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THE EFFECT OF PYROLYSIS TEMPERATURE STRATIFICATION ON THE CHEMICAL COMPOUND OF WOOD VINEGAR PRODUCTION FROM HARDWOOD, SOFTWOOD, AND BAMBOO

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ABSTRACT

Generally, wood vinegar (WV) is produced from one-step carbonization for all purposes, i.e., antibacterial, food preservative, and agriculture. This carbonization process will result in WV with high phenol content. High phenol is beneficial for antimicrobials but can cause damage to plants if the WV concentration is not suitable. This research aimed to examine the effects of pyrolysis temperature stratification on three other biomass pyrolysis. This study uses hardwood, softwood, and nonwood waste, which are pyrolyzed with temperature stratification, namely 200, 300, 400, and 500 ºC. Proximates of raw material, pH, specific gravity, acetic acid, phenol, FTIR, and GCMS were used to characterize the physicochemical properties of the WV. The results showed that the pyrolysis temperature stratification affected the physicochemical of WV. The lowest acetic acid and phenol primarily obtained at a temperature of 200 ºC, found in teak wood vinegar (TWV), followed by bamboo (BWV) and pine wood (PWV), i.e., 1.92%, 4.9%, 8.02% (acetic acid) 0.1%, 0.2%, and 0.52% (phenol) respectively. In general, liquid smoke at 200 ºC is dominated by 2-methoxy phenol (in TWV & PWV), but at BWV, it is dominated by 2,6-Dimethoxyphenol. There were four dominant groups of compounds, namely acids, phenols, lactones, and carbonyls.

Keywords: Wood Vinegar, Lignocellulose, Pyrolysis, Teak, Pine, Bamboo.

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INTRODUCTION

Wood vinegar (WV) is a by-product of the carbonization or pyrolysis process, and charcoal is the main product. Wood vinegar has light yellow to reddish-brown or blackish-brown and scents like a smoky odor.[1,2] Wood vinegar has been widely researched and applied for some utilization as an alternative reduction of the dependence on synthetic chemicals. It's usually used in agriculture, stimulates plant growth, and counters pests and diseases as herbicides, seed germination, antimicrobe, antioxidant medicinal, food preservative, and smoky aroma. The benefit of WV is obtained from organic components contained in WV liquid. It is reported that over 200 compounds were identified in wood vinegar from different sources, especially organic acids, and phenolic compounds.[3,4,5,6,7] According to Theapparat[2], many factors affected the physicochemical activity of wood vinegar in its application, such as the carbonization system, refining method, and chemical composition of lignocellulosic biomass. Lignocellulosic biomass is considered a renewable or sustainable resource, abundant and inedible, that can source energy, carbon, biofuels, chemicals, and value-added products. Most lignocellulosic biomass is waste from other forest and farm industries, an event from household waste.[8,9] The benefits produced by WV depend on the raw material characteristics and the pyrolysis process. WV can be made from various raw materials from forestry, plantations, agriculture, and household waste.[10,11] However, each type of biomass has different compositional characteristics and levels of chemical compounds that can affect the composition of the resulting liquid smoke compounds[12], especially phenol, and acetic acid. According to Hans & Allison,[13] since wood is a biological raw material, its chemical composition and physical characteristics are naturally

