



## Yield and Quality of Liquid Smoke From Sawdust Waste of Sengon (Paraserianthes Falcataria L. Nielsen), Red Meranti (Shorea SPP.) and Camphor (Dryobalanops SP.)

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### ABSTRACT

Sengon, red meranti and camphor sawdust waste has the potential to be processed into liquid smoke through pyrolysis process by indirect combustion method obtain grade 3 liquid smoke, then distilled to obtain grade 2, and redistilled to obtain grade 1 liquid smoke. Liquid smoke is widely used in agriculture, forestry, fisheries, health, and animal farming. This research aims to determine the yield and quality of liquid smoke from the sawdust of sengon, red meranti and camphor as raw materials following the SNI 8985:2021. The results of liquid smoke yield from grade 3, grade 2 and grade 1 of sengon sawdust was 10.07%, 6.93% and 5.37%; red meranti was 13.6%, 7.09% and 5.43%, while camphor was 20.77%, 13.68% and 6.68%. Liquid smoke specific gravity from sengon was 0.998, 0.996 and 0.994; red meranti was 1.000, 0.999 and 0.995, camphor was 1.002, 1.000 and 0.998. The pH values of liquid smoke from sengon 3.16, 3.89 and 2.67; red meranti 3.19, 2.94 and 2.80; camphor 3.47, 3.20 and 2.90. The color of liquid smoke was brownish yellow to transparent slightly brownish. Floating material was not found on all liquid smoke. Only the specific gravity value does not meet SNI 8985:2021

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## **INTRODUCTION**

Sengon wood, red meranti, and lime wood are commercial woods in Indonesia that are widely utilized by the community and the wood industry, among others as raw materials in the plywood industry, the lumber milling industry, the composite board industry, building construction, and furniture. The processing and use of these three types of wood produce a lot of waste in the form of sawdust, which requires consideration of solutions to utilize it into high-value products and broad applications. One alternative solution for processing wood sawdust waste is to process it into liquid smoke.

Liquid smoke is a product produced from the pyrolysis process where a condensation (liquefaction) process is carried out from combustion at high temperatures with or without oxygen, either directly or indirectly from biomass that has a high content of hemicellulose, cellulose, lignin, and carbon compounds (Anggraini, 2017 and Ridhuan et al., 2019). According to Yaman (2004), pyrolysis is the decomposition of the chemical components that make up substances such as hardwood by heating it with limited oxygen to cause the oxidation of complex carbon molecule breakdown, which is dominated by carbon or charcoal, while distillation is the process of separating solutions using heat as a separating agent.

Liquid smoke can be used as an antiseptic, antimicrobial, antioxidant, and as a natural preservative for wood and food materials. Grade 3 liquid smoke undergoes purification to separate unwanted chemical compounds (such as tar compounds) using pyroglutamic acid chemicals, and can also be achieved through distillation and/or adsorption, followed by further redistillation, resulting in grade 2 and grade 1 liquid smoke that have different chemical compositions and applications (Saputra et al., 2020). Grade 3 liquid smoke is used in the coagulation of latex sap and as a wood preservative against wood-destroying organisms, grade 2 liquid smoke can be used as a preservative for raw food with a smoky flavor, while grade 1 liquid smoke is used for preserving processed food with the best quality (Fauzan & Ikhwanus, 2017). Liquid smoke is caused by chemical compounds such as acid compounds, phenols, and carbonyls which are utilized as preservatives for wood, and as food preservatives that are quite safe and provide a distinctive flavor to food, as well as a fungicide for plants (Sani, 2020).

## LITERATURE REVIEW

Research on liquid smoke from sengon wood, red meranti, and lime is very limited. Previous studies were limited to raw materials from mixed wood powder waste, focusing only on the production and utilization of grade 3 liquid smoke, while grade 2 and grade 1 are very difficult to find. Maulina et al. (2020) investigated the characteristics of grade 3 liquid smoke based on temperature and pyrolysis time, stating that the characteristics of various raw materials for liquid smoke differ due to the physical and chemical properties of each wood powder. Suryani et al. (2022), who studied the activity, content, and chemical composition of grade 3 liquid smoke derived from mixed wood sawdust, stated that the contents of lignin, hemicellulose, and cellulose vary depending on the type of wood, and are also influenced by the moisture content of the wood and the temperature during the pyrolysis process.

