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EFFICACY OF PYROLIGNEOUS ACID FROM PINEAPPLE WASTE BIOMASS AS WOOD PRESERVING AGENT

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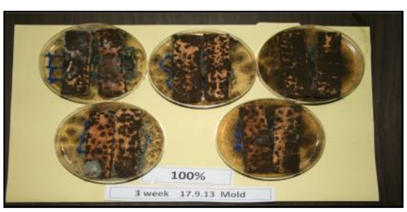
Graphical abstract



Abstract

Improper management of lignocellulosic biomass generated from agricultural activities would lead to serious environmental problems. Pyrolysis offers a simple yet efficient alternative technique where Pyroligneous acid (PA) is a major by-product obtained during slow pyrolysis of lignocellulosic biomass. In this study, the potential anti-termites and anti-fungal properties for PA obtained from the pyrolysis of pineapple waste biomass were investigated. PA from pineapple waste biomass showed insignificant inhibition properties against both *Pycnoporus sanguineus* and *Coriolus versicolor*, but were successful in inhibiting the growth of both *Aspergillus niger* and *Botryodiplodia theobromae* for 7 days when applied at 70% (v/v) and 100% (v/v) concentrations. PA also exhibited good anti-termites properties based on the 100% mortality of *Coptotermes curvignathus* after one week incubation. GC-MS analysis revealed the presence of phenolic compounds and phenol with ortho substituents such as 2,6-dimethoxyphenol and 2-methoxy-4-methylphenol. Both compounds have been reported to play an important role in termiticidal activity from previous studies. This study indicates that PA from pineapple waste can act as antifungal and antitermite agents but not as anti-wood decaying fungi. This result can be used as a good preliminary indication for future application of PA from pineapple waste biomass as wood preservative.

Keywords: Pyroligneous acid, rubberwood, antifungal, antitermites, phenols

Abstrak

Pengurusan biojisim lignoselulosa yang tidak teratur dijana daripada aktiviti pertanian akan membawa kepada masalah alam sekitar yang serius. Pirolisis menawarkan teknik alternatif berkesan lagi mudah di mana asid Pirolignеous (PA) sebagai produk sampingan utama yang diperoleh ketika pirolisis perlahan biojisim lignoselulosa. Dalam kajian ini, potensi PA daripada pirolisis sisa biojisim nanas sebagai anti anai-anai dan antikulat telah disiasat. PA daripada sisa biojisim nanas menunjukkan sifat perencatan yang tidak ketara terhadap kedua-dua *Pycnoporus sanguineus* dan *Coriolus versicolor*, tetapi berjaya dalam menghalang pertumbuhan *Aspergillus niger* dan *Botryodiplodia theobromae* selama 7 hari apabila digunakan pada kepekatan 70% (v/v) dan 100% (v/v). PA juga menunjukkan ciri-ciri anti anai-anai yang baik berdasarkan 100% kematian *Coptotermes curvignathus* selepas satu minggu inkubasi. Keputusan analisis GC-MS mendedahkan kehadiran sebatian fenolik dan fenol dengan penukargantian orto seperti 2,6-dimetoksifenol dan 2-metoksi-4-metilfenol. Kedua-dua sebatian telah dilaporkan memainkan peranan penting dalam aktiviti termitisidal oleh kajian sebelumnya. Hasil kajian menunjukkan PA dari sisa nanas boleh bertindak sebagai antikulat dan agen anti anai-anai tetapi tidak sebagai anti kulat pereput. Keputusan ini boleh digunakan sebagai petunjuk awal yang baik untuk aplikasi PA daripada sisa biomas nanas sebagai pengawet kayu pada masa akan datang.

