A Comparative Study on the Inhibitory Ability of Various Wood-Based Composites against Harmful Biological Species

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Japanese pine sawyer beetle, pine shoot beetle, and Formosan subterranean termite were selected to investigate the inhibitory abilities of solid wood and wood-based composites (MDF and WPCs) made with *Eucalyptus urograndis* and *Melaleuca leucadendra*. The chemical components in the extractives of the two types of wood were also analyzed by GC-MS. The results indicated that the inhibitory ability can generally be listed in descending order as WPCs, MDF, and solid wood when made by the same wood filler. However, samples in each group made using *Melaleuca leucadendra* exhibited a higher inhibitory level than samples made using *Eucalyptus urograndis*. 2,3-dihydro-2,2-dimethyl-3,7-benzofurandiol, which was identified in the extractives of both woods (14.169% in *Eucalyptus urograndis* and 12.686% in *Melaleuca leucadendra*), was a significant factor for inhibition due to its high toxicity to insects. The chemical components with greatest potential for inhibition were stigmast-4-en-3-one (8.656%) in *Eucalyptus urograndis* and both 3-demethyl-colchicine (2.642%) and squalene (1.649%) in *Melaleuca leucadendra*. Additionally, perlite-based MDF showed the best inhibitory ability, possibly because the alimentary of the insects are prone to injury by perlite. PVC-based WPCs had a greater inhibitory level than HDPE-based WPCs due to the presence of the Cl element in PVC, as well as the addition of calcium zinc stabilizer and inorganic filler.

Keywords: Solid wood; MDF; WPCs; Inhibitory ability; GC-MS

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INTRODUCTION

The accelerating development of international economic integration and global trade has led to a continuous reduction of forestry resources and fast growing product demands for solid wood and wood-based materials. Global wood materials demand is predicted to reach 5.6 billion m^3 in 2020 (Akbulut *et al*. 2008). Hence, to fill the huge gap, exploration and utilization of novel substitute products such as wood plastic composites (WPCs) in the fields of decking, fencing, furniture, door, flooring, window, decoration, landscaping, and packaging have been investigated as alternatives to conventional wood-based composites including plywood, particle boards (PB), medium-density fiberboards (MDF), and laminated veneer lumber (LVL) (Ayrilmis 2013; Fabiyi *et al*. 2009; Kirkpatrick and Barnes 2006).

The applications of ordinary wood-based composites are often limited due to their high sensitivities to fungal decay and insects (Baileys *et al*. 2003; Barnes and Amburgey

1993). The long-horned beetle, powder post beetle, death watch beetle, bark beetle, and termite are common natural enemies to wood-based composites (Fleming *et al*. 2003; Campbell 1929; Christiansen *et al*. 1987; Kard 2003). Conversely, there are a great many inherent advantages for the new wood-based composites, WPCs, which are mainly comprised of polymer matrices and biomass fiber materials. WPCs have the advantages of being light weight, having a high strength/stiffness to density ratio, being non-toxic, producing low CO_2 emissions, and being machineable and recyclable (Ashori 2008; Thompson *et al*. 2010). At one time, most manufacturers and researchers considered WPCs to have excellent resistance to biodegradation due to the outstanding encapsulation of biomass fiber in the polymer matrix (Schirp *et al*. 2008; Segerholm *et al*. 2012a).

However, it has been recently reported that the initial biological degradation of WPCs due to microorganisms and harmful biological species can occur when the outermost thin layer of the composite is damaged by a long exposure to ultraviolet radiation, temperature, oxygen, and moisture (Segerholm *et al*. 2012b; Gnatowski 2009; Ibach *et al*. 2011). Furthermore, there are some accelerating effects on the bio-deterioration of WPCs due to the complex chemical additives (plasticizers, lubricants, stabilizers, and colorants) that are included in various sorts of plastic (Schirp *et al*. 2008). Some previous publications also have shown that microorganisms (mainly mould and fungi) can weaken the aesthetic quality and mechanical strength of WPCs through discoloration and degradation (Karimi *et al*. 2007; Dawson-Andoh *et al*. 2004; Iiyoshi *et al*. 1998). In the case of harmful insects, researchers at the USDA Forest Products Laboratory demonstrated that nibbled and rough WPCs surfaces caused by termites were clearly visible after three years of exposure (Schirp *et al*. 2008). Other studies also indicated that there were a very few PP-based WPCs samples that can provide full protection against termite attack (Tascioglu *et al*. 2013; H'ng *et al*. 2011). HDPE-based WPCs made by guayule plant fiber have proved to be highly resistant to termites due to natural chemical constituents in the guayule plant (Chow *et al*. 2002). However, to date, there are no publications concerning PVC-based WPCs laboratory testing of termites and other harmful insects, or a comparison among solid wood, MDF, and WPCs.