Based on this, it is necessary to conduct research on the yield and quality of liquid smoke from the waste of sengon wood chips, red meranti, and lime at each of its grades, and it is hoped that this can provide basic information on the characteristics and appropriate utilization of each grade of liquid smoke.

## METHODOLOGY

### Research Procedure

#### Preparation of Raw Materials

The raw material of sawdust waste from sengon wood, red meranti, and lime, each weighing 15 kg, was taken from several wood milling industries in the city of Samarinda. The wood powder underwent natural drying by being sun-dried under direct sunlight until it reached an air-dry moisture content (8-12%). Measurement of Moisture Content of Raw Materials Before Pyrolysis. After natural drying, the moisture content of each type of wood powder raw material was measured in 5 repetitions by weighing the air-dry weight ( $m_u$ ), followed by drying in an oven at a temperature of  $103 \pm 2^\circ\text{C}$  for 48 hours. After that, the sample was placed in a desiccator for 15 minutes and then weighed to obtain its dry weight ( $m_o$ ) using a digital scale. The moisture content value was calculated based on the ASTM D4442-92 standard, (2003) using the following formula:

$$MC = \frac{m_u - m_o}{m_o} \times 100 (\%) \dots\dots\dots (1)$$

KeExplanation:

MC = moisture content of dry air (%)

$m_u$  = weight of dry air sample (g)

$m_o$  = weight of dry furnace sample (g)

#### Measurement of Raw Material Density.

Density measurement is performed on test samples sized 2x2x2cm with 5 (five) repetitions, conducted under natural drying along with wood sawdust. The dimensions are measured using calipers to obtain the dry air volume value ( $v_u$ ), and weighed to determine its weight ( $m_o$ ). The test samples are then dried in an oven at  $103 \pm 20^\circ\text{C}$  for 48 hours, then placed in a desiccator for 15 minutes and dimensions are measured to obtain the dry furnace volume ( $v_o$ ) and weighed for the dry furnace weight ( $m_o$ ). The values of dry air density and dry furnace density are based on ASTM D2395-14 standards using the formula:

$$\rho_u = \frac{m_u}{v_u} \text{ (g/cm}^3\text{)} \dots\dots\dots (2)$$

$$\rho_o = \frac{m_o}{v_o} \text{ (g/cm}^3\text{)} \dots\dots\dots (3)$$

Description:

$\rho_u$  = Density of dry air (g/cm<sup>3</sup>)

$\rho_o$  = Density of dry furnace (g/cm<sup>3</sup>)

$m_u$  = Dry weight of air (g)

$m_o$  = Dry weight of furnace (g)

$v_u$  = Dry volume of air (cm<sup>3</sup>)

$v_o$  = Dry volume of furnace (cm<sup>3</sup>)

Production of Liquid Smoke Grade 3, Grade 2, and Grade 1. The pyrolysis process of each raw material (saw dust from sengon wood, red meranti, and lime) into liquid smoke grade 3 is carried out by placing 15 kg of dry raw material into the pyrolysis furnace, then burned indirectly with limited air using coal briquette fuel until the pyrolysis process is completed for 8 hours at a temperature between 350-400°C. The vapor produced from the pyrolysis process is channeled through water-cooled condenser pipes to produce liquid smoke grade 3, followed by precipitation to separate liquid smoke grade 3 from the tar content.

Liquid smoke grade 3 is produced through the distillation process using a distillation pot heated over a gas stove. The vapor that results from the heating is channeled through cooling pipes (condensers) to become drops of liquid smoke grade 2. This process is carried out until no more liquid smoke drips and the bottom of the pot dries, leaving behind a crust. Liquid smoke grade 2 undergoes a re-distillation process to produce liquid smoke grade 1, where the process stages are the same as those for producing liquid smoke grade 2.