Kata kunci: Asid piroligneous, kayu getah, antikulat, anti anai-anai, fenol

1.0 INTRODUCTION

Pineapple (*Ananas comosus*) is an herbaceous perennial plant species that has been cultivated in Malaysia for more than 90 years as cash crop and the plantation areas keep expanding in peat soil area. Malaysia is one of the world major pineapple producers along with Thailand, Philippines, Indonesia, Hawaii, Ivory Coast, Kenya, Brazil, Taiwan, Australia, India and South Africa [1]. Large-scale production would also result in large volumes of biomass being generated where if not properly disposed, would directly contribute to environmental problems such as soil and water pollution. Conventional biomass management technique of open burning is effective but not favourable due to air pollution. These conditions have increased the need to find alternative management techniques that preferably would not only reduce the environmental impact of such processes but can also be turned into valuable products and energy.

Pineapple biomass composed of about 252.0 g of glucan, 63.2 g of xylan and 182.6 g of lignin per kg dry biomass feedstock [2, 3]. One of the conversion techniques available is pyrolysis, which can be defined as a heating process at high temperature without the presence of oxygen. Pyroligneous acid (PA), also known as wood vinegar is one of the by-products from the pyrolysis process. Some of its characteristics are as follows: a crude condensate produced from smoke distillation, reddish-brown, comprises of water and a complex mixture of major compound groups namely carboxylic acid, hydroxyaldehydes, hydroxyketones, sugars and phenolics [4, 5, 6]. PA also has various high commercial value chemicals compounds such as acetic acid, acetone, methanol, formic acid, guaiacol, catechol, syringol, vanillin, furan, carboxaldehydes, isoeugenol and pyrone [4, 6], which has been used in various applications such as sterilizing agent, deodorizer, fertilizer, antimicrobial and plant growth promoting agent [7,4], antioxidant [8] and as a wood preservative agent [5].

Lately, the use of boron and copper-chromium-arsenate, CCA compounds as conventional wood preserving agents [10, 11] has been restricted due to its toxic properties notably after long-term exposure. CCA-treated timber, commonly used in outdoor wood products such as fences, decking and playground equipment, posed a threat through the possible leaching of either Cu, Cr or As into the surrounding environment which can be easily be transferred to the human skin owing to its high solubility in solution.

In this study, the potential of pyroligneous acid (PA) produced from the carbonisation of pineapple waste biomass as wood preserving agent was investigated. The growth-inhibitory effect of various concentrations of PA on *Pycnoporus sanguineus*, *Coriolus versicolor, Aspergillus niger* and *Botryodiplodia theobromae* was evaluated using rubberwood (*Hevea brasilliensis*). PA was also characterised for its active chemical compounds using instrumental analysis.

2.0 METHODOLOGY

2.1 General

The pH values for PA from pineapple waste biomass were determined using a pH meter (Eutech Instrument). Fourier Transform Infrared (FT-IR) Spectrometer (Shimadzu, Japan) was used to analyse chemical functional groups present in PA while quantitative determination of major compounds present were carried out using Gas Chromatography-Mass Spectrometry (HP-7890A, Agilent, USA). The sample was prepared using the following procedures; PA was extracted using dichloromethane (CH_2Cl_2) with a ratio of 1:1. The organic phase (bottom layer) was collected and underwent solvent removal using rotary evaporator (Heidolph 4000, Germany) to yield DPAP prior to GC-MS analysis. Sample (2μl) was injected into the capillary column with a flow rate of 1 ml/min using He as the carrier gas. The stationary phase used was 5% (v/v) phenyl and 95% (v/v) dimethylpolysiloxane with oven temperature setting as follows: 10 min at 40°C, heated at 5°C/min to 150°C, held for 1 min and then heated again at 10°C/min to 280°C and held for another 3 min. Compounds identification were based on comparison of their mass spectra with the National Institute of Standards and Technology (NIST) library.

2.2 Materials

200 kg of pineapple waste biomass including stem and leaves of Josapine hybrid variety were collected from pineapple plantation at Parit Ghani, Simpang Renggam, Johor. The samples were cut into small pieces of irregular shape (average length of 12-15 cm) and further carbonised in a charcoal kiln for 48 h at temperatures ranging from 200 to 500°C at one local charcoal manufacturing company, Maju Jaya Organik Sdn. Bhd located in Kluang, Johor. The smoke released from the heating process was allowed to cool down by passing through multistage condensers

to yield pyroligneous acid. Then, the sample was stored in the dark at temperature below 20°C prior used [34].

