022), which shows that the longer the pyrolysis time, the lower the density of the liquid smoke. From these test results, it was also found that there was no significant change in the specific gravity of liquid smoke over the pyrolysis time. Treatment W3 had an average liquid smoke density of 0.9903 due to the dominance of light organic fractions or water and low dissolved compound content. Specific gravity measurements are also greatly influenced by temperature. The higher the pyrolysis temperature, the more cellulose, hemicellulose, and lignin are decomposed and condensed into smoke liquid containing acetic acid, methanol, and phenol, thereby increasing its density (Triastuti *et al.* 2019). When compared to the SNI 8985:2021 quality standard, treatments W1 and W2 are declared to meet the quality standard, while treatment W3 does not meet the standard because it is below the specified minimum limit.

The results of the ANOVA test for specific gravity shown in Table 5 indicate that the significance value is greater than 0.05, namely 0.998. Therefore, it can be concluded that the treatments given have no significant effect on the parameters tested.

Conclusions

The results of the yield data calculations show significant results, meaning that the duration of pyrolysis combustion affects the yield of liquid smoke produced from sengon wood waste.

Based on SNI 8985:2021, the 90-minute treatment meets quality standards for color, pH (quality category 2), acetic acid (quality category 2), and specific gravity, while the parameters of floating material and phenol do not meet the standards. The 120-minute treatment shows similar results, meeting quality standards for color, pH (quality category 2), acetic acid (quality category 2), and specific gravity, but failing to meet quality standards for floating materials and phenol. The 150-minute treatment met quality standards for color and pH (quality category 2), but not for acetic acid (quality category 2). Additionally, the parameters of floating matter, phenol, and specific gravity did not meet the standards.

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