**Data Analysis of the Research**

The liquid smoke produced is calculated for its yield value (%) and the quality of the liquid smoke is analyzed, including pH value, specific gravity, color, and floating materials, and then compared to the SNI 8985:2021 standard regarding the quality of liquid smoke (crude liquid smoke lignocellulosic as raw material). Liquid Smoke and Tar Yield Yield is the ratio of the amount of product produced (output of liquid smoke) to the amount of biomass raw materials used (input). The yield is determined using the following equation:

$$R3 = \frac{\text{Output 3}}{\text{Input 3}} \times 100\% \dots\dots\dots (4)$$

$$R2 = \frac{\text{Output 2}}{\text{Input 3}} \times 100\% \dots\dots\dots (5)$$

$$R1 = \frac{\text{Output 1}}{\text{Input 3}} \times 100\% \dots\dots\dots (6)$$

$$\text{tar} = \frac{\text{Output tar}}{\text{Input 3}} \times 100\% \dots\dots\dots (7)$$

Description:

R3, R2, R1 = Yield of liquid smoke grade 3, grade 2, and grade 1 (%)

Output = Weight of liquid smoke produced (kg)

Input = Weight of raw material (kg)

tar = Yield of tar in liquid smoke (%)

**pH Test of Liquid Smoke.**The pH value is a parameter to measure the acidity level of a product. The pH value of liquid smoke is measured using a pH meter. Perform calibration of the pH meter by immersing the pH meter electrode in buffer solutions of pH 4.0 and 6.86 at room temperature of 25°C. The pH meter electrode should be rinsed with distilled water and dried with a tissue. Liquid smoke is placed in a 20 ml beaker glass, then immerse the pH meter electrode, and record the pH value displayed by the pH meter. Calculate the average pH value of each liquid smoke from 3 repeated measurements.

**Specific Gravity Test of Liquid Smoke**

The measurement of the specific gravity of liquid smoke follows the AOAC standard (1995) by comparing the weight of liquid smoke to the weight of water. The steps are to weigh the 10 ml pycnometer in a dry and empty condition (mp), empty and dry the pycnometer in the oven, then fill the pycnometer with 10 ml of distilled water and weigh it (ma), then repeat the procedure of filling and weighing the pycnometer containing 10 ml of liquid smoke (mc). The specific gravity (SG) of liquid smoke is calculated using the formula:

$$BJ = \frac{mc-mp}{ma-mp} \dots\dots\dots (8)$$

Description:

BJ = Specific Weight

mc = Weight of the picnometer containing liquid smoke (g)

ma = Weight of the picnometer containing aquades (g)

mp = Weight of the empty picnometer (g)

**Color and Floating Material Test for Liquid Smoke**

The test for the quality of color and the presence of floating materials in liquid smoke according to SNI 8985:2021 is carried out by visual observation using direct eyesight on the liquid smoke, where the floating material test is to observe the presence of materials in the form of oil on the surface of the liquid smoke.

**RESULTS AND DISCUSSION**

**Moisture Content and Raw Material Density**

The average density value of the raw materials used in the production of liquid smoke is as follows:

Table 1. Average Density Value of Dry Air and Dry Furnace of Raw Materials

Type	Humidity dry air (%)	Density	
		Dry air (g/cm <sup>3</sup> )	Dry furnace (g/cm <sup>3</sup> )
sengon wood	12,17	0,37	0,34
Red merant	12,24	0,58	0,54
Lime	13,23	0,87	0,82

The value of moisture content and the highest density is found in the type of lime wood, followed by red meranti wood, and the lowest in sengon wood. The moisture content and density of the raw materials can affect the yield and

quality of the liquid smoke produced due to the different chemical components of the wood. High moisture content in raw materials can increase the yield because a lot of condensed water mixes with the liquid smoke, but the quality of the liquid smoke decreases because the chemical content of the liquid smoke decreases. Putri et al., (2023) state that high moisture content affects the yield and quality of the liquid smoke produced due to the condensation of water vapor which slows down the pyrolysis process and decreases the levels of acid and phenol in the liquid smoke. Triwahyudi, (2017) states that the yield and quality of liquid smoke in pyrolysis production are influenced by the density of the raw materials, chemical content of plants and combustion conditions, where high-density wood tends to have more wood constituent substances but requires longer pyrolysis time and higher temperatures in the process of decomposing its chemical components.

