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Preliminary study on the chemical components of west kalimantan's ubah rukkok wood (*Santiria griffithii*) liquid smoke

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ABSTRACT

The use of wood as a raw material for liquid smoke production is still limited. Despite the presence of important compounds including lignin, cellulose, and hemicellulose that contribute to the formation of liquid smoke. Indonesia has a lot of potential in biomass utilization, with a wide variety of wood species, but this potential is mostly restricted to small-scale and specific applications. Ubah rukkok wood (*Santiria griffithii*), a lesser-known species, could serve as a substitute raw material for liquid smoke production, in order to reduce the strain on natural forests and more widely used wood species. This study aims to identify the chemical components of liquid smoke produced from Ubah Rukkok wood using gas chromatography-mass spectrometry. Additionally, a UV-Vis spectrophotometer was employed to analyze the total phenolic content, and high-performance liquid chromatography was used to measure the total acid content. The findings of this study contribute to the understanding of the potential of Ubah Rukkok wood as a sustainable source for liquid smoke production. The results revealed that 16, 18, and 20 chemical compounds, including phenol, acid, and carbonyl compounds and their derivatives, were detected at pyrolysis temperatures of 300 °C, 350 °C, and 400 °C, respectively. At pyrolysis temperatures of 300 °C, 350 °C, and 400 °C, the liquid smoke yields were 7.5%, 9%, and 13%, with total phenol content of 19.734 mg GEA/g, 14.778 mg GEA/g, and 13.109 mg GEA/g, and total acid content of 1.741%, 1.490%, and 1.859%. The study's findings shed light on Ubah Rukkok wood's potential as a source of raw liquid smoke that may be used for various industrial purposes.

Keywords: wood, liquid smoke, ubah rukkok, *Santiria griffithii,* pyrolysis.

INTRODUCTION

The use of wood as a raw material for liquid smoke production remains understudied. Despite the existence of important components including lignin, cellulose, and hemicellulose which play a crucial role in liquid smoke production. The production of lignocellulosic biomass for varied energy products, such as liquid smoke [1], is the main focus of current research trends in response to concerns about global warming, unstable energy prices [2], and the depletion of fossil fuel sources. Indonesia, with its diverse range of wood species, has a lot of potential for using biomass. However, its application has been restricted to certain applications and small-scale manufacturing [3]. One alternative wood source for liquid smoke production is Ubah Rukkok wood (*Santiria griffithii*), which can help to reduce the strain on natural forests and more commonly used wood species. Ubah Rukkok is often collected for industrial applications due to its resistance to termites and fungi, which further supports the ideals of sustainable forest management. However, as a lesser-known species, information regarding its potential for liquid smoke production is still underexplored. The components of Walnut wood (*Santiria leavigata*), which belongs to the same genus and family as ubah rukkok, is used as an approximation to represent the components of ubah rukkok wood. Chemical components of walnut wood include cellulose (54.83%), lignin (29.02%), pentosan (16.18%), silica (0.59%), with a reduced silica (0.59%) and ash (1.16%) level [4]. Its lignin content falls into the moderate range, ranging from 18% to 33% [5]. However, it is expected that ubah rukkok wood will differ from those in other woods that are commonly used.

The presence of lesser-known woods, such as Ubah Rukkok (*S. griffithii*), is relatively abundant in the Sambas region of West Kalimantan, particularly in Semparuk District, which are frequently used in the furniture business and produce waste like sawdust, wood boards, and wood chunks. Significant amounts of wood waste are produced by the sawmilling sector, including 14.3% wood cuts, 10.4% sawdust, and 25.9% wood slats. It may be possible to turn this sawdust waste into a raw material for making liquid smoke [6]. Waste from the furniture sector is not included in this number [7]. The use of lesser-known wood species as raw materials for the production of liquid smoke, chances for product diversification from forest resources which can enhance the economic value of the wood and lowering reliance on environmentally hazardous synthetic chemicals.