Our present work aimed at a comparative study of the inhibitory abilities (including the antifeedant, repellent, and resistant activities) of solid wood, conventional MDF, and WPCs (including HDPE and PVC) against harmful biological species (Japanese pine sawyer beetle, pine shoot beetle, and Formosan subterranean termite). In addition, in order to investigate the mechanism for the various inhibitory results, the chemical components of two wood species were extracted by alcohol/benzene and were analyzed using gas chromatography-mass spectrometry (GC-MS).

EXPERIMENTAL

Raw Materials

Eucalyptus urograndis and *Melaleuca leucadendra* with their wood fibers (6- to 20-mesh) and wood flour (40- to 60-mesh) were supplied by Baigao MDF Manufacturing Ltd. Co., China. *Pinus massoniana* sawdust was obtained from our laboratory. HDPE (5000S) with a density of 0.95 g/cm^3 and a melt flow index of 0.7 g/10 min was purchased from Daqing Petrochemical Co., China. PVC (DG-800) with an average degree of polymerization of 800 and a density of 1.35-1.45 g/cm^3 was purchased from Tianjin Dagu Ltd. Co., China. Urea-formaldehyde (UF) resin adhesive with solid content of 60%, viscosity of 0.19 Pa·s, perlite for MDF and additives for WPCs preparation including modifier (silane), lubricant (PE wax), calcium zinc stabilizer, and inorganic fillers ($CaCO_3$) were provided by Guangzhou Minshan New Material Ltd. Co., China.

Harmful Biological Species

Larvae of Japanese pine sawyer beetle and pine shoot beetle were artificially fed under a temperature of 27±2 °C and a relative humidity of 70±5%. Larvae from the same generation, age, and similar size were selected for the subsequent tests. Formosan subterranean termite adults were collected from bitten *Pinus massoniana* lumber in our laboratory.

Preparation of Samples

Solid wood preparation

Two types of solid wood materials listed in Table 1 were dried at 40 °C to a local equilibrium moisture content (15%) and were stored in a sealed container for later use.

MDF preparation

Wood fiber was dried to a moisture content of 5% or less. Subsequently, 10% UF resin (percentage based on solids content and oven-dry fiber weight) was sprayed onto the wood fiber as it was being rotated in a drum-type blender. Resinated fiber materials were pre-pressed and final pressed for about 6 to 8 min in a temperature range from 130 to 180 °C and pressure range from 1.5 to 4 MPa, forming MDF boards with dimensions of 500 mm × 500 mm × 8 mm and average densities of 0.90 g/cm^3. As to perlite-based MDF, another 10% perlite was added into wood fiber with the same steps as mentioned.

WPCs preparation

Wood flour (60 phr) was dried at 105 ± 2 °C in an oven to ensure the moisture content was less than 1%. Wood flour and thermoplastic resins (HDPE or PVC) were premixed in a high-speed mixer (SHR-10A, Zhangjiagang, China) operated at 1600 rpm at a temperature of 80 °C for 5 min. The additives, which included 2 phr silane and 1 phr PE wax for HDPE based WPCs, the same silane and PE wax with supplementary calcium zinc stabilizer (3 phr) and inorganic fillers (5 phr $CaCO_3$) for PVC based WPCs, were mixed at 105 °C for 10 min. Subsequently, the blend was extruded by a conical twin-screw extruder (LSE-35, Guangzhou, China) as a sheet in the temperature range from 130 to 185 °C from hopper to die zone with a rotational speed ranging from 10 to 25 rpm.

