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Properties of Pyrethroids-Treated Particleboards Manufactured from Rubberwood and Oil Palm Empty Fruit Bunches (EFB)

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ABSTRACT

The incorporation of small amounts of pyrethroid-based preservatives (Organic solvent-based permethrin (OSP), Water-based permethrin (WP) and deltamethrin) into particleboards made from latex timber clone rubberwood (RRIM 2002) *(Hevea brasiliensis)*, empty fruit bunches (EFB) of oil palm *(Eleasis guineensis)* and rubberwood + EFB (70:30 parts) blend through spraying during blending of furnish significantly increased the resistance of the boards to white rot *(Pycnoporous sanguineus)* and subterranean termite *(Coptotermes curvignathus)* attacks. This paper discusses the physical and mechanical properties of the pyrethroid-treated particleboards. These properties were compared with those of boric acid-treated and untreated particleboards. The preservative treatment did not significantly affect the internal bond (IB) and modulus of rupture (MOR) of rubberwood and rubberwood + EFB blend particleboards. However, the modulus of elasticity (MOE) of these boards increased when treated with either WP, or OSP. For the EFB boards, all pyrethroid compounds reduced the IB of the board whereas the MOR and MOE were either reduced or unaffected. However, the thickness swelling (TS) of rubberwood particleboard, improved when treated with all the pyrethroid-based preservatives, whilst the other two types of boards were less stable when treated with OSP or WP. Among the three types of particleboards, the mechanical properties of EFB particleboards were affected most by the pyrethroid treatments. The mechanical and physical properties of treated particleboards from rubberwood and admixture were comparable or better than those of the untreated particleboards. Boric acid treatment reduced the MOR of all particleboards but other properties were either improved or unaffected.

Keywords: Boric acid, empty fruit bunches, particleboard, pyrethroids, rubberwood

INTRODUCTION

Fabricating particleboards from rubberwood and rubberwood blended with oil palm empty fruit bunches (EFB) have been shown to have a huge potential (Chew and Ong 1985; Rahim *et al.*, 1994). Research has been conducted on fabricating homogenous and heterogenous layered particleboards from admixtures of these materials (Rahim *et al.*, 1994; Abdul Karim *et al.*; 1994, Zaidon *et al.*, 2007). The results indicated that most of the properties are satisfactory and meet the minimum Japanese Industrial Standards of particleboard (JIS A 5908) (JIS 2003). In general, rubberwood composites are less susceptible to rotting fungus and subterranean termite compared to solid wood (Zaidon *et al.,* 2002; Zaidon *et al.,* 2003). The higher resistance of the composites towards the deteriorating agents was attributed to the utilization of formaldehyde based adhesives (Behr, 1972). Due to the environmental impact caused by formaldehyde emission from the binder of the composites, improvements to these products are being made through the use of low formaldehyde

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emission adhesives such as the E1-grade melamine urea formaldehyde (maximum formaldehyde emission < 0.01 ppm).

This type of adhesive, however, has relatively inferior bonding strength, hence is more susceptible to biodegradable agents. Research have shown that the resistance of rubberwood composites to fungal and termite attack can be enhanced through incorporation of small amounts of boron compounds and chromated copper arsenate (CCA) (Zaidon *et al.*, 1998; Zaidon *et al.*, 2002; Zaidon *et al.*, 2003). Nevertheless, these compounds are not preferred nowadays due to their toxicity hazards and potential environmental pollution. Thus, new and more environment friendly preservative formulations are sought to preserve particleboards. Pyrethroids are a potential group of preservatives that can serve as an alternative to boron and CCA. Pyrethroids are a synthetic form of pyrethrin that has insecticidal properties. They are one of the least poisonous insecticides to mammals (Ray, 1991; Tomlin, 1994). Some of the pyrethroids that have been formulated into preservatives include permethrin, cypermethrin and deltamethrin and they are available in the market under different trade names.