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variable and have different chemical components, especially the ratio of syringyl and guaiacyl (S/G) unit at lignin on hardwood, softwood, and non-wood.[14] The ability of liquid smoke as an antimicrobial is influenced by phenolic compounds and organic acid compounds.[15] For antimicrobial purposes, wood vinegar generally uses in high concentrations, even in some antimicrobial studies using pure wood vinegar without dilution.[16] High phenol is helpful as an antimicrobial activity in non-plant use but causes phytotoxicity in plant leaves[17], so it is necessary to dilute wood vinegar before use on plants. However, the dilutions in several studies have different concentrations, from 0.002% to 1%[10,18] with varying responses. However, Tiilikkala *et al.*[17] stated that 1% of Birchwood vinegar alone could cause phytotoxicity in eggplant leaves. This phenomenon occurs because wood vinegar generally comes from a single-stage production at a temperature of 400-600 ºC,[10] which produces liquid smoke from the decomposition of polysaccharides, and lignin has been wholly decomposed.[6,10] Thus, information about temperature is an essential factor that must consider. The research on temperature stratification has not been done much, especially on different biomass, hardwood, softwood, and non-wood. Pyrolysis temperature stratification allows wood vinegar production with varying levels of phenol and organic acids at each temperature for antimicrobial, plant growth, or other purposes, while still producing mature charcoal. Hence, This research aimed to look into this study aimed to investigate the effect of temperature stratification on the characteristic of WVs. This study can be helpful for further utilization of wood vinegar, especially for sustainable agriculture in pest management, organic fertilizers, or growth stimulants so that it can support the SDGs no 2 programs, namely ending hunger, food security and improving nutrition and sustainable agriculture.

EXPERIMENTAL

Material and Equipments

The materials were teak wood, pine wood, and Andong bamboo waste. Bamboo was collected from Bogor District West Jawa. Thirty years old pine wood waste was collected from Sukabumi District West Jawa; meanwhile, 30 years old teak wood was obtained from Jepara District, Central Java. The samples were cut off into small pieces (ranging 4 - 6 cm in length and wide) and placed at room temperature for two weeks before the carbonization process. Each sample was crushed in a mill and then sieved for holocellulose, alpha-cellulose, lignin, and extractive analysis. The sample sizes were all less than 30-40 mesh.

Biomass Carbonization

The pyrolysis process was conducted in a stainless steel vertical tube reactor (20 cm in diameter and 45 cm high). In every run, about 2.5 kg of sample was loaded on the reactor. Then, the reactor is tightly closed and put into the furnace chamber. An electric furnace was used as a reactor heat source and connected to a condenser unit to obtain wood vinegar. Then, the reactor was heated from 25 ºC to 500 ºC. Wood vinegar was collected at temperature stratification 200, 300, 400, and 500 ºC and applied to three different raw materials with three replications. The wildwood vinegar was precipitated for three months. After that, three layers appeared on the crude wood vinegar, the top is a thin layer of oil, the middle is a thick layer of wood vinegar, and the bottom is a thin layer of wood tar. The middle layer was siphoned by a volumetry pipette and filtered using filtered paper Whatman 42, then collected on the different bottles. The yields of wood vinegar were calculated based on the weight of the sample.

Acetic Acid Analysis

The determination of acetic acid in wood vinegar was analyzed by titration following the SNI 01-3711-1995 method. This analysis used 5 g of the wood vinegar mixed with 25 mL distilled water, put into a 250 ml measuring flask, and added distilled water until the mark. Then a 25 mL solution was taken into a 250 mL Erlenmeyer, and five drops of 0.1% phenolphthalein were added. After that, a 0.1 N NaOH solution, normalized with potassium hydrogen phthalate, was gradually added to the solution until the color changed.

$$\text{Acetic acid value, \%} = \frac{\text{V x N x fp x 60,5 x 100}}{w}$$

V = NaOH solution for sample titration (mL)
N = normality of NaOH solution
fp = dilution factor
60.5 = equivalent weight of acetic acid
W = weight of the sample (mg)

Phenol Analysis

The Folin-Ciocalteu (FC) technique was used to calculate the total phenolic. 50 mg of WV diluted with methanol in a 10 mL measuring flask. Then, 0.5 mL dilute WV, 0.5 mL of FC reagent, 6 ml of distilled water, and 3 mL of 10% (w/v) solution of anhydrous sodium carbonate (Na_2CO_3) were filled in a 10 mL measuring flask, then let stand for thirty minutes. The total phenols were measured at an absorbance of 758 nm and using pure water for zero adjustments.

Specific Gravity

WV-specific gravity was determined by the pycnometer method and calculated by the following formula:

$$Density = \frac{(Pycno\ weight+sample)\ -(Empty\ pycno\ weigh\ )y}{(Pycno\ weight+distil\quad water)-(Empty\ pycnometer\ weigh\ )}$$

pH

The potential of hydrogen (pH) was measured by an Amtast AMT 20 pH meter.