Table 1. List of Tested Samples

Groups	Types	Materials
A-1	Solid wood	*Eucalyptus urograndis*
A-2	Solid wood	*Melaleuca leucadendra*
B-1	MDF	*Eucalyptus urograndis* based MDF
B-2	MDF	*Melaleuca leucadendra* based MDF
B-3	MDF	*Melaleuca leucadendra*/Perlite-based MDF
C-1	WPCs	HDPE/*Eucalyptus urograndis* composites
C-2	WPCs	PVC/*Eucalyptus urograndis* composites
C-3	WPCs	PVC/*Melaleuca leucadendra* composites

Characterization

Antifeedant activity measurement

The test samples listed in Table 1 were cut into small sheets of 20 to 50 grams with a thickness of 3 to 4 mm. Small dents were made in the samples (not penetrated) for the placement of insects. Two Japanese pine sawyer beetle larvae and four pine shoot beetle larvae for each group were put into a glass jar with wet cotton and additional food (*Pinus massoniana* sawdust). The test samples were taken out of the glass jar, cleaned by brush, and weighed after 1, 3, 5, and 7 days. Antifeedant rates in triplicate were calculated according to equation (1). A comparison of the means was done using Duncan's multiple range tests by SPSS software at 95% confidence levels,

$$AR = \frac{A_0 - A_1}{A_0} \times 100\% , \tag{1}$$

where AR is the antifeedant rate at a certain time, A_0 is the weight variation of the control group (*Pinus massoniana* sawdust), and A_1 is the weight variation of other test samples.

Repellent activity measurement

The test samples were cut, smashed in a high-speed disintegrator, and then sieved to the specified particle size in the range from 100- to 120-mesh using a vibrating screen. Filter paper and wet cotton were placed at the bottom of a glass cylinder (diameter of 25 cm, height of 12 cm). Then, the bottom was accurately divided into four sections like a cross. *Pinus massoniana* sawdust was placed on two sections, and the other two sections were used for placing other test sample particles. Afterward, 20 larvae were put in the center of the glass cylinder so the larvae could choose their respective favorite site for living. The numbers of insects at different sections were recorded, and the repellent rate was calculated using equation (2) after 24 h. Tests were performed in triplicate to obtain an average value, and statistical analysis was done using Duncan's multiple range tests by SPSS software.

$$RR = \frac{B_0 - B_1}{B_0} \times 100\% \tag{2}$$

In Eq. 2, RR is the repellent rate, B_0 is the number of insects in the *Pinus massoniana* sawdust section, and B_1 is the number of insects in the other test sample sections.

Resistance activity measurement

The different test sample particles used as food for insects were put into petri dishes with wet cotton. Thirty Formosan subterranean termites were placed in each group. The petri dishes sat in insectariums, the numbers of termites were recorded every few days, and the death rates for different test samples were calculated using equation (3). Each group was tested in triplicate for standard deviation,

$$DR = \frac{D_1}{D_2} \times 100\% \tag{3}$$

where DR is the death rate, D_1 is the number of dead termites at a certain time, and D_2 is the total number of termites at the beginning of the test.

GC-MS analysis

The analysis of chemical components was carried out on a 6890N-5975C gas chromatograph/mass spectrometer (Agilent, American). A DB-5MS silica capillary chromatographic column was used for the separation. The injector and detector temperatures were 260 °C and 300 °C, respectively. The initial temperature was maintained at 80 °C for 4 min, then was gradually elevated to 200 °C at a heating rate of 10 °C /min and was held for 10 min at 300 °C. The column flow velocity of the helium gas was 1.4 mL/min at a split ratio of 30:1; EI was used as the ion source with an electronic energy of 70 eV and ion source temperature of 230 °C. The sector mass analyzer was set to scan from 30 to 500 amu. The identification of the chemical components of wood extractives was done by computer comparison of mass spectra with this in Wiley and NIST database.