2.3 Pre-treatment of the Rubberwood with PA

Evaluation on the effectiveness of PA as wood preserving agent was carried out at the Wood Mycology Laboratory, Forest Research Institute of Malaysia (FRIM), located in Kepong, Selangor. Three types of test were carried out, namely, molds and blue sapstain, fungi-decay and termite. For each test, specific numbers of rubberwood (*Hevea brasiliensis*) blocks were used as follows: fungi decay test - 320 pieces (19 mm in length, width, thickness); molds and blue sapstain test - 160 pieces (70 mm in length, 20 mm in width, 7 mm in thick), and 50 pieces (25 mm in length, 25 mm in width and 6 mm in thick) for the termite test. The moisture content (% of dry basis) of rubberwood sample prior to treatment was calculated based on ASTM method D1413-76 (reapproved 1994): Standard Test Method for Wood Preservatives by Laboratory Soil-Block Cultures [12]. The initial weight of a piece of rubberwood (dimension 19 mm x 19 mm x 19 mm) was recorded as W_1. At the end of the treatment period, the wood specimen was dried in a drying oven (600 Memmert) at 105°C for 24 hours, weighted and designated as W_2. The percentage of dry basis was determined according to the following correlation, % dry basis = $[(W_1-W_2) / W_2] \times 100$. For the treatment process, 8 different concentrations of PA were used namely (in % v/v); 0.01, 0.1, 0.5, 1.0, 10, 30, 50 and 100. Wood specimen were placed in the 3 liters vacuum bell jar (as treating chamber) and impregnated with PA at 90 psi for 1 hour. The mixtures were left to immerse for another 3 hours at room temperature. Subsequently, the wood blocks were taken out and the excess solution was wiped off, weighed immediately and allowed to dry to constant weight for 3 weeks at room temperature. The extent of PA retention by the rubberwood blocks was calculated based on the gain in weight relative to the untreated rubberwood blocks, which acted as control.

2.4 Evaluation on Efficacy of PA as Wood Preserving Agent

2.4.1 Decay Fungi Resistance Test

The decay fungi resistance test was carried out according to the ASTM test method D1413-76 (ASTM 1976, reapproved 1994) [12] using both local and global white rot fungi. Two strains of white-rot fungi, *Pycnoporus sanguineus* (WML 006) and *Coriolus versicolor* (WML 002) were grown on malt extract agar, MEA (600 g Bacto™ Agar, 600 g Bacto™ Malt Extract, 800 ml distilled water) slants in petri dish at 27°C prior to use. The PA-treated rubberwood test blocks were conditioned to constant weight and exposed to both fungi. After 12 weeks of incubation at 27°C and 70% of relative humidity (RH), the fungi mycelium were brushed off and weighted immediately. The rubberwood blocks were then dried at 60°C and the weight loss was determined as percentage of total rubberwood test block mass.

2.4.2 Mold and Blue Sapstain Test

The mold and sapstain resistance tests were carried out according to the ASTM D4445 method (Standard Test Method for Fungicides for Controlling Sapstain and Mold on Unseasoned Lumber, Laboratory Method) [13]. Strains used were *Aspergillus niger* (ATCC 9642) and *Botryodiplodia theobromae* (WML 007) respectively. The rubberwood blocks were exposed to mold and sapstain in a sealed petri dish at 27°C and 70% of RH. The test was carried out for a period of 4 weeks with weekly observation by calculating the number of days for mold to start growing on the test block together with coverage area of mold on the test block.