Active substances including phenols, acetic acid, and carbonyls found in the liquid smoke created when wood biomass is pyrolyzed have antimicrobial qualities [8] and may find application as termiticides[9], fungicides [10], antibacterial agents [11], insecticides [12], and antioxidants [13]. This study evaluated and characterize the chemical components of liquid smoke from ubah rukkok wood (*S. griffithii*) using gas chromatography-mass spectrometry (GC-MS). In addition to determining the molecular weight and formula and producing charged molecules, the investigation aims to comprehend how the temperature of pyrolysis affects the chemical components that are created [14]. These facts are essential for assessing liquid smoke's possible uses in a variety of sectors, including as a natural preservative.

METHODOLOGY

Pyrolysis process

To enhance the quality and consistency of the final liquid smoke, the raw material must be pretreated before to the pyrolysis process. In order to reach a moisture level of 12% to 18%, the raw material is dried [15]. The sample used in this study is wood dust that passes through a 10-mesh sieve and is retained on a 14-mesh sieve. One kilogram of the sample is placed into the pyrolysis reactor, which is then sealed to prevent the escape of volatile compounds. A thermocouple and condenser system are installed to monitor temperature and collect condensed liquid. The pyrolysis process is conducted at temperatures of 300 °C, 350 °C, and 400 °C for 150 minutes. During pyrolysis, the wood undergoes thermal decomposition, releasing gases that pass through the condenser. After passing through the condenser, these gases are cooled and condensed into liquid smoke, which is then collected in a liquid smoke tank. Figure 1 shows the pyrolysis device, showing the flow of substances

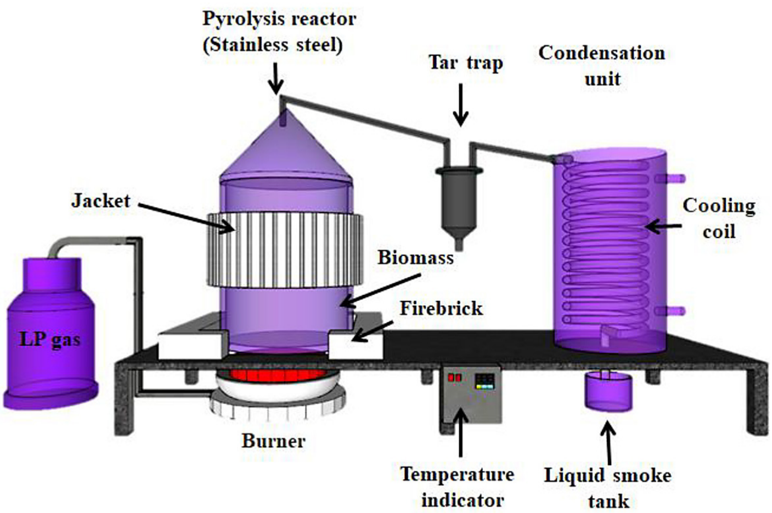

Figure 1. Ubah rukkok wood pyrolysis schematic

through the system, key operating conditions, and the collaborative working principle of the reactor, condenser, and other associated devices.

Identification of liquid smoke components

The components of volatile compounds were identified using a GAS CHROMATOGRAPHY-MASS SPECTROMETRY instrument [16], the total phenol was measured using a UV-Vis spectrophotometer [17], and the total acid content was examined using a high-performance liquid chromatography instrument [18].

RESULT AND DISCUSSION

Liquid smoke yield

The liquid smoke yield from pyrolyzing Ubah Rukkok wood (*S. griffithii*) at different temperatures showed varying yield values. Figure 2 shows the output of liquid smoke from Ubah Rukkok wood (*S. griffithii*) with pyrolysis temperature 300–400 °C.