RESULTS AND DISCUSSION

Antifeedant Activity Analysis

As seen in Table 2, there was a significant difference in the antifeedant rates (AR) between group A and groups B and C but a small difference for group B and C. It was observed that the AR gradually increased with time. The lowest AR for the two species of harmful insects was obtained from group A (solid wood). The AR of group C was generally higher than that of group B, which indicated that there was a better antifeedant activity for WPCs than for MDF, except for C1 (HDPE-based WPCs) and B-3 (perlite-based MDF). This was because WPCs contained less wood than regular MDF. In addition, most of the wood flour in the WPCs was encapsulated by thermoplastic resin, forming a discontinuous path that made WPCs less susceptive to insect attack.

Table 2. Antifeedant Rates (AR) of Different Samples against Japanese Pine Sawyer Beetle and Pine Shoot Beetle

Groups	AR of Japanese pine sawyer beetle (%)*				AR of pine shoot beetle (%)*			
	1d	3d	5d	7d	1d	3d	5d	7d
A-1	50.61 (2.11) f	56.72 (1.51) f	62.11 (0.88) g	67.13 (1.15) e	38.63 (0.36) g	49.81 (0.20) g	51.72 (0.50) f	66.73 (0.57) f
A-2	68.93 (0.73) e	71.60 (0.36) e	78.91 (0.24) f	86.32 (0.44) d	44.14 (0.75) f	52.13 (0.67) f	62.13 (1.07) e	74.01 (0.26) e
B-1	73.10 (1.22) d	76.11 (1.53) d	80.42 (0.42) e	87.25 (0.77) d	74.31 (0.32) e	83.35 (0.17) e	86.41 (0.30) d	90.22 (0.33) d
B-2	78.94 (0.70) c	83.53 (1.18) c	86.83 (0.37) d	94.76 (0.10) b	78.92 (0.83) d	85.55 (0.24) d	89.03 (0.30) c	94.85 (0.22) b
B-3	83.62 (0.37) b	91.52 (0.36) a	95.63 (0.85) a	97.38 (0.14) a	87.63 (0.28) b	92.44 (0.39) b	97.85 (0.24) a	99.39 (0.17) a
C-1	80.82 (0.73) c	83.40 (0.49) c	87.62 (0.46) cd	91.62 (0.35) c	79.83 (0.62) d	85.16 (0.20) d	87.25 (0.14) d	91.63 (0.36) c
C-2	84.81 (1.19) b	85.66 (0.51) b	88.61 (0.36) c	93.47 (0.30) b	81.36 (0.46) c	86.76 (0.33) c	91.32 (0.48) b	92.82 (0.51) c
C-3	89.21 (1.28) a	90.44 (0.64) a	92.70 (0.75) b	96.38 (1.36) a	95.85 (0.67) a	97.69 (0.52) a	98.10 (0.22) a	99.11 (0.22) a

Data are the means of three replicates, values in parentheses are standard deviations.
* Means within each column followed by different letters are significantly different ($p < 0.05$).

Compared with solid wood, MDF was denser and less porous. As a result, it took a longer time for insects to bite and digest MDF than solid wood. We found that the difference of resin (PVC and HDPE) had an influence on the antifeedant rates, which can be attributed to the presence of the Cl atoms in PVC, as well as the addition of calcium zinc stabilizer and inorganic filler ($CaCO_3$) for PVC-based WPCs. With respect to the high AR for B-3, it can be deduced that alimentary canals of harmful insects were easily injured when perlite mainly containing SiO_2 and Al_2O_3 was added to MDF formulations (Topçu and Işıkdağ 2007).

Solely considering groups A, B, and C that were made by the same wood, the data showed that the AR of A-2, B-2, and C-3 were higher than that of A-1, B-1, and C-2, respectively. This can be due to the variations of chemical components in different wood species and favorite foods of different harmful insects. The specific reasons can be explained in the latter part of GC-MS analysis.