FTIR

Raw material powder and wood vinegar samples were analyzed using FTIR (Thermo Scientific Nicolet iS5) to see the presence of functional groups. Sawdust and wood vinegar samples were prepared and then analyzed by FTIR using the ATR (Attenuated total reflection) method. The test conditions were 4000 – 650 nm, beamsplitter: KBr, and window: diamond.

GCMS

The chemical composition of WV was characterized using Pyr GCMS (Shimadzu QP 2010, Japan). Helium (99.99%) was employed at 1 ml/minute as carrier gas. The column oven temperature was set at 50 ºC (± 5 minutes) and programmed to increase to 280 ºC. The mass spectroscopic setting was; an ion source temperature of 200 ºC, detector temperature of 280 ºC, and pyrolizer temperature of 300 ºC. about 0.2 µL of the sample was injected into the sample inlet. The appropriate peak area calculated the relative compound's value.

RESULTS AND DISCUSSION

The Chemical Component of Lignocellulose Samples

The chemical components, as analyzed in three biomass lignocellulose, i.e., teak wood, pine wood, and bamboo, can be seen in Table-1. The highest holo cellulose contents were 71.91% in teak wood, followed by Andong bamboo and pine wood, i.e., 71.42% and 69.57%, respectively. Furthermore, the highest cellulose content occurred with teak wood (45.53%), followed by bamboo (44.61%) and pine wood (43.69%). Teak wood has the highest lignin content in teak wood (29.76%), followed by pine wood and bamboo, 29.03% and 27.42%, respectively. According to Rowell[19] in comparison to hardwood species, softwood species have higher lignin (26-34%) and cellulose content (40-45%). However, in this study, hardwood, especially teak wood, had higher cellulose and lignin content than softwood (pine). Nevertheless, hardwood, softwood, and non-wood have different compositions of cellulose, hemicellulose, lignin, and extractives which can affect the chemical compounds of WV products. The results of the S/G ratio analysis showed that the teak wood samples had an S/G ratio of 0.79, pine wood 0.62, and bamboo 1.58, respectively. The data follows the research of Kacikova[20] that teak wood has an S/G ratio of 0.71-0.81. Also, the S/G ratio of bamboo is in the range of 1.1-3.0.[21]

Table-1: Properties of Chemical Components From Teak Wood, Pine Wood, and Bamboo

Sample	Water content (%)	Holocellulose (%)	Cellulose (%)	Hemi-cellulose (%)	Lignin (%)	Ektraktif (%)	SG ratio
Teak wood	11.02±0.14	71.91±0.79	45.53±0.45	26.37±1.14	29.76±1.60	8.33±0.80	0.79±0.02
Pinewood	10.99±0.3	69.57±0.58	43.69±1.05	25.87±1.63	29.03±0.99	4.13±0.20	0.62±0.03
Bamboo	11.04±0.13	71.42±1.39	44.61±0.58	26.80±1.97	27.42±0.54	3.78±0.16	1.58±0.03

At the same time, the S/G ratio of pine is slightly lower than Lukmandaru,[22] which has an S/G ratio of 0.57 The S/G ratio is helpful for efficiency in the pulping and demethylation process, especially at Harwood and some non-wood biomass which requires fewer chemicals in the pulping and bleaching process than softwood because hardwood has syringyl-rich lignin, which is less condensed.[23,24]