The production of liquid smoke from the pyrolysis of Ubah Rukkok wood (*S. griffithii*) increased as the pyrolysis temperature increased, according to the results shown in Figure 2. While lignocellulosic compounds break down more intensely at higher temperatures, the production of liquid smoke also increases [19]. This process generates more gaseous and liquid products, such as liquid smoke, while reducing the amount of biochar. More volatile compounds are created when lignocellulosic compounds decomposition at ideal high temperatures, and these compounds eventually condense into liquid smoke. As seen by the increase in yield percentage, greater pyrolysis temperatures generally improve the efficiency of turning wood into liquid smoke. For one kilogram of Ubah Rukkok wood (*S. griffithii*) raw material, the maximum yield of 13.5% was obtained at a pyrolysis temperature of 400 °C. The yields of liquid smoke obtained from pyrolysis at 300 °C and 350 °C were 7.5% and 9%, respectively.

This study is similar with the research by Maulina and Putri [20], which showed that raising the pyrolysis temperature produces more components that can condense into liquid smoke. At pyrolysis temperatures of 150 °C, 200 °C, and 250 °C, the maximum yield was achieved at 250 °C, with a yield percentage of 20.69% [20]. Higher pyrolysis temperatures affect the chemical content of the liquid smoke in addition to increasing the yield. High temperatures generally result in a higher amount of organic acids and phenolic compounds, which are essential for liquid smoke's antibacterial and antioxidant qualities [21]. Another study found that producing liquid smoke from coconut shell and Pelawan wood with lignin levels of 27% and 37.74%, respectively, at a pyrolysis temperature of 450 °C produced yields of 56.67% and 35% [22]. The high moisture content of the coconut shell is thought to be the reason for the variations in yield levels. Though it may lower its quality, including lowering its acid content, high moisture content can enhance the amount of liquid smoke produced [23]. Figure 3 displays the liquid smoke from Ubah Rukkok wood (*S. griffithii*), the byproduct of pyrolysis.

The darker color of liquid smoke at low pyrolysis temperatures compared to high temperatures

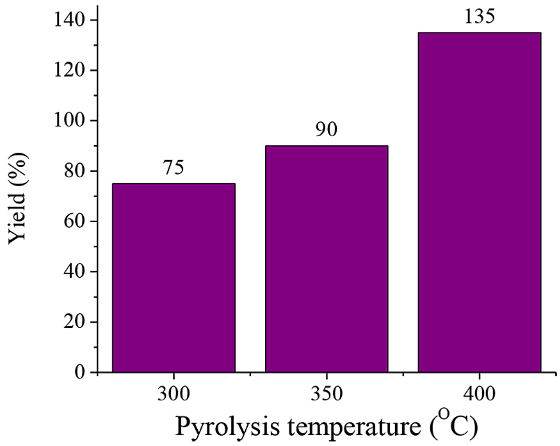

Figure 2. Yield of liquid smoke from Ubah Rukkok wood (*S. griffithii*)

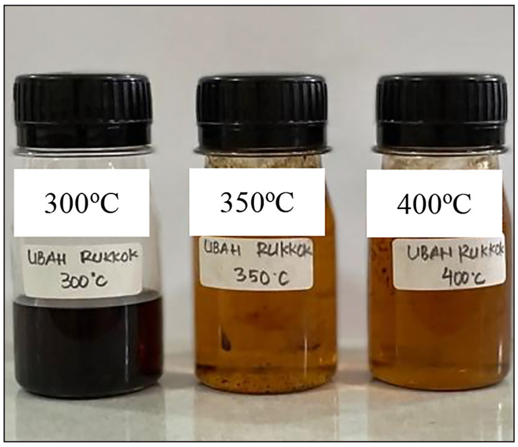

Figure 3. Liquid smoke from Ubah Rukkok wood (*S. griffithii*)