Previous studies revealed that treatment of low formaldehyde emission MUF-bonded particleboards made from blending juvenile rubberwood, EFB and rubberwood-EFB through soaking of particles with 0.02% deltamethrin and 2% boric acid solutions enhanced the resistance of the product against white rot fungus (*Pycnoporous sanguineus*) and termite (*Coptotermes curvignathus*) attacks (Zaidon *et al.*, 2007). Most of the strength and physical properties, however, were reduced except for particleboards fabricated from empty fruit bunches. Improper curing of adhesive was identified as the cause for the poor performance of boards. This was attributed to the interference caused by the dry salt retention during manufacture of the board. It was thought that the pressing time used in the previous study, as recommended by the resin supplier was not sufficient to fully cure the resin. In another study, the incorporation of small amounts of pyrethroid-based and boric acid preservatives into particleboards made from rubberwood (clone RRIM 2002), empty fruit bunch (EFB) and rubberwood-EFB blend through spraying during blending resulted in significant increase in resistance to white rot and subterranean termite attacks (Zaidon *et al.*, 2008). However, the effects of these treatments on the mechanical and physical properties of the particleboards are unknown.

This paper reports the mechanical and physical properties of pyrethroid-treated rubberwood, EFB and rubberwood + EFB blend particleboards. The change in properties over untreated and boric acid-treated boards is also discussed.

MATERIALS AND METHODS

The materials used in this study were four-year-old latex timber clone rubber tree, *Hevea brasiliensis* Müll Arg. (clone RRIM 2002) which was extracted from Besut Terengganu and empty fruit bunches (EFB) from oil palm trees (*Elaeis guinensis* Jacq.) supplied by SABUTEK Sdn. Bhd, Telok Intan, Perak. Both materials were chipped, flaked and screened into 0.5-2.0 mm sized particles. The particles were dried to 5% moisture content (MC). The adhesive used in this study was a low formaldehyde (E1-grade resin) (MUF-E1, maximum permissible formaldehyde emission < 0.1 ppm) supplied by Malaysian Adhesive Company, Sdn. Bhd., Shah Alam. New formulations of pyrethroid-based preservatives (water-based permethrin, organic-solvent-based preservative, and deltamethrin) were used as treatment solutions. The concentration of the solution was calculated and the amount of active ingredients to be loaded in each board was maintained at the level recommended by the producers (Data sheet 2000, 2003 and NA). The active ingredients and concentration of each chemical compound are listed in Table 1. OSP is an organic solvent based preservative, while WP and deltamethrin are water-based preservatives. Analytical grade boric acid (orthoboric acid, H_3BO_3) was also used for comparison purposes.

Manufacture of Particleboard

Single layered particleboards with dimensions 340 mm x 340 mm x 10 mm with target density of 650 kg m^{-3} and final MC of 12% were fabricated. The parameters used for manufacture of the particleboards are summarized in Table 2. Boards from each treated and untreated rubberwood, EFB and rubberwood + EFB blend (70 parts rubberwood and 30 parts EFB) were made. Preliminary work showed that a higher composition of rubberwood in the admixture

TABLE 1
Chemical composition of preservatives used

Preservative	Composition	Concentration
Organic solvent-based permethrin (OSP)	Tributyltin napthenate	3.5%
	Permethrin	0.2%
	Dichlofuanid	0.1%
	Solvent Organic	96.2%
	(Total active ingredient)	(3.8%)
Water-based permethrin (WP)	Disodium octaborate	10%
	Benzalkonium chloride	2.0%
	Permethrin	0.2%
	Water	87.8%
	(Total active ingredient)	**(12.2%)**
Deltamethrin	Deltamethrin	0.2%
	Water	99.8%
	(Total active ingredient)	**(0.2%)**
Boric acid	Orthoboric acid	100% (solid)
	(Total active ingredient)	**(100%)**

[1]Data sheet 2000, [2]Data sheet 2003, [3]Data sheet NA

resulted in superior quality particleboard. The preservative solutions of various concentrations were sprayed onto the furnish, which was first blended with 11% MUF-EI and 1% wax. The concentrations of the solution were calculated to obtain loading of active ingredients in each board as recommended by the producers (Data sheet 2000, 2003, NA). For boric acid treatment, a pre-weighed solid salt was first dissolved in distilled water to produce a solution. The treated furnish was blended for 15 min to ensure uniform distribution of active ingredients in the boards. The furnish was then formed in a former, pre-pressed and subsequently pressed in a hot press at 160^{0}C. The pressing time for each individual treatment varied from 370 s to 520 s. Variations in pressing time for different pyrethroid treatments has been reported by Zaidon *et al.* (2007). For each treatment combination, a total of 6 boards were produced. Prior to cutting into testing blocks, all boards were conditioned at 20^{0}C and 65% relative humidity until equilibrium, i.e. 12% EMC.