**Liquid Smoke and Tar Yields**

The pyrolysis process from sawdust feedstock is followed by distillation and redistillation resulting in yields of grade 3, grade 2, and grade 1 liquid smoke as follows:

Table 2. Yields of Liquid Smoke from Sawdust of Sengon, Meranti Merah, and Kapur

Type	Grade 3		Grade 2		Grade 1		Tar	
	(kg)	(%)	(kg)	(%)	(kg)	(%)	(kg)	(%)
sengon wood	1,510	10,07	1,040	6,93	0,805	5,37	0,010	0,067
red Merant	1,960	13,06	1,064	7,09	0,815	5,43	0,012	0,080
Lime	3,116	20,77	2,052	13,68	1,001	6,68	0,018	0,120

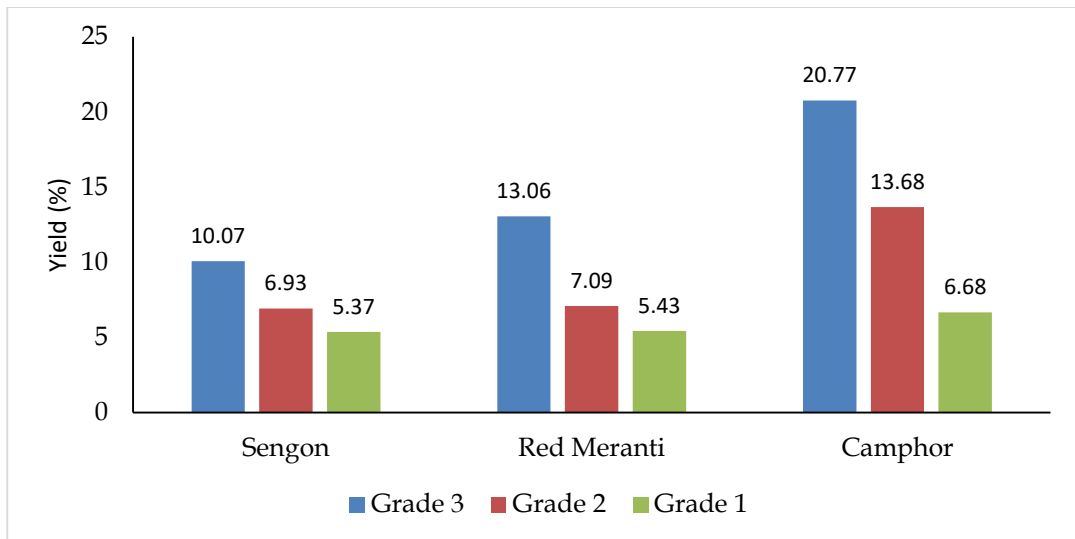


Figure 1. Liquid Smoke Yield from Sawdust of Red Meranti, Sengon, and Lime Wood

The liquid smoke yield at each grade level shows that lime wood produces the highest yield, followed by red meranti wood, with the lowest yield from sengon wood. This is due to the density values and moisture content of the raw materials in this study, where the density and moisture content of lime wood are

the highest, followed by red meranti wood and the lowest in sengon wood. The liquid smoke yield tends to follow the density and moisture content of the type of raw material, where higher density and moisture content will result in higher yields. Ratnawati & Hartanto (2010) and Ridhuan et al. (2019) state that liquid smoke yield is influenced by several factors, namely type, moisture content, density, composition, particle size of the raw material, as well as temperature and rate of the pyrolysis process. The yields of liquid smoke and tar also tend to be higher from wood raw materials with high lignin content. (Yudianto et al., 2024), where the research results of Jasni et al. (2016); Lukmandaru et al. (2015) and Marhaen (2016) mention that the lignin content of limestone wood is 34%, red meranti wood is 26.85%, and sengon is 26.80%. The decrease in the yield of liquid smoke at each grade and tar compound is caused by the distillation process and repeated distillation (redistillation). Liquid smoke distillation is a heating process of liquid smoke based on differences in boiling points and then cooled to separate chemical components with the aim of obtaining better quality liquid smoke (Ridhuan et al., 2021). The distillation process also causes the elimination of tar compounds, heavy fractions, and other impurities that form scum on the distillation pot, which reduces the yield of liquid smoke and produces liquid smoke with purer components (Septian & Nur, 2020). The higher the purity level of liquid smoke (*grade*), the lower the percentage of yield obtained due to repeated purification processes through redistillation which removes more unwanted components as well as impurities such as tar and other undesirable compounds.