is due to the chemical composition formed during the pyrolysis process. At low temperatures pyrolysis is often incomplete, so complex compounds such as partially depolymerized lignin, tar, and heavy aromatic compounds are more dominant. This compound contributes to the higher viscosity and darker color of liquid smoke. In contrast, higher pyrolysis temperatures encourage a more complete decomposition of lignin and cellulose, resulting in compounds such as phenols, carbonyls, and organic acids with lighter colors [24]. The liquid smoke produced with a pyrolysis temperature of 300 °C has a dark brown color, while the liquid smoke produced at pyrolysis temperatures of 350 °C and 400 °C is light brown, as shown in Figure 3. The carbonyl concentration in liquid smoke gives it its dark brown color. The higher its carbonyl content (Table 1), the greater its potential for a brown color. As shown in Table 1, the higher the pyrolysis temperature, the lower the carbonyl concentration. Liquid smoke produced at a pyrolysis temperature of 300 °C has the most intense brown color, indicating that it contains a higher concentration of carbonyl compounds.

Table 1. GC-MS analysis results of liquid smoke from Ubah Rukkok (*S. griffithii*) at pyrolysis temperatures of 300 °C, 350 °C, and 400 °C

No	Component	Chemical formula	Area (%)		
			300 °C	350 °C	400 °C
Phenol					
1	Phenol	C_6H_5OH	20.32	17.63	17.21
2	Phenol, 2-methyl-	C_7H_8O	1.9	2.27	2.45
3	Phenol, 3-methyl-	C_7H_8O	2.05	1.99	2.23
4	Phenol, 2-methoxy-	$C_7H_8O_2$	2.33	1.73	1.84
5	2-Furanmethanol	$C_5H_6O_2$	1.44	1.67	-
6	Creosol	$C_8H_{10}O_2$	-	0.52	0.54
7	Phenol, 2,6-dimethoxy-	$C_8H_{10}O_3$	-	10.7	0.97
8	2-Furanmethanol, tetrahydro-	$C_5H_{10}O_2$	-	2.28	-
Acid					
9	Palmitic Acid, TMS derivative	$C_{16}H_{31}O_2$	0.47	-	-
10	Butanoic acid, 4-hydroxy-	$C_4H_8O_3$	-	2.4	-
11	Hexanoic acid, 1-methylethyl ester	$C_9H_{18}O_2$	-	-	0.62
Carbonyl					
12	3-Penten-2-one, 4-methyl-	$C_6H_{10}O$	4.95	4.89	4.39
13	2-Pentanone, 4-hydroxy-	$C_5H_{10}O_2$	2.44	2.99	2.62
14	2-Pentanone, 4-hydroxy-4-methyl-	$C_6H_{12}O_2$	52.57	50.9	47.25
15	2-Propanone, 1-(acetyloxy)-	$C_5H_8O_3$	0.81	1.13	0.9
16	2-Cyclopenten-1-one, 2-methyl-	C_6H_8O	0.87	1.42	1.76
17	2-Cyclopenten-1-one, 3-methyl-	C_6H_8O	1.7	1.11	1.77
18	Furfural	$C_5H_4O_2$	4.6	-	6.58
19	Butyrolactone	$C_4H_6O_2$	0.75	-	-
20	Furan-2-carbonyl chloride, tetrahydro-	$C_5H_7ClO_2$	1.67	-	-
21	Cyclopentanone	C_5H_8O	-	1.24	1.47
22	2-Cyclopenten-1-one	C_5H_6O	-	3.57	-
23	1,2-Cyclopentanedione, 3-methyl-	$C_6H_8O_2$	-	1.19	1.16
24	2-Furanmethanol	$C_5H_6O_2$	-	-	1.59
25	2-Furanmethanol, tetrahydro-	$C_5H_{10}O_2$	-	-	1.72
26	Ethanone, 1-(2-furanyl)-	$C_6H_6O_2$	-	-	2.25
27	2-Cyclopenten-1-one, 2,3-dimethyl-	$C_7H_{10}O$	-	-	0.7
Other					
28	3-Hexene, (Z)-	C_6H_{12}	1.13	-	-

Chemical components of liquid smoke

Gc-ms (gas chromatography-mass spectrometry) analysis

A variety of chemical components were found in the liquid smoke from ubah rukkok wood (*S. griffithii*) when it was analyzed using Gas Chromatography-Mass Spectrometry (GC-MS) at pyrolysis temperatures of 300 °C, 350 °C, and 400°C. The number of chemical compounds produced at each temperature varied, with 16 being produced at 300 °C, 18 at 350 °C, and 20 at 400°C, based according to this investigation. Table 1 displays the entire results of the GC-MS study.