TABLE 2
Parameters used for manufacture of the particleboards

Raw materials	Rubberwood (Clone RRIM 2002)
	Empty fruit bunches (EFB)
	Rubberwood-EFB blend (70:30 parts)
Target board density	650 kg m^{-3}
Target board MC	12%
Board size	(340 x 340 x 10) mm^3
Adhesive	
1. MUF-E1 grade (55.8% solid)	11% (w/w of particles)
2. Industrial grade Hardener, (NH_4Cl)	1% (w/w of solid resin)
3. Wax	1% (w/w of particles)
Preservatives	
1. OSP	5% solution (w/w of particles) or 0.19%a.i
2. WP	5% solution (w/w of particles) or 0.61% a.i
3. Deltamethrin	5% solution (w/w of particles) or 0.01% a.i
4. Boric acid	0.5% solution (w/w of particles) or 0.5% a.i.

Evaluation of Mechanical and Physical Properties

The boards were trimmed at the edges and cut into required dimensions for physical and mechanical tests. The tests conducted were static bending, internal bond, thickness swelling and water absorption. The static bending and internal bond tests were carried out using Universal Testing Machine (INSTRON, 50 kN). These were conducted according to Japanese Industrial Standard of Particleboard (JIS A 5908) (JIS 2003).

Statistical Analysis

Statistical analyses were performed on the physical and mechanical properties data to test if there are significant changes between the treated and untreated boards. Since a wide variation of density was found on the boards (570-740 kg m^{-3}), an analysis of covariance (ANOCOV) was performed to correct for expected differences in physical and mechanical properties due to density. Thus, density was chosen as a concomitant variable. Adjusted means were separated using Least Significant Difference (LSD) method.

RESULTS AND DISCUSSION

The adjusted values for mechanical and physical properties of treated and untreated particleboards are summarized in Table 3. For modulus of rupture (MOR) and modulus of elasticity (MOE) values, the negative signs indicate a reduction in the value of properties, while for thickness swelling and water absorption, the negative sign reflects an improvement in dimensional stability.

Properties of Treated Rubberwood Particleboards

There was no difference in internal bond (IB) on deltamethrin, OSP-treated and the untreated rubberwood particleboards. The IB values of these boards ranged from 0.91 to 1.05 N mm^{-2}. These values were comparable to the IB value found for boric acid-treated boards (0.98 N mm^{-2}). A significant reduction of 7.0% was found for the average IB values of OSP-treated boards. The MOR and MOE pyrethroid-treated boards were significantly higher than the untreated boards. The MOR increased by 8-15% from the original strength of 16.8 N mm^{-2}, while the MOE increased by 6-15% from the original stiffness of 1719 N mm^{-2}. Boric acid treatment significantly reduced the MOR by 21.9% to 13.1 N mm^{-2}, but this treatment did not affect the MOE of the boards. With regards to physical properties, all pyrethroid-treated boards exhibit lower thickness swelling (11.5-11.6%) compared to untreated boards (17.2%) and boric acid-treated boards (19.2%). Thickness swelling (TS) measures the dimensional stability of the boards. Lower TS indicate a more stable board. The results show that the dimensional stability of pyrethroids-treated rubberwood particleboard improved by about 33%. The water absorption (WA) value varied with treatments. deltamethrin treatment reduced the water absorption of the board and this value was comparable to boric-acid-treated board, i.e. 49.1% and 44.1%, repectively. The other two treated boards had relatively higher WA (between 72.3% and 76.7%) compared to the untreated board (71.9%), but this difference was not significant. In general, the IB, MOR and TS of pyrethroid-treated particleboards surpass the requirement level for Type 13 boards as indicated in the Japanese Industrial Standard (JIS 2003). Only boards treated with OSP passed the standard requirement of MOE. It is also interesting to note here that only the untreated particleboards passed the IB and MOR tests.