Effect of Stratification Temperature on Wood Vinegar Yield

The properties of wood vinegar from hardwood, softwood, and bamboo with different pyrolysis temperature ranges are shown in Table-2. Based on the result, the maximum yield reached 22.02% in TWV, followed by BWV, 19.35%, obtained at 400 ºC, and PWV has the highest product yield, 13.70% at 500 ºC. The lowest yield of WV was obtained on BWV at 500 ºC 4.2%. Generally, when the pyrolysis temperature increases, the WV yield will increase and decrease back. The pyrolysis temperature stratification gave different yields between the raw materials. At a temperature of 200 ºC, teak wood produced 6.70% WV, lower than WV from bamboo and pine at the same temperature, which had 12.6%, and 15.08%, respectively. Even on pine WV, 200 ºC was the highest yield that obtained compared to the temperature of 300, 400, and 500 ºC. The high yield of PWV at 200 ºC can be caused by the characteristics of the anatomical structure of the wood. It is known that the structure of pine wood (softwood) is more superficial, homogeneous, and uniform than hardwood wood which is more complex and varies not only in cell types but also in shape, arrangement, and size.[25] The simple anatomical structure of the wood makes it easier for the liquid to escape or evaporate in softwood when the temperature reaches 100-200 ºC. Pyrolysis also produces tar (total aerosol residue). Table-2 shows obtained the lowest tar yield at a temperature of 200 ºC in all samples, but the highest tar was produced at 400 ºC for teakwood at 6.92 ± 1.05 and bamboo at 4.79 ± 0.25, while in pine wood, the highest tar was obtained at 500 ºC of 4.52±0.33. The high tar yield from teakwood can be caused by high lignin content and high extractives (Table-1). Tar is a complex mixture of ingredients that are produced by pyrolysis or gasification, containing heterocyclic organic matter, chain, cyclic and aromatic hydrocarbons or defined as all organic pollutants that have greater molecular weight than benzene.[26]

Table-2: Yields of WVs from Three Different Lignocellulose and Stratification of Pyrolysis Temperature

Temperature, ºC	Yield, %					
	Teak wood		Pinewood		Bamboo	
	WV	Tar	WV	Tar	WV	Tar
200	6.70 ±0.97	0.03±0.02	15.08±1.63	0.9±0.07	12.6±1.12	0.17±0.01
300	13.62±1.47	2.23±0.66	8.77±1.55	1.32±0.31	10.44±1.14	1.10±0.32
400	22.02±2.91	6.92±1.05	12.38±0.63	2.66±0.05	19.35±1.31	4.79±0.25
500	8.21±3.31	3.18±1.09	13.70±0.54	4.52±0.33	4.20±1.25	1.68±0.72

pH

pH is a quality character regulated in the SNI 8385 2021 for wood vinegar. The results of the pH analysis (Table-3) show that the collection of wood vinegar at higher temperature stratification will tend to produce a lower pH. PWV has the lowest pH at 400 ºC, i.e. 1.89 and BWV has the highest pH at 500 ºC i.e. 3.39. Table 3 shows that the pH of pine wood WV tends to be lower in all temperature stratifications. This result is probably due to the presence of extractive substances, namely pine resin, which will contribute to the acidity of the WV. According to the literature, the acid index of *pine merkusii* and *p. oocarpa* resins is between 176-179 m KOH/g and 134.0 - 137.35 m KOH/g.[27,28]

Acetic Acid

Acetic acid is also a quality standard in the SNI 8985-2021. The results of acetic acid analysis (Table-3) show that the TWV at 200 ºC has the lowest acetic acid content of 1.92, followed by BWV, i.e. 4.90%, and PWV at 8.02%. Meanwhile, the highest acetic acid content was obtained at 400 ºC for all raw materials for TWV, BWV, and PWV, namely 13.26%, 13.46%, and 13.81%. At a temperature of 400 ºC, all samples produce acetic acid, which is not much different. According to Lu[29], in the pyrolysis process, organic acids are mainly obtained from the decomposition of hemicellulose. Meanwhile, polysaccharides, cellulose, and hemicellulose, form anhydraosugar, carboxylic acids, furans, ketones, and aldehydes. At the same time, lignin is mainly composed of aromatic compounds of low molecular weight with guaiacyl units or phenolic units.[30]

Specific Gravity

The specific gravity of WV can be seen in Table-2. There is a tendency for specific gravity increment when the pyrolysis temperature increase, although not significant. WV at 200 ºC has the lowest specific gravity, i.e. TWV 1.0057, PWV 1.0413, and BWV 1.0279, respectively. While the highest specific gravity at 500

oC is 1.0769, 1.1187, namely teak and pine, in liquid smoke bamboo, the most increased specific gravity is at a temperature of 400 oC, 1.0576. Specific gravity shows the number of components in WV that affect the weight of WV. The results of the specific gravity of WV from this study meet the requirements of the WV standard of SNI 8985 2021.