2.4.3 Termite Test

The termite resistance against PA-treated wood block was carried out according to method as outlined in ASTM D3345-08: Laboratory Evaluation of Wood and Other Cellulosic Materials for Resistance to Termites [14]. Sand (150 g) was introduced into the glass container and autoclaved for 65 min at 121°C. One piece of wood test block was placed at the bottom of the container with one edge of the block stacked up against the side of the container together with 30 ml of distilled water and left for 2 hours. Then, 400 subterranean termites namely *Coptotermes curvignathus* Holmgren (Isoptera: Rhinotermitidae) were added into each containers, where 90% consist of worker termites while the remaining 10% were soldier termites. The containers were maintained at 22°C and 70% of RH for 4 weeks. A total of 5 replicates were used for all treatments. After week 1 and week 4 of the testing period, termite activity in each bottle was rated visually. At the end of the test period, mean changes in test blocks for each variable test was analysed statistically using analysis of variance (ANOVA) and Tukey's post-hoc test. All results were interpreted according to AWPA E1-09: Standard method for laboratory evaluation to determine resistance to subterranean termites [15].

3.0 RESULTS AND DISCUSSION

3.1 Characterization of PA

The smoky dark brown PA showed an acidic characteristic with pH value of 3.78. Major compounds determined in the dichloromethane extract of PA (DPAP) from pineapple waste include 2,6-dimethoxy phenol (21.27 %), phenol (13.69 %), 3-hydroxy-4-methoxybenzoic acid (6.38 %) and 2-methoxy-4-methyl phenol (3.44 %). Meanwhile, major chemical functional groups for the PA from pineapple waste biomass are summarized in Table 1. The FT-IR spectrum in Figure 1 revealed the presence of hydroxyl and carbonyl groups with prominent peaks at 3442 and 1634 cm^{-1}, respectively. Meanwhile, the absorption at 1416 cm^{-1} can be attributed to the C-H stretching from methylene group, C-O ether and aromatic compounds were also indicated by the absorption at 1062 cm^{-1} and 695 cm^{-1}, respectively. The decomposition of cellulose and hemicellulose in pyrolysis process produced carbonyl groups such as carboxylic acid, aldehydes and ketones, together with phenol and alcohol. The C=O stretching group was observed at frequency 1634 cm^{-1}.

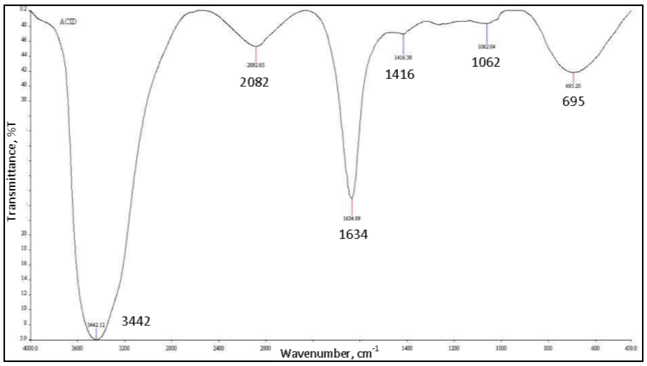


Figure 1 FTIR spectrum of dichloromethane extract of PA

Other FTIR analysis using different types of PA also reported similar profiles for chemical constituents present. PA from mangrove [5], bamboo [9], rice straw, jute-stick and bagasse [16] recorded the stretching vibration between 3600-3200 cm^{-1} which indicated the presence of water impurities and other polymeric alcohols in the pyrolytic oil. Meanwhile, the absorbance peak between 1775-1650 cm^{-1} represented the C=O stretching vibration, displaying the existence of ketones, aldehydes and carboxylic acids [16]. The O-H vibration is corresponding to water vapour peak, where the hydroxyl group easily forming hydrogen bond within or between molecules during pyrolysis of biomass. This resulted in the formation of water and carbonyl groups. The pronounced oxygenated functional groups of O–H; C=O; C–O and aromatic compounds showed that the PAs were highly oxygenated and therefore, very acidic, as have also been indicated by the elemental composition and the pH value. The presence of hydrocarbon groups C–H; C=C; and alcohols indicate that the liquids have the potential to be used as fuel [16]. Meanwhile, the GC-MS analysis on the dichloromethane extract of pineapple PA (DPAP) revealed high abundance of phenolic constituents in the extract. Many phenolic compounds were recorded as antimicrobial agents [29, 30] and exhibited strong termiticidal activity against *Odontotermes assamensis* [31].