**pH (Potential of Hydrogen) of Liquid Smoke**

The pH value of the liquid smoke from sawdust of sengon wood, red meranti, and lime from grade 3, grade 2, and grade 1 can be seen in the table below:

Table 3. pH Value of Liquid Smoke from Sawdust of Sengon Wood, Red Meranti, and Lime

Type	pH (Potential of Hydrogen)		
	Grade 3	Grade 2	Grade 1
sengon wood	3,16	2,89	2,67
Red Merant	3,19	2,94	2,80
Lime	3,47	3,20	2,90
SNI 8985:2021 Mutu 1 = 1,50 - 2,75 Mutu 2 = 2,76 - 4,50			

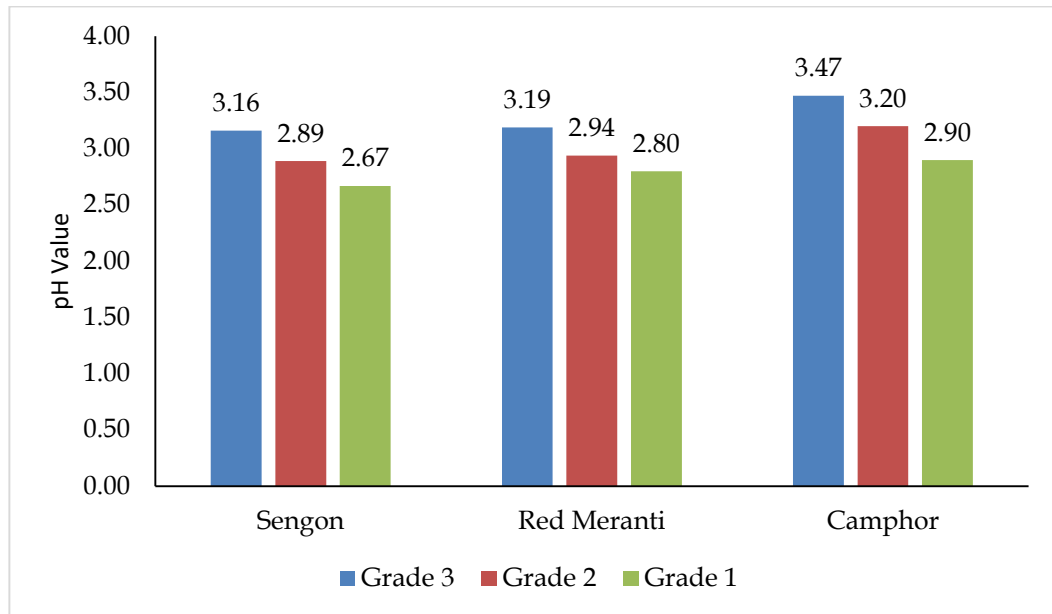


Figure 2. pH Value of Liquid Smoke from Red Meranti Wood, Sengon and Lime Sawdust

The pH value of liquid smoke depends on the concentration of organic acids and phenolic compounds resulting from the decomposition of cellulose, hemicellulose, and lignin. Liquid smoke mainly consists of acidic compounds such as acetic acid and other acids as well as phenolic compounds that lower the pH value, making liquid smoke acidic (Mariyamah et al., 2024). The decrease in pH value (increase in acidity) in each grade of liquid smoke is caused by the processes of pyrolysis, distillation, and redistillation which increase the content of organic acid compounds such as acetic acid and other acids as well as phenols in subsequent distillates (Puteri et al., 2024).

The highest pH value of liquid smoke from limestone wood is followed by the pH of liquid smoke from red meranti wood, and the lowest is from acacia wood. This is caused not only by the different chemical contents but also by the moisture content of the raw materials, where the moisture content in this study is highest in limestone wood and lowest in acacia wood. Restuhadi (2015) states that high moisture content of raw materials leads to higher moisture and pH levels in liquid smoke.

One of the parameters for assessing the quality of liquid smoke is the pH value; the lower the pH value, the better the quality of the liquid smoke. The acidity properties of liquid smoke, which are obtained from the content of organic acid compounds and phenols, support the preservative properties that can inhibit the growth of fungi, bacteria and wood-destroying organisms. The utilization of liquid smoke as an anti-termite against dry wood termites and subterranean termites has a significant effect (Indrayani et al., 2023). Acid compounds more strongly inhibit bacterial growth than phenol compounds, while phenol compounds provide the specific aroma desired in smoked food products (Widiya et al, 2013). The acidity of liquid smoke, apart from serving as a preservative for wood and food, can also be used as a coagulant in latex (as a substitute for formic acid), thus lowering the pH of the latex (Komarayati et al.,

2018). The pH value of liquid smoke from sawdust of sengon wood, red meranti, and lime at all grades meets the quality standard of liquid smoke according to SNI 8985:2021.