Repellent Activity Analysis

The repellent rates of different samples against pine shoot beetle are shown in Table 3. The average repellent rates corresponding to groups A, B, and C were 56.27%, 78.97, and 78.18%, respectively. It can be found from Duncan's multiple range tests that there were marked differences between group A and groups B and C, but only a small variation between group B and C. It can be concluded that wood-based composites had a superior repellent ability against harmful insects to solid wood. Moreover, the added UF adhesives, as well as additives in MDF and WPCs, respectively, had important effects; these substances may have released various odors or low-concentration toxic substances to repel insects. The repellent rate of both woods showed a minor variation (53.48% and 59.05%), while the repellent rates of MDF and WPCs were almost not affected by different woods (77.45% and 77.12% for B-1 and B-2, respectively, and 79.90% and 79.63% for C-2 and C-3, respectively). Besides, the better environmentally friendly characteristic for HDPE resin without Cl atoms than PVC probably was the reason why C-1 (HDPE based WPCs) showed the relatively lower RR (75.00%).

Table 3. Repellent Rates (RR) of Different Samples against Pine Shoot Beetle

Groups	Number of Larva for Test Groups	Number of Larva for Control Group	RR (%)*
A-1	6.33 (0.47)	13.67 (0.47)	53.48 (5.18) b
A-2	6.00 (0.82)	14.00 (0.82)	59.05 (5.61) b
B-1	3.67 (0.47)	16.33 (0.47)	77.45 (3.47) a
B-2	3.67 (0.94)	16.33 (0.94)	77.12 (7.39) a
B-3	3.00 (0.00)	17.00 (0.00)	82.35 (0.00) a
C-1	4.00 (0.00)	16.00 (0.00)	75.00 (0.00) a
C-2	3.33 (0.67)	16.67 (0.67)	79.90 (3.47) a
C-3	3.33 (0.94)	16.67 (0.94)	79.63 (6.55) a

Data are the means of three replicates, values in parentheses are standard deviations.
* Means within each column followed by different letters are significantly different ($p < 0.05$).

Resistance Activity Analysis

Termite resistance results are presented in Table 4. In general, the resistant activities of C were the highest; A was the least resistant, with B in the middle. The samples in each group made from *Melaleuca leucadendra* exhibited higher resistance ability than those made from *Eucalyptus urograndis*. This is due to the two wood extractives having different quantities and types of toxic chemical components, which correlated well with previous publications (Chow *et al*. 2002), as well as the analysis in the latter part of GC-MS. Meanwhile, the data in Table 4 reveal that not all the wood-based composites exhibited improved resistance ability over that of solid wood itself. The extruded HDPE/*Eucalyptus urograndis* WPCs (C-1) and compressed *Eucalyptus urograndis*-based MDF (B-1) had a similar resistance to that of natural *Melaleuca leucadendra* wood (A-2), with a mortality of 100% in 25 days.

The reasons for the higher resistance ability of the PVC-based WPCs compared to the HDPE-based WPCs prepared by the same wood as well as the perlite-based MDF were the same as mentioned above.

Table 4. Mortality of Different Samples against Formosan Subterranean Termite Adults at Different Days

Groups	Mortality (%) at Different Days									
	2d	4d	6d	10d	14d	18d	25d	30d	40d	50d
X	0	0	0	0	0	0	0	1.67 (1.67)	3.33 (1.67)	3.33 (1.67)
A-1	18.33 (3.33)	46.67 (6.67)	53.33 (6.01)	68.33 (6.67)	71.67 (4.41)	86.67 (6.01)	93.33 (5.77)	100 (0.00)		
A-2	5.00 (2.89)	36.67 (4.41)	55.00 (2.89)	61.67 (9.28)	76.67 (7.27)	90.67 (4.41)	100 (0.00)			
B-1	16.67 (6.01)	31.33 (7.27)	46.67 (6.01)	58.33 (8.22)	71.67 (7.27)	88.33 (4.41)	100 (0.00)			
B-2	16.67 (1.67)	33.33 (3.33)	63.33 (4.41)	70.00 (5.77)	93.33 (5.77)	100 (0.00)				
B-3	20.00 (5.00)	50.00 (5.77)	90.00 (5.77)	100 (0.00)						
C-1	6.67 (4.41)	36.67 (4.41)	46.67 (5.27)	66.67 (3.28)	71.67 (4.41)	90.00 (6.01)	100 (0.00)			
C-2	20.00 (5.77)	43.33 (4.41)	53.33 (2.89)	66.67 (4.41)	83.33 (5.77)	100 (0.00)				
C-3	16.67 (4.41)	50.00 (5.77)	76.67 (6.67)	93.33 (2.89)	100 (0.00)					

The data are the means of three replicates, values in parentheses are standard deviations.