Table 1 Functional groups present in PA from pineapple waste biomass compared to PA from other types of lignocellulosic materials

Raw materials to produce PA	Frequency, cm^{-1}	Functional group	Class of compound
Pineapple waste biomass	3442	O-H	Polymeric O-H, water impurities
	1634	C=O	Carboxylic acid, ketones, aldehydes
	1416	CH_2 bending	Alkanes
	1062	C-O, O-H	Alcohols, phenol, esters, ethers
	695		Aromatic compounds
Rice-straw, jute-stick and bagasse PA (Islam *et al*., 2003)	3600-3200	O-H	Polymeric O-H, water impurities
	3050-2800	C-H stretching	Alkanes
	1775-1650	C=O	Carboxylic acid, ketones, aldehydes
	1680-1575	C=C	Alkenes
	1550-1475	NO_2	Nitrogenous compounds
	1490-1325	C-H bending	Alkanes
	1300-950	C-O, O-H	Alcohols, phenol, esters, ethers
	900-650		Aromatic compounds
Mangrove (Lee *et al*., 2011)	3600-3200	O-H	Polymeric O-H, water impurities
	3500-3200	N-H	Amine compounds
	3000-2800	C-H	Alkanes
	1300-950	C-O, O-H	Alcohols, phenol, esters, ethers
Bamboo (Lee *et al*., 2011)	3600-3200	O-H	Polymeric O-H, water impurities
	3000-2800	C-H	Alkanes
	1600-1500	N-O	Nitrogenous compounds
	1600-1400	C=C	Alkenes
	1300-950	C-O, O-H	Alcohols, phenol, esters, ethers

3.2 Decay Fungi Resistance Test

After twelve weeks of being exposed to *P. sanguineus* (WML 006) and *C. versicolor* (WML 002), all treated and untreated rubberwood blocks showed visible fungi colonisation on the surface of the wood blocks. The percentage of weight loss and level of resistance for all blocks is summarised in Table 2. Based on the results shown in Table 2, there was no significant difference between the mean weight loss values for all formulations (the resistance classes were based on weight loss of test blocks as determined according to

ASTM D-2017-71 Standard). All test blocks exposed to both *P. sanguineus (WML 006) and C. versicolor (WML 002)* exhibited the same resistance effect with mean weight loss ranging from 39.34% to 31.01%. Amongst them, the test blocks treated with 100% PA showed the lowest mean weight loss at 30.36% and 31.01%, respectively.

Table 2 Average weight loss and resistance class of wood blocks after exposure to *P. sanguineus* and *C. versicolor*

Concentration of PA (%)	Average weight loss (%)		Resistance class
	Pycnoporus sanguineus	***Coriolus versicolor***	
100	30.36 ± 3.83	31.01 ± 4.81	Moderately resistant
70	33.69 ± 2.97	32.21 ± 4.75	Moderately resistant
30	35.79 ± 6.57	36.65 ± 4.92	Moderately resistant
10	39.11 ± 4.52	38.08 ± 5.29	Moderately resistant
1	36.86 ± 3.89	36.10 ± 4.07	Moderately resistant
0.5	38.27 ± 5.42	38.51 ± 3.64	Moderately resistant
0.1	39.34 ± 4.41	37.73 ± 2.73	Moderately resistant
0.01	37.96 ± 5.51	33.51 ± 5.71	Moderately resistant
Control	25		Resistant

The moderate resistance effect against all treated blocks might be due to high water content in pineapple PA which is about 95.7% [17] even though previous report showing that the antifungal activity of PA is likely to be higher against white-rot fungi than brown-rot fungi [18]. In this study, the resistance effect against wood-decaying fungi could be enhanced using highly concentrated PA since the GC-MS result on DPAP showed that phenolic compounds are prominent in the extract. Previous studies on different sources of PA have also revealed that phenolic and acid content in PA contribute directly to the antimicrobial activity [19-23] by increasing the membrane permeability [32]. This condition proceeds through the interaction with proteins and lipids of the membrane thus forming a layer around the cells or by inhibiting special enzymes [33].