### Specific Gravity of Liquid Smoke T

The specific gravity of liquid smoke from sawdust of sengon wood, red meranti, and lime at grade 3, grade 2, and grade 1 is as follows:

Table 4. Specific Gravity of Liquid Smoke from Sawdust of Sengon Wood, Red Meranti, and Lime

Type	Berat Jenis		
	Grade 3	Grade 2	Grade 1
sengon wood	0,998	0,996	0,994
red meranti	1,000	0,999	0,995
Lime	1,002	1,000	0,998
SNI 8985:2021	Mutu 1 : 1,0050 - 1,050		Mutu 2 : 1,0050 - 1,050

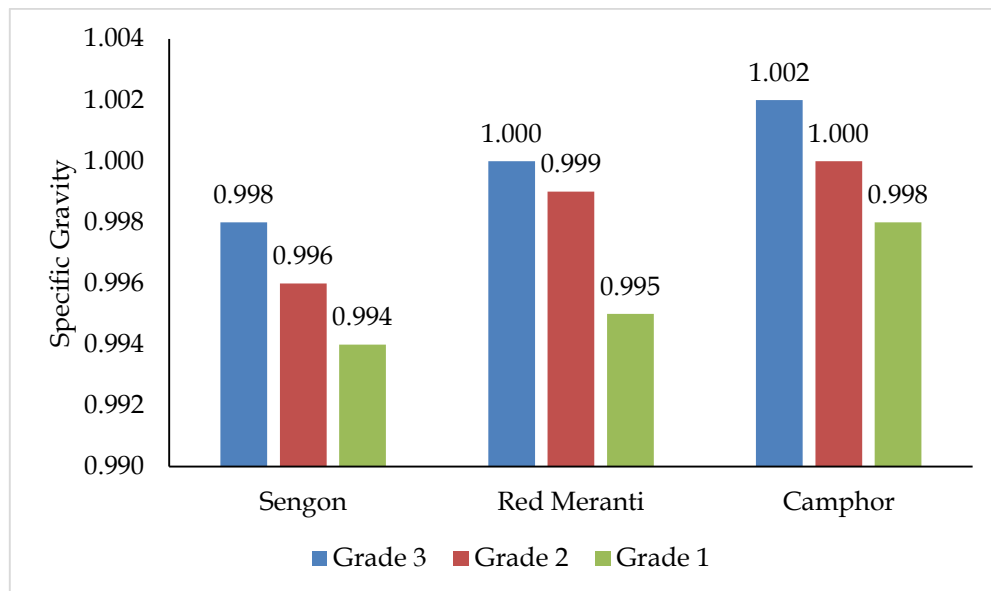


Figure 3. Specific Gravity of Liquid Smoke from Sengon Wood Sawdust, Red Meranti, and Lime

The specific gravity of liquid smoke grade 3, grade 2, and grade 1 shows a decreasing trend after undergoing distillation and redistillation processes. This is due to the reduction of heavy fractions such as tar and Polycyclic Aromatic Hydrocarbons (PAH) that are eliminated during the distillation and redistillation processes, resulting in liquid smoke with improved quality. Nasruddin (2015) states that the specific gravity of liquid smoke increases with the presence of chemical compounds from the groups of tar, phenol, and polycyclic aromatic hydrocarbons (PAH) as a result of the pyrolysis process of lignin, cellulose, and hemicellulose.

The pyrolysis process degrades cellulose, hemicellulose, and lignin, producing carboxylic acids and carbonyl compounds, while lignin

decomposition produces phenolic compounds, guaiacol, syringol, as well as undesirable compounds such as polycyclic aromatic hydrocarbons (PAH) (Mariyamah et al., 2024). In addition to the pyrolysis process, the purification of liquid smoke through repeated distillation aimed at purifying liquid smoke components from unwanted chemical compounds can lead to a decrease in specific gravity (Oktafany et al., 2016). The specific gravity of liquid smoke from three types of raw materials does not meet the SNI 8985:2021 standards for both quality 1 and 2. It has been previously explained that this may be caused by the chemical content, moisture content, raw material size, as well as pyrolysis processes such as temperature and processing rate that affect the yield and quality of liquid smoke.