GC-MS Analysis

The analytical results of extractives from both woods are shown in Tables 5 and 6, respectively. As listed in Table 5, there were generally 28 marked peaks for the extractives of *Eucalyptus urograndis*. The five main components (relative content of above 5%) were as follows: 2,3-dihydro-2,2-dimethyl-3,7-benzofurandiol (14.169%), (Z)-13-docosenamide (11.886%), dibutyl phthalate (10.880%), stigmast-4-en-3-one (8.656%), and 4-ethoxy-2,5-dimethoxybenzaldehyde (6.794%). The chemical components that were responsible for the inhibition were 2,3-dihydro-2,2-dimethyl-3,7-benzofurandiol and stigmast-4-en-3-one. The former can kill insects with a high toxicity, whereas the latter may attract insects due to its inherent cardiotonic growth-promoting and sexual reproduction-inducing activities (Chaudhry 2002; Chapalmandugu and Chaudhry 1992; Seo *et al*. 2007; Jamaluddin *et al*. 1995).

Seventeen chemical constituents of *Melaleuca leucadendra* wood extractives are also listed in Table 6. There were six main components, including (Z)-13-docosenamide

(16.439%), 2,3-dihydro-2,2-dimethyl-3,7-benzofurandiol (12.686%), dibutyl phthalate (12.059%), phthalic acid, di(2-propylpentyl) ester (9.877%), and 2-butyl-1,1-dimethyl-hydrazine (9.730%). Three of these were the same in *Eucalyptus urograndis* wood. In addition to 2,3-dihydro-2,2-dimethyl-3,7-benzofurandiol in both woods, strongly toxic 3-demethyl-colchicine, a major native alkaloid with anti-mitotic, anti-inflammatory, and anti-tumor drug values (Brossi *et al.* 1988, 1990; Dubey *et al*. 2008), and squalene, with anti-bacterial and insect disinfestation activities (Zhao and Sun 2004), although having low relative contents of 2.642% and 1.649%, respectively, have shown positive effects in supporting the resistance of organisms (Brossi 1990; Zhao and Sun 2004). In short, the extractives of the two types of wood correlated well with the analyses of antifeedant, repellent, and resistance activities against the harmful biological species.

Table 5. Chemical Components of *Eucalyptus urograndis* Wood Extractives

Retain Time (min)	Names of Chemical Components	Relative Content (%)
5.245	Ethylbenzene	2.220
5.805	Phosphoryl fluoride	2.729
11.722	2-Propenoic acid, 6-methylheptyl ester	0.951
12.302	Silane, diethyl(trans-4-methylcyclohexyloxy)undecyloxy-	3.442
13.515	3-Isopropoxy-1,1,1,7,7,7-hexamethyl-3,5,5-tris(trimethylsiloxy)tetrasiloxane	3.334
14.561	Silane, [[4-[1,2-bis[(trimethylsilyl)oxy]ethyl]-1,2-phenylene]bis(oxy)]bis[trimethyl-	3.297
14.738	3-Dimethylaminoanisole	3.417
14.976	5H-Indeno[1,2-b]pyridin-4-ylamine	1.489
15.131	Tetradecane, 4-methyl-	1.830
15.577	2,3-dihydro-2,2-dimethyl-3,7-Benzofurandiol	14.169
16.313	Phthalic acid, decyl isobutyl ester	1.609
16.634	Cyclobutanone, oxime	0.715
17.028	Dibutyl phthalate	10.880
17.411	4-Ethoxy-2,5-dimethoxybenzaldehyde	6.794
20.738	2,2'-methylenebis[6-(1,1-dimethylethyl)-4-methyl- Phenol	0.797
21.826	Bis(2-ethylhexyl) phthalate	3.769
23.215	Dodecanoic acid, undecyl ester	1.264
23.277	Isobutyl octan-2-yl carbonate	3.503
24.437	(Z)-13-Docosenamide	11.886
26.707	Dinaphtho[2,3-b:1',2'-d]pyran-7-one	2.085
28.852	Heptadecanoic acid, heptadecyl ester	0.990
29.349	1-Ethoxy-4'-methoxy-2,2'-binaphthyl-1,4-dione	1.956
29.702	6-Octadecenoic acid	1.610
30.987	Heptasiloxane, hexadecamethyl-	0.711
31.246	4-Methyl-1,3-dihydro-2H-1,5-benzodiazepin-2-one tbdms	1.659
31.712	Picolinyl 8-(5-hexyl-2-furyl)-octanoate	3.325
32.458	Stigmast-4-en-3-one	8.656
37.205	3-Methoxyandrosta[16,17-b]furan-2'-imine, 3'-methylene-N-cyclohexyl-	0.910