The GC-MS analysis of liquid smoke from Ubah Rukkok wood (*S. griffithii*) at pyrolysis temperatures of 300 °C, 350 °C, and 400 °C revealed the primary components found were carbonyl, acids, and phenolic compounds. These components were reliably found at all three temperatures, suggesting that some compounds are stable under various pyrolysis temperatures. Despite the variation in pyrolysis temperatures, several new compounds appeared at each temperature. However, the pyrolysis mechanism produced comparable products even under varying heating settings. This study is in line with previous research by Desvita *et al*. [25], which examined the chemical contents of liquid smoke formed from cocoa pod shells (*Theobroma cacao L.*). The result showed variation in the chemical contents of each liquid smoke sample produced at different pyrolysis temperatures. At pyrolysis temperatures of 300 °C, 340 °C, 380 °C, and 400 °C, respectively, the percentages of phenolic compounds were 45.49%, 29.78%, 33.60%, and 49.87%, indicating that they were the primary components. In the liquid smoke from cocoa pod shells, phenol and its derivatives, including 2-methyl-p-cresol, 3-methylphenol, 1-propanol, 2-amino-1-octanamine, n-methyl-2-amino-1-propanol, and 4-ethylphenol, were the most abundant compounds found [24].

A similar study conducted by Komarayati and Wibisono [25] differences in the chemical components for each type of wood have been investigated in a related work which used GC-MS to investigate the chemical components of liquid. These five species of wood produced liquid smoke that was mostly containing acetic acid, carbamic acid, and phenol (phenol, 2,6-dimethoxyphenol) [26]. Characterization of liquid smoke components from various woods with different pyrolysis temperatures has been carried out [27, 28]. Oramahi et al. [29] examined the components of liquid smoke from medang wood (*Cinnamomum sp.*) at different pyrolysis temperatures. The study found 2-methoxy-phenol, phosphonic acid, 5-methyl-2-furancarboxaldehyde, 2,6-dimethoxy-phenol, creosol, and 1-(2-furanyl)-ethanone in liquid smoke at 370 °C. However, liquid smoke at 400 °C contained 2-methoxy-phenol, 5-methyl-2-furancarboxaldehyde, phenol, 1-(2-furanyl)-ethanone, 2-methyl-2-Cyclopenten-1-one, and creosol. Phosphonic acid, 2-methoxy-phenol, 2,6-dimethoxy-phenol, 5-methyl-2-furancarboxaldehyde, 1-(2-furanyl)-ethanone, and creosol were also found in liquid smoke at 430 °C. Phenolic compounds and their derivatives were the most often found components in the liquid smoke from ubah rukkok wood (*S. griffithii*), according to the GC-MS analysis.

The result demonstrates that the primary components in the liquid smoke from the pyrolysis of ubah rukkok wood (*S. griffithii*) are phenolic and carbonyl compounds using GC-MS. The analysis reveals the primary of carbonyl compounds at pyrolysis temperatures ranging from 300 °C to 400 °C [30]. Phenolic components predominant at lower pyrolysis temperatures (about 300 °C), but carbonyl compounds and organic acids rise at higher temperatures (about 400 °C) [31]. Phenolic and carbonyl compounds are consistently the primary results of biomass pyrolysis at temperatures between 300 °C and 400 °C [23]. One component of biomass that breaks down at relatively moderate temperatures (240 °C to 300 °C) is hemicellulose [32]. Hemicellulose decomposes into light gases like furfural and organic acids at these temperatures. Hemicellulose decomposition contributes very little to the synthesis of phenols because its main byproducts are non-aromatic chemicals. At temperatures between 300 °C and 450 °C, cellulose then starts to break down, producing mostly volatile substances like levoglucosan and other carbonyl compounds like furfural. More carbonyl compounds are formed than phenol when cellulose is further broken down at temperatures above 350 °C. The primary procedure in the formation of phenol is lignin degradation, which takes place at higher temperatures (250 °C to 500 °C) [33]. As a result of the increased degradation of phenolic compounds and the predominance of cellulose and hemicellulose at these temperatures, the biomass decomposition pathway generally changes from phenol production to carbonyl compounds between 300 °C and 400 °C. Therefore, there is comparatively less production of acids.