Table-3: The Properties of WVs from Three Different Lignocellulose and Stratification of Pyrolysis Temperature

Sample	Temp °C	Color	Yield %	pH	Specific gravity	Acetic acid %	Phenol %
Teak wood	200	Yellowish	6.70 ±0.97	2.62±0.19	1.0057±0.002	1.92±0.99	0.10±0.07
	300	Light brown	13.62±1.47	2.09±0.02	1.0501±0.009	12.04±1.03	0.79±0.15
	400	Redish brown	22.02±2.91	2.05±0.02	1.0874±0.011	13.26±0.46	1.40±0.17
	500	Dark brown	8.21±3.31	2.13±0.05	1.0769±0.007	10.38±1.36	1.25±0.08
Pinewood	200	Redish brown	15.08±1.63	2.08±0.07	1.0413±0.007	8.02±0,99	0.52±0.06
	300	Dark brown	8.77±1.55	1.93±0.01	1.0741±0.005	12.53±0.32	0.82±0.07
	400	Dark brown	12.38±0.63	1.89±0.02	1.0953±0.002	13.46±0.19	1.19±0.09
	500	Dark brown	13.70±0.54	1.90±0.02	1.1187±0.007	13.15±0.46	1.48±0.12
Bamboo	200	Yellowish	12.6±1.12	2.43±0.02	1.0279±0.028	4.90±0.52	0.20±0.02
	300	Redish brown	10.44±1.14	2.37±0.03	1.0342±0.005	11.36±0.55	0.60±0.09
	400	Dark brown	19.35±1.31	2.54±0.03	1.0576±0.003	13.81±0.31	1.11±0.01
	500	Redish brown	4.20±1.25	3.39±0.48	1.0340±0.012	6.85±2.07	0.77±0.15
SNI 8985-2021		Yellow to brown	-	a. 1.5 - 2.75 b. 2.76-4.5	a. 1.005-1.050 b. 1.005-1.050	a. 8.00-15.00 b. 1.10-7.99	a. max 2 b. max 2

Remarks: a. Grade 1; b. Grade 2

Phenol

The results showed that the stratification of pyrolysis temperature obtained different phenol levels (Table-3). The lowest phenol was obtained at 200 °C in all wood vinegar; TWV, PWV, and BWV were 0.1%, 0.52%, and 0.2%, respectively. Meanwhile, the highest phenol was obtained at 400 °C in TWV and BWV, i.e., 1.40% and 1.11%, while the highest phenol in PWV was obtained at 500 °C, i.e., 1.48% (Table-3). According to Lu[29], phenol is produced by the fragmentation or breaking of the C−C and ether bonds in lignin during pyrolysis. The detection of phenol at 200 °C is possible from the phenol in the lignocellulosic extractive substance, which begins to come out with the degraded cell fluid at a temperature of 120-200 °C. TWV contains 4-Ethyl-2-methoxyphenyl, 2-methoxy-4 methyl phenol, and 2-methoxyphenyl, which are included in guaiacol (Guaiacyl lignin), then there are also 2,6-Dimethoxyphenol, 4-Hydroxy-3,5-Dimethoxy, and benzaldehyde (syringyl lignin). This phenol indicates that the primary units of lignin in TWV are guaiacyl and syringil. Phenols in PWV are guaiacol (2-methoxyphenyl), 4-hydroxy-3-methoxy benzaldehyde (vanillin), 2-methoxy-4-propyl phenol (5-propyl-guaiacol), acetovanillone (Ethanone, 1-(4-hydroxy- 3-methoxyphenyl), all of which include guaiacyl lignin. In addition, there is also p-hydroxyphenyl monomer lignin, namely phenol izal. This result indicates that the primary unit of lignin in PWV is dominated by guaiacyl. Meanwhile, phenol in BWV are p-Ethylguaiacol (4-ethyl-2-methoxyphenyl), guaiacol (2-methoxy phenol), acetovanillone (ethanone, 1-(4-hydroxy-3-methoxyphenyl), also syringyl lignin derivatives namely methylsyringol (1,2,3- trimetoxybenzene), and p-hydroxyphenyl lignins, namely m-Ethylphenol (3-ethylphenol) and phenol izal. The data indicates that the BWV consists of guaiacol, syringil, and p-hydroxyphenyl. This result follows Kishimoto[23], who stated that hardwood is dominated by syringyl and guaiacyl in a particular ratio, softwood is dominated by guaiacol lignin, and non-wood, such as bamboo consists of guaiacyl, syringil, and p-hydroxyphenyl.