3.3 Mold and Sapstain Resistance Analysis

After 4 weeks being exposed to both mold and blue sapstain, all treated and untreated rubberwood blocks showed fungi colonisation on the surface of the blocks. Molds infestation on rubberwood will cause colour change from pale yellow to dark green or black and the causal of blue sapstain was identified through the resultant bluish decolouration that developed on rubberwood [24]. The number of days required for the growth of mold and blue sapstain on the wood block is as summarised in Table 3.

Based from the results shown in Table 3, the use of 70% and 100% of PA as wood preserving agent were successful in inhibiting the growth of both mold and blue sapstain for 7 days, which is a significant finding as the control wood test block, i.e., without treatment using PA, showed mold and sapstain coverage after 1 and 2 days of contact respectively. Other PA concentrations used i.e. 0.01% - 30% showed around 50% mold and blue sapstain growth after 4 days of incubation. At moisture content greater than 20%, molds establishment can occur on non-treated wood in 24-48 hours if optimum temperature is allowed and rapid drying of the wood does not occur [25]. According to ASTM D4445, the growth of mold and blue sapstain were estimated visually using a scale of 0 to 5, with 5 being the maximum intensity covered by fungi and mold. Table 4 showed the six-point sapstain fungal severity rating over the wood samples in the field test.

Table 3 Number of days required for *A. niger* and *B. theobromae* to grow on treated wood blocks

Concentration of PA (%)	Days required for growth of *A. niger*	Days required for growth of *B. theobromae*
100	7	7
70	7	7
30	3	2
10	3	2
1	3	2
0.5	1	2
0.1	2	2
0.01	2	3
control	1-2	1-2

Table 4 Six-point sapstain fungal severity rating over the wood samples in the field test

Rating	Coverage description on samples
0	No Fungus
1	1-10%
2	11-25%
3	26-50%
4	51-75%
5	>75%

3.4 Termites Resistance Analysis

The result of the accelerated laboratory efficacy test for a no-choice feeding test in accordance to ASTM D3345-08 (with result interpretation using AWPA E1-09) is shown in Table 5 and the evaluation of visual rating is displayed in Table 6.

Table 5 Evaluation for efficacy of treated and untreated rubberwood to subterranean termites during the laboratory test in accordance to ASTM D3345-08 standard (result interpretation using AWPA E1-09)

Treatment	Concentration (%)	Termite bioassay			
		Weight loss (g)	Weight loss (%)	Density (g/cm³)	Visual rating
Pineapple wood vinegar	100	0.474	17.92	0.684	9.4
	70	0.347	13.68	0.662	9.2
	30	0.384	14.35	0.692	9.0
	10	0.415	15.44	0.698	9.0
	1	0.459	18.04	0.668	9.2
	0.5	0.341	13.18	0.683	9.0
	0.1	0.456	17.80	0.669	8.4
	0.01	0.463	17.13	0.698	8.2
Solvent control	0	0.572	20.91	0.694	7.8
Untreated rubberwood	-	0.572	21.76	0.663	7.4
Virulence (termites only)	-	-	-	-	-

Termites mortality rate is based on average number of termites died in 5 test bottles after 4 weeks. Rating: 100%, complete; 67-99%, heavy; 34-66%, moderate; 0-33%, slight.
Mean value for percentage of weight loss (%) are not significantly different (P<0.05) according to ANOVA

Table 6 Visual rating criteria based on visual inspection from AWPA E1-09 standard