The IB and MOR recorded for the untreated rubberwood particleboard in this study were respectively 12.5% and 5.6% lower than those found for particleboard made from particles of rubberwood derived from mature trees. Zaidon *et al.* (2001) reported that particleboards produced from 25 years-old rubberwood had IB of 1.04 N mm^{-2} and MOR 17.8 N mm^{-2}. This was anticipated due to the higher content of hemicellulose rather than cellulose in the juvenile wood which contributes to fiber strength. On the contrary, when treated with a boron compound, a significant reduction in IB (9.3%) and MOR (17.8%) was recorded for boards of juvenile rubberwood compared to those fabricated from particles of mature rubberwood. The IB and MOR for the latter were 1.08 N mm^{-2} and 15.93N mm^{-2} (Zaidon *et al.*, 2001). The higher reduction in the properties was probably attributed to thermal degradation of juvenile cellulose of the rubberwood. The presence of boric acid in the board coupled with strong heat (160^{0}C) from the hot press lowers the pH in the MUF resin system and accelerates hydrolysis in the resin with more formaldehyde being released from the resin polymer, which results in

TABLE 3
Adjusted mean mechanical and physical values and percent change in properties for pyrethroids and boric-acid treated particleboards compared with untreated

	Preservative treatments					
Properties/ a.i. w/w)	Deltamethrin 0.01%	OSP 0.19%	WP 0.61%	Boric acid 0.5%	Untreated 0.0%	JIS Type 13 board 0.0%
			Rubberwood particleboard			
IB (N mm^{-2})	1.05^{A1}±0.23	0.96^{A}±0.18	0.85^{B}±0.30	0.98^{A}±0.26	0.91^{A}±0.23	0.2
Change (%)	15.4	5.2	-7.0	7.7		
MOR (N mm^{-2})	18.2^{A}±2.40	18.6^{AB}±2.96	19.3^{A}±1.30	13.1^{C}±3.10	16.8^{B}±2.68	13.02
Change (%)	8.3	11.1	14.9	-21.9		
MOE (N mm^{-2})	1820^{B}±204	1972^{A}±394	2189^{A}±258	1751^{C}±89	1719^{B}±453	2000
Change (%)	5.9	14.7	27.3	1.9		
TS (%)	11.5^{B}±1.80	11.6^{B}±3.0	11.6^{B}±1.60	19.2^{A}±1.05	17.2^{A}±4.94	12
Change (%)	-32.9	-32.5	-32.6	11.4		
WA	49.1^{B}±4.50	76.7^{A}±5.40	72.3^{A}±5.60	44.1^{B}±8.10	71.9 ^{A} ±14.0	
Change (%)	-31.8	6.7	0.6	-38.8		
			EFB particleboard			
IB (N mm^{-2})	0.60^{BC}±0.28	0.67^{BC}±0.19	0.56^{C}±0.15	1.02^{A}±0.27	0.80^{B}±0.27	0.2
Change (%)	-24.9	-16.1	-29.9	27.7		
MOR (N mm^{-2})	26.9^{A}±4.64	16.5^{C}±3.78	17.4^{BC}±5.50	19.6^{B}±3.12	22.0^{B}±3.62	13.0
Change (%)	22.1	-25.2	-20.9	-9.0		
MOE (N mm^{-2})	898^{C}±110	1003^{BC}±144	1191^{A}±250	1083^{BA}±225	1276^{A}±188	2000
Change (%)	-29.6	-21.4	-6.7	-15.1		
TS (%)	10.6^{A}±0.78	11.6^{A}±2.03	11.6^{A}±1.60	8.90^{B}±0.98	11.3^{A}±2.8	12
Change (%)	-6.9	6.7	2.7	-28.4		
WA	51.3^{B}±3.40	81.8^{A}±8.0	74.0^{A}±8.0 0.6	57.2^{B}±8.13	75.3^{A}±18.0	
Change (%)	-32.0	9.3	-1.3	-24.0		
			Rubberwood + EFB (70:30) particleboard			
IB (N mm^{-2})	0.97^{B}±0.28	1.0^{B}±0.15	0.96^{B}±0.13	1.21^{A}±0.12	0.80^{B}±0.20	0.2
Change (%)	21.3	25.0	20.0	51.3		
MOR (N mm^{-2})	19.9^{A}±2.49	20.4^{A}±3.34	18.3^{A}±2.94	18.2^{A}±2.04	19.4^{A}±1.76	13.0
Change (%)	4.7	7.5	-5.3	-4.2		
MOE (N mm^{-2})	1467^{BC}±87	1319^{C}±394	1674^{B}±206	1716^{A}±92	1392^{C}±56	2000
Change (%)	5.4	-5.2	20.3	23.3		
TS (%)	12.0^{B}±1.23	9.38^{C}±1.25	13.7^{B}±2.30	17.1^{A}±2.40	12.1^{B}±1.23	12
Change (%)	-0.7	-25.6	15.7	-41.2		
WA	48.4^{BC}±4.43	41.4^{C}±7.16	51.1^{AB}±8.17	41.8^{C}±2.11	56.4^{A}±5.82	
Change (%)	-13.6	-26.8	-8.9	-25.3		

[1]Means within a row followed by the same alphabets are not significantly different at $p \leq 0.05$, [2]Percent change over untreated and ± are standard deviations

degradation of IB, thus affecting the MOR. The loss of formaldehyde due to these factors was reported by Pizzi (2003).