Table 6. Chemical Components of *Melaleuca leucadendra* Wood Extractives

Retain Time (min)	Names of Chemical Components	Relative Content (%)
4.945	2-Propanol, 1-propoxy-	2.929
8.934	2-Propanol, 1-(2-ethoxypropoxy)-	17.579
9.193	2-butyl-1,1-dimethyl- Hydrazine	9.730
11.722	2-Ethylhexyl acrylate	1.252
12.302	Estra-1,3,5(10)-trien-17-one, 2-[(trimethylsilyl)amino]-3-[(trimethylsilyl)oxy]-	2.097
13.349	1H-Cyclopropa[a]naphthalene, 1a,2,3,5,6,7,7a,7b-octahydro-1,1,7,7a-tetramethyl-, [1aR-(1a.alpha.,7.alpha.,7a.alpha.,7b.alpha.)]-	0.964
13.515	3-Isopropoxy-1,1,1,7,7,7-hexamethyl-3,5,5-tris(trimethylsiloxy)tetrasiloxane	2.050
14.561	Benzeneacetic acid,.alpha.,3,4-tris[(trimethylsilyl)oxy]-,methyl ester	1.679
15.142	Nonadecane	1.517
15.577	2,3-dihydro-2,2-dimethyl-3,7-Benzofurandiol	12.686
16.323	Phthalic acid, isobutyl 3-methylbut-3-enyl ester	1.556
17.038	Dibutyl phthalate	12.059
21.836	Phthalic acid, di(2-propylpentyl) ester	9.877
23.277	Sulfide,1- propenyl 1-propynyl	3.297
24.437	(Z)-13-Docosenamide	16.439
24.779	Squalene	1.649
31.702	3-demethyl- Colchicine	2.642

CONCLUSIONS

1. Overall, compared to MDF and WPCs, solid wood materials showed the lowest inhibitory ability against biological species. Better performances were observed for WPCs in antifeedant and resistant activities than MDF but almost the same in repellent activity when made with the same wood filler. However, samples in each group made using *Melaleuca leucadendra* exhibited a higher level than those made using *Eucalyptus urograndis* due to the various chemical components in their extractives.
2. 2,3-dihydro-2,2-dimethyl-3,7-benzofurandiol, which was found in the extractives of both woods with the relative content of 14.169% in *Eucalyptus urograndis* and 12.686% in *Melaleuca leucadendra*, was a significant factor on inhibition due to its high toxicity to insects. The chemical components with the great potential for inhibitory effects were stigmast-4-en-3-one (8.656%) in *Eucalyptus urograndis*, 3-demethyl-colchicine (2.642%), and squalene (1.649%) in *Melaleuca leucadendra*.
3. There was a higher inhibitory level for PVC-based WPCs than for HDPE-based WPCs at the same wood filler, which can be attributed to the existence of the Cl element in PVC molecular chains as well as the addition of calcium zinc stabilizer and inorganic filler ($CaCO_3$).
4. The perlite-based MDF showed the best inhibition activity with AR (97.38%, 99.39%), RR (82.35%), and 100% mortality (10 d), possibly because the alimentary of the insects are prone to injury by perlite. Based on this, it is recommended that some perlite can be added to improve the inhibitory level of wood-based composites.

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