Rating	Description
10	Sound
9.5	Trace, surface nibbles
9	Slight attack, up to 3% of cross sectional affected
8	Moderate attack, 3-10% of cross sectional area affected
7	Moderate/severe attack, penetration, 10-30% of cross sectional area affected
6	Severe attack, 30-50% of cross sectional area affected
4	Very severe attack, 50-75% of cross sectional area affected
0	Failure

The percentage of weight loss for treated wood blocks differ significantly (P<0.05) between untreated and solvent only-treated control blocks [F= 21.106, P= 1.519 x 10^{-12}]. The rubberwood blocks treated with 0.5% PA gave the lowest weight loss in termites test (13.18% relative to initial weight). However, the weight loss does not differ significantly (P>0.05) with 3 other concentrations, 70% (weight loss 13.68%), 30% (weight loss 14.35%) and 10% (weight loss 15.42%). The highest weight loss within the treated samples is 1% wood vinegar (18.04%) and is comparable to weight loss by sample with solvent control (20.91%) and untreated rubberwood (21.76%).

According to Kartal *et al*. [25] and Brenton & Fritgerald [26], 5% is the limit toxic threshold for effective wood protection against termites. Weight loss for treated rubberwood in this test range from 13-18% is 2-3 times higher than the toxic threshold limit. Whereas similar study against termite workers, *Odontotermes sp*. using coconut shell PA showed high termicidal activity at dilution of 1:50, wood vinegar: sterile water (v/v) [28]. Yatagai *et al*. [28] stated that the organic acid fraction of PA and acetic acid might be responsible for the termicidal activity against *R. speratus*. The largest component of the three PA from mixed wooden chips of *Cryptomeria japonica* (Thunb. ex L.f.) D. Don, *Pseudotsuga menziesii* (Mirb.) Franco, *Q. serrata* and *P. densiflora* that exhibited termiticidal activity was acetic acid [28]. However it must also be noted that part of the weight loss might be due to mold attack and not by termite feeding as showed by the higher visual rating given in the treated samples.

Result on visual rating was presented in accordance to AWPA E1-09 standard. Generally, treated samples showed a better visual rating with 9.4 to 8.2 (slight to moderate attack). Lower visual rating indicating more severe sign of termite feeding was seen in both solvent control and untreated rubberwood. Complete termite mortality is shown by all treated samples. Similarly, untreated rubberwood and solvent control also showed heavy termite mortality (67-99%) since there was no phenolic compounds presence in the treatment. Test jars with termite only (used as virulence test) showed complete mortality only after three weeks of testing.

Observation made on termite activities during the test period showed that majority of termites were actively attacking all the treated samples during the first week of testing. For the mortality rate of termites, most of termites in 100% wood vinegar container died on the first week and termites in 70%, 30%, 10% and 0.5% wood vinegar died on the second week of testing. Based on previous study conducted by Yatagai *et al.* [28], phenolic compounds with ortho para substituents showed more termiticidal activity compared to others. This fact was supported with the presence of 2,6-dimethoxyphenol, 3-hydroxy-4-methoxybenzoic acid and 2-methoxy-4-methylphenol in PA from pineapple waste biomass. Phenols with ortho position substituent were found to fit the receptor site of termite which contributed to termiticidal activity of the compounds. However, the bulkiness of ortho position substituent around hydroxyl group such as 2,6-dimethoxyphenol will decrease the volatility, hence decreasing the activity of phenols itself. Another possible cause of mortality was the presence of toxic mold as a result of high humidity inside the test jars and spread of mold attacking termite carcasses from the treated samples.

4.0 CONCLUSION

Pyroligneous acid from pineapple waste biomass showed good potential to be applied as as antifungal and antitermite agent but not as anti-wood decaying fungi. This finding can be used as a good preliminary indication for any future application of PA from pineapple waste as wood preservative. It is also worthy to note on the importance of concentrating and extracting the phenolic and acid content in pyroligneous acid prior to use as wood preservative in future.

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