FTIR

The WV functional groups were analyzed using FTIR. Based on Fig.-1, it can see that the FTIR spectrum of TWV, PWV, and BWV has a broad absorption band at a wave number of 3279-3363 cm^{-1}, which is a

hydrogen bond, i.e., hydroxyl OH, which is strengthened by the presence of an absorption band at 1600-1300. cm^{-1}, which is the OH bending. Absorption at 1701-1712 cm^{-1} exhibits the appearance of vibrations of the C=O carbonyl group (ketone, aldehyde, ester, or carboxyl). In TWV and PWV at 200 ºC, and 300 º,C and BWV at 200-500 ºC, the wave absorption band of 1700 is very smooth or weak. The carbonyl group levels can cause this at 200 and 300 lower than 400 and 500 ºC, as well as the presence of conjugation with other carbonyl groups (aldehydes, ketones, esters, and carboxylic acids) in WV, which will decrease the peak intensity of the double bond or aromatic and decrease the absorption frequency of carbonyl.[31] Absorption at wave numbers around 2900 and 1634-1640 cm^{-1} exhibits the appearance of a strain of the carbonyl functional group (C=O). Although the wavelength of 2900 cm^{-1} looks smooth at 200 and 300 ºC, the GCMS results confirm the presence of the carbonyl group at that temperature range. Absorption at 1370 cm^{-1} shows the C−H group on CH_3 lignin, and wave number between 1310-1410 cm^{-1}, which is 1367-1395 cm^{-1}, indicates phenol; OH strain, which is strengthened by absorption band at 1271-1295 cm^{-1}. In comparison, the wave numbers 1016, and 1051 cm^{-1} indicate the C−O strain, which, when referring to Nandianto[31], is a hydroxyl compound.