According to the GC-MS analysis, acid compounds were found in relatively small amounts in the liquid smoke from ubah rukkok wood (*S. griffithii*), compared to other components like phenols and carbonyls. This due to lower pyrolysis temperatures result in the production of acid contents. More complex organic molecules, such carboxylic acids, have a tendency to further decomposition into more volatile compounds, like ketones, aldehydes, and hydrocarbons, at higher pyrolysis temperatures (such as 300 °C, 350 °C, and 400 °C). High temperatures cause acids to break down easily, which decreases their detection level. As the pyrolysis temperature rises, acid components break down and more phenolic and carbonyl chemicals are produced [34].

Phenol analysis

According to the analysis's results, when the pyrolysis temperature was raised from 300 °C to 400 °C, the amount of total phenol decreased. The Folin-Ciocalteu technique was used to analyze total phenol. Figure 4 displays results of the total phenol analysis conducted on the liquid smoke from ubah rukkok wood (*S. griffithii*).

According to Figure 3, when the pyrolysis temperature increases from 300 °C (19.743 mg GEA/g) to 400 °C (13.109 mg GEA/g), the total phenol concentration decreases. This phenomenon indicates more phenolic compounds are produced at lower pyrolysis temperatures (300 °C), but these phenolic compounds start to break down or the decomposition into other volatile products at higher temperatures. Higher temperatures increase the phenol concentration to decrease, which is in line with results from a number of recent research. The depolymerization of lignin brought on by high-temperature pyrolysis results in its thermal decomposition into simpler gaseous components, which lowers the pyrolysis product's phenol concentration [35]. Significant amounts of phenol are produced when lignin is burned down between 300 °C and 350 °C. However, at temperatures higher than 350 °C, these phenolic compounds start to break down into volatile compounds like carbon dioxide and hydrocarbons, which lowers the quantity of phenol present. In line with previous studies, the percentage of phenol generated decreases with increasing pyrolysis temperature; at 300 °C, it is 6.7%, and at 400 °C, it is 0.75% [36].

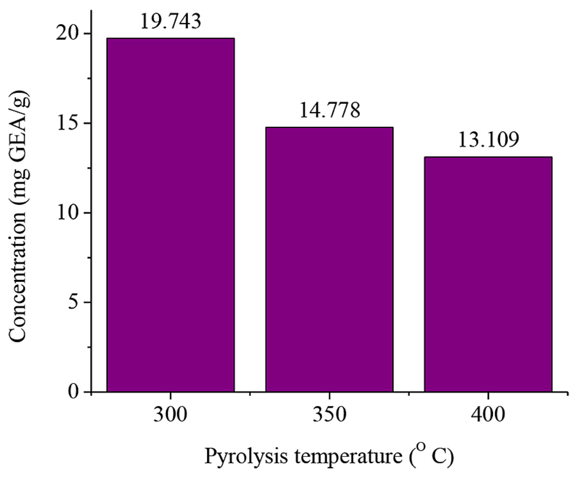

Figure 4. Total phenol analysis results (Folin-Ciocalteu method) of liquid smoke from ubah rukkok wood (*S. griffithii*)

In comparison to previous studies, the results of the total phenol analysis of liquid smoke from Ubah Rukkok (*S. griffithii*) reveal a reduced phenol content. In addition, the phenol content of liquid smoke made from Gelam wood is higher, ranging from 2.429% to 9.231% [37]. Temperature and pyrolysis duration are critical parameters in optimizing the yield of phenol chemicals in wood vinegar [38, 39]. The amount of lignin and the temperature at which pyrolysis occurs are two of the variables that affect the amount of phenol in liquid smoke. The higher the lignin content, the greater the potential for higher phenol formation. Furthermore, choosing the right temperature during the pyrolysis process is important for maximizing lignin breakdown and raising the degradation reaction's efficiency [40].