**Color and Floating Material of Liquid Smoke.**

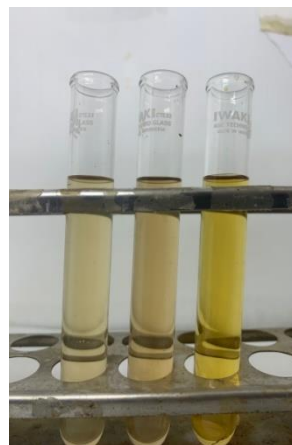
Identification of color and observation of floating materials on the surface of liquid smoke from sengon wood sawdust, red meranti, and lime at grade 3, grade 2, and grade 1 conducted visually by looking at it with the naked eye can be seen in the table below:

Table 5. Color of Liquid Smoke from Sengon Wood Sawdust, Red Meranti, and Lime

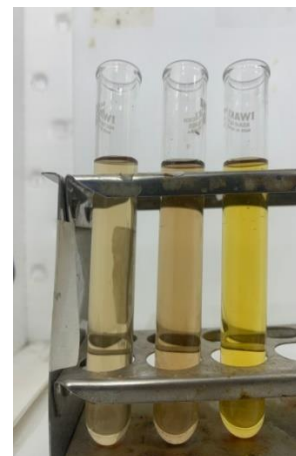
Raw materials	Color		
	Grade 3	Grade 2	Grade 1
sengon wood	Brown Brown	Clear Brown	Clear somewhat Brown
Red meranti	Brown Brown	Clear Brown	Clear somewhat Brown
Lime	Brown Brown	Clear Brown	Clear somewhat Brown
SNI 8985:2021 ( <i>grade 3</i> )		Yellow to Brown	



Sengon Wood



Red Meranti



Camphor

Figure 4. Observation of Color and Floating Materials in Liquid Smoke from Sengon Wood Sawdust, Red Meranti, and Lime

The liquid smoke color grade 3 from the three types of raw materials has a yellowish-brown color, grade 2 has a brownish-clear color, and liquid smoke grade 1 from the three types of raw materials has a clear color with a slight brown tint. According to Kresnawaty et al., (2017), the brown to reddish color in liquid smoke is influenced by the content of carbonyl and tar compounds. The color differences in liquid smoke indicate changes in the composition of active compounds in the liquid smoke, and the composition of active compounds such as phenol gives a yellow color to the liquid smoke (Rizal et al., 2020). The color test results for the liquid smoke grade 3 from sengon wood sawdust, red meranti, and lime have met the SNI 8985:2021 standard, which is yellow to brown.

The testing for the presence of floating materials in the liquid smoke from sawdust of red meranti, sengon, and lime wood showed no floating materials on the surface in liquid smoke grades 3, 2, and 1. Floating materials in liquid smoke are usually indicated by the presence of a thin oil layer derived from volatile constituents and essential oils released from organic materials during the combustion process; these compounds are not completely soluble in water, thus forming a thin layer on the surface of the liquid smoke (Suryani et al., 2020). The results of the floating materials testing in the liquid smoke from the sawdust of sengon, red meranti, and lime wood in grades 3, 2, and 1 meet the quality criteria 1 and quality 2 of the SNI 8985:2021 standard.

## **CONCLUSION AND RECOMMENDATION**

The highest yield of liquid smoke grade 3 is produced from sawdust of lime wood at 20.77%, followed by red meranti at 13.06%, and the lowest from sengon at 10.07%. The pH value of liquid smoke for each grade from all types of raw materials ranges from 2.67 to 3.47, meeting the SNI 8985:2021 standard. The specific gravity of each grade of liquid smoke is highest for lime wood sawdust, followed by red meranti, and lowest for sengon, which does not meet the SNI 8985:2021 standard. The color of the liquid smoke tends to be yellowish-brown, and no floating materials were found in the liquid smoke, thereby meeting the SNI 8985:2021 standard.

## **FUTHER STUDY**

The pyrolysis process in this study was conducted for 8 hours at a temperature of 350 - 400°C, and further research is needed with different temperature treatments and pyrolysis time/rate. It is necessary to perform a chemical component analysis of the liquid smoke from each grade of all raw materials studied to determine the chemical compound content and the reasons for the failure to meet the specific gravity of liquid smoke according to the SNI 8985:2021 standard.

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