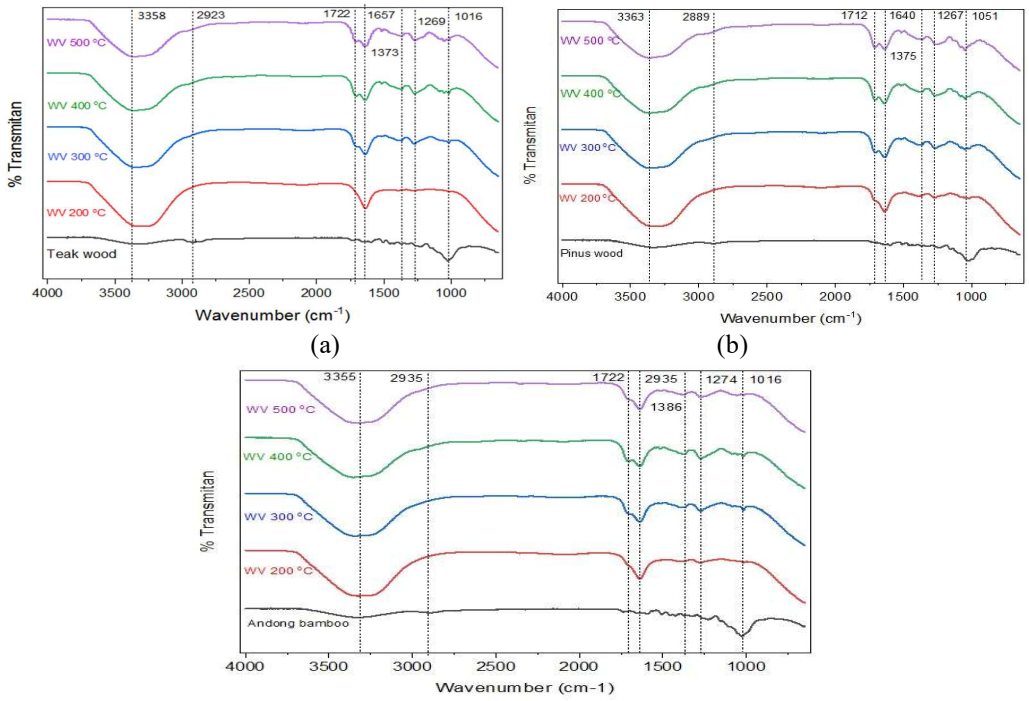


Fig.-1: FTIR of TWV (a), PWV (b) and BWV (c)

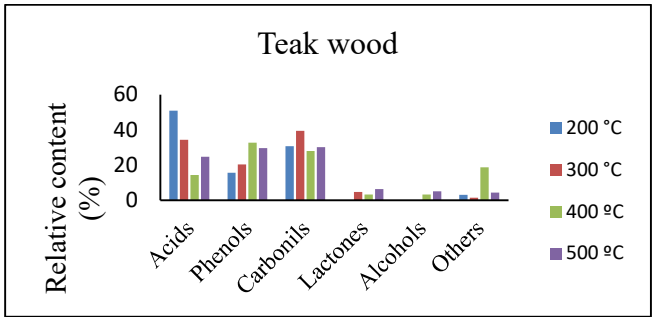
Chemical Compound

The chemical composition of WV was carried out using GCMS. The relative content of pyrolysis products and the distribution of chemical composition are presented in Fig.-1. It can see that the pyrolysis temperature stratification produces different amounts of compounds at each temperature. Meanwhile, for the types of raw materials, there are variations in the number of chemical compounds that are not much different. Liquid smoke is taken based on the stages of temperature 200-500 ºC and produces components that vary at each temperature. The GCMS results showed that the chemical components of TWV at 200 ºC were 13 components dominated by acetic acid (50.84%), carbonyl (30.64%), and other compounds (3.03%), and no lactone and alcohol were detected. At 300 ºC, 30 compounds were detected, which were dominated by carbonyl groups (39.4%), organic acids (34.27%), phenols (20.33%), lactones (4.66%), and others (1.34%), but alcohols not detected. The relative compound content at 400 ºC detected 31 chemical compounds dominated by phenol (32.68%) followed by a carbonyl (27.96%), organic acids (14.29%), lactones (3.21%), alcohol (3.21%). %) and others (18.65%). Meanwhile, teak liquid smoke at a temperature of 500 ºC detected 30 chemical compounds, dominated by a carbonyl (30.16%) followed by phenol (29.63%), organic acids (24.66%), lactone (6.32%), alcohol 4.93% and other compounds (4.3%). There are