Total acid analysis

The findings of the total acid analysis indicate that the total acid content decreases slightly decreasing at 350°C and increasing at 400 °C. The results of the total acid analysis of liquid smoke from Ubah Rukkok (*S. griffithii*) are shown in Figure 5. The data was collected using a diode array detector and a high-performance liquid chromatography device.

The total acid content shows fluctuations, with a slight decrease at 350 °C (1.490%) and an increase at 400 °C (1.859%). This pattern indicates that acid compounds are formed in considerable amounts at lower to medium pyrolysis temperatures (300–350 °C), but their volatilization leads

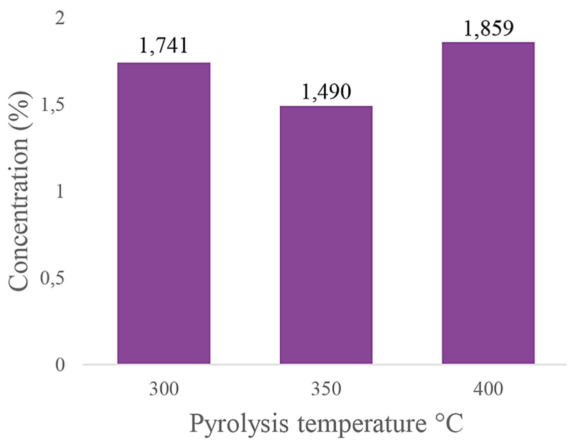

Figure 5. Total acid analysis of liquid smoke from *Ubah Rukkok* (*S. griffithii*) wood

to a decrease at 350 °C. The production of organic acids increases by secondary reactions that happen when the temperature is raised to 400 °C. These results are similar with earlier research [41], that shown that acid compounds – especially carboxylic acids – volatilize at low temperatures but that as temperatures rise, additional pyrolysis processes occur that produce new acids. Temperatures above 350 °C speeds up the decomposition of cellulose and hemicellulose, increasing the amount of organic acids produced in liquid smoke [42].

Phenol and acid content exhibit distinct patterns with respect to pyrolysis temperature. After the temperature reaches 400 °C, the acid content increase while the phenol level decreases as the temperature increases. This effect implies that phenolic compounds can break down into acid compounds and other volatile chemicals at higher temperatures. Particularly through the thermal degradation of lignin and hemicellulose, a number of phenolic compounds that decompose at high temperatures aid in the production of acid products. Large amounts of phenol are produced by lignin at lower temperatures, but as the temperature rises, further decomposition results in acid compounds through secondary reactions [43].

CONCLUSIONS

The GC-MS instruments was used to identify the chemical components of liquid smoke, and 16 compounds were found at a pyrolysis temperature of 300 °C, 18 at 350 °C, and 20 at 400 °C. The identified compounds belong to the primary categories of liquid smoke components, including phenol and its derivatives, acids and their derivatives, and carbonyl compounds and their derivatives. The liquid smoke yields produced at 300 °C, 350 °C, and 400 °C were 7.5%, 9%, and 13%, respectively. The findings of the total phenol analysis (19.734 mg GEA/g, 14.778 mg GEA/g, and 13.109 mg GEA/g) and the total acid analysis (1.741%, 1.490%, and 1.859%) show at the pyrolysis temperatures of 300 °C, 350 °C, and 400 °C. Further research on the scalability and commercialization of Ubah Rukkok wood-based liquid smoke could open up new opportunities for sustainable and natural alternatives such as a natural perticide or fungicide in agricultural sector.

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