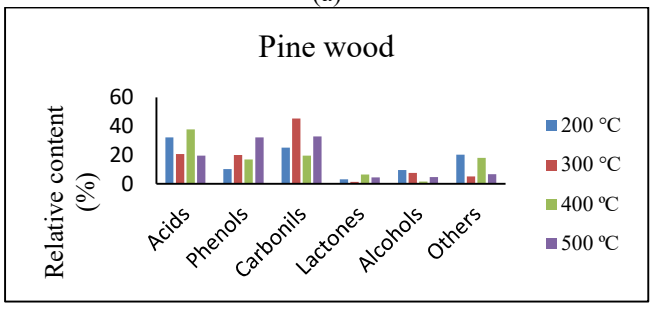
24 chemical components of PWV at 200 ºC, dominated by acid (32.25%), carbonyl (25.04%), other compounds (20.16%), phenol (10.14%), alcohol (9.42%), and lactones (2.99%). Liquid smoke at 300 ºC detected 26 chemical compounds, dominated by a carbonyl (45.37%), followed by acid (20.63%), phenol (20%), alcohol (7.46%), other compounds (5.16%)), and lactone (1.38%). PWV at 400 ºC detected 21 chemical compounds, dominated by acids (37.68%), followed by a carbonyl (19.6%), phenol (16.87%), other compounds (14.81%), lactone (6, 38%), and alcohol (4.66%). Meanwhile, at 500 ºC, 27 chemical compounds were detected, dominated by a carbonyl (32.81%), followed by phenol (32.13%), acid (19.39%), other compounds (6.67%), alcohol (4,68%), and lactones (4.32%). The chemical components of BWV at 200 ºC contained 19 chemical compounds, dominated by acid (55%), carbonyl (26.7%), phenol (15.63%), other compounds (20.16%), lactone (2.43%), and alcohol (0%). Bamboo liquid smoke at 300 ºC detected 28 chemical compounds, dominated by acid (30.2%), phenol (29.53%), carbonyl (20.27%), alcohol (13.31%), lactone (6.69 %) and other compounds (0%). Liquid smoke at 400 ºC detected 30 chemical compounds, dominated by phenol (31.77%), acid (31.61%), carbonyl (30.27%), lactone (5.48%), other compounds (0.87 %) and alcohol (0%). Meanwhile, in liquid smoke at a temperature of 500 ºC, 30 chemical compounds were detected, dominated by phenol (33.45%), acid (31.82%), carbonyl (26.16%), lactone (5.18%), other compounds (03 0.01%) and alcohol (0.38%). The low amount of WV chemical compounds at 200 ºC is since not many chemical components of wood are degraded at that temperature besides water and extractive substances. This condition corresponds to the opinion of Dietenberger and Hasburgh [32] that at temperatures of 100 and 200 ºC, wood is dehydrated, producing water vapour, gases, and other non-flammable liquids, CO, CO_2, glyoxal, formic, and acetic acid, as well as natural extractive will decompose between 150-200 ºC. According to Theapparat[2], the chemical compounds contained in WV will vary depending on the type of biomass and different pyrolysis temperature conditions. Figure-2 shows that the chemical compounds identified in the TWV, PWV, and BWV are acids, phenols, carbonyls, lactones, alcohols, and others with different relative contents.

CONCLUSION

The lowest acid and phenol levels were obtained at 200 ºC and the highest at 400-500 ºC. Lignin-derived phenols in hardwood WV dominated; guaiacyl and syringil, softwood WV were dominated by phenolic derivatives of guaiacyl lignin, while bamboo WV detected phenols from guaiacyl, syringil, and p-hydroxyphenyl derivatives. Wood vinegar production by pyrolysis temperature stratification produces different chemical compositions. This condition allows the use of wood vinegar that is more diverse and specific for antimicrobial and plant growth stimulants or other services.



(a)



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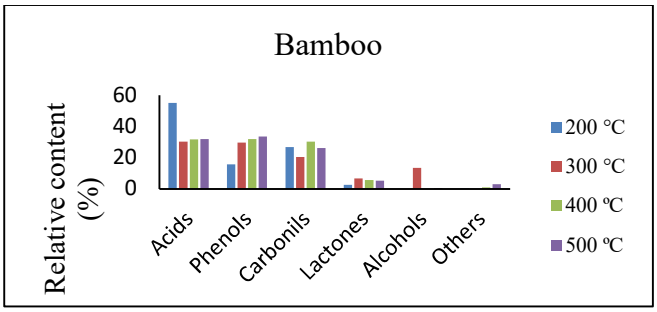

(c)

Fig.-2: Profiles of Six Groups of Chemical Compounds a. TWV, b. PWV, c. BWV

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CONFLICT OF INTERESTS

All author (s) declared that this research has no conflict of interest.

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