Properties of Treated EFB Particleboards

The IB for these boards were substantially reduced by 16-30% when treated with pyrethroids. On the contrary the bonding quality of boric-acid treated boards increased by 28%. The mean IB value for untreated boards was 0.80 N mm^{-2}. The significant reduction of IB in pyrethroid-treated EFB boards may be attributed to insufficient curing of the resin as indicated by the lower IB values. The incorporation of pyrethroids into the EFB furnish during blending may have changed the curing rate of the adhesive. Pizzi (2003) reported that melamine urea formaldehyde (MUF) resin requires an acidic condition (pH 4.5) to cure. Since EFB fiber is slightly alkaline in nature, the pH of glueline may change which subsequently slows down the polymerization reaction rate. Thus prolonged higher temperature is required to fully cure the resin. The gel time of admixture of MUF and pyrethroid preservatives has been reported to vary from 370 s to 520 s (Zaidon *et al.*, 2007) but the curing time of the adhesive when blended with EFB particles is not known and worth investigating. However, the IB values for all the treated and untreated boards conform with Type 13 board specified in JIS. With the exception of deltamethrin, other treatments reduced the MOR of the board. The MOR values for boards treated with WP and OSP were reduced by 21% and 25%, respectively, from the untreated with a value of 22.0 N mm^{-2}. Nevertheless, deltamethrin treatment increased the MOR of the board by 22% (26.9 N mm^{-2}). Pyrethroid treatments reduced the MOE of the boards even though the reduction was not significant for boards treated with WP. The mean MOE value for untreated board was 1276 N mm^{-2}. MOE was lowered by 29.6% (898 N mm^{-2}) for deltamethrin-treated board, by 21.4% (1003 N mm^{-2}) for OSP-treated board and by 6.7% (1191 N mm^{-2}) for WP-treated board. The MOE value for boric acid-treated board was reduced by 15.1% (1083 N mm^{-2}). Overall, the MOR of both treated and untreated EFB boards meet the minimum requirements of JIS standard for Type 13 board.

In terms of dimensional stability, the TS of deltamethrin-treated (10.6%), OSP-treated (11.6%) and WP-boards did not differ significantly from the untreated board (11.3%). and boric acid-treated boards had dimensional stability higher by 26.4% and 18.2%, respectively compared to untreated boards. TS of these boards achieved the standard requirement of JIS type 13 board. With respect to water absorption, only deltamethrin and boric acid treatments reduced the water absorption of the boards, i.e, by 32% and 24%, respectively from the untreated board absorption of 75.3%. For other treatments, however, the WA values did not differ significantly ($p \leq 0.05$).

Properties of Treated Rubberwood + EFB Blend Particleboards

Most of the properties for both untreated and treated boards showed values that ranged between those of rubberwood and EFB particleboards, and in many cases, the properties were more similar or leaned toward those of rubberwood particleboards. The IB of untreated blended board was similar to EFB board with a mean value of 0.80 N mm^{-2} whereas the IB values for pyrethroid-treated boards (0.96-1.0 N mm^{-2}) were comparable or slightly better than treated rubberwood boards (see Table 3). Similar to EFB boards, boric acid treatment significantly increased the IB (1.21 N mm^{-2}) of the blended boards. Apart from OSP and WP-treated boards, the MOR of these boards was superior to rubberwood boards, but inferior to EFB boards. Preservative treatments did not significantly affect the strength of these admixture boards (MOR values ranged from 18.2 to 20.4 N mm^{-2}). The MOR value for untreated boards was 19.4 N mm^{-2}. Deltamethrin and OSP treatments did not affect the stiffness of the boards (MOE 1319 and 1467 N mm^{-2}, respectively), but WP treatment increased the MOE by 20.3% to 1674 N mm^{-2}. A comparison of rubberwood and EFB boards showed that the mean MOE of admixture board was lower than that of rubberwood, but markedly higher than EFB.

Thickness swelling in untreated blended boards (12.06%) was comparable to EFB particleboards (11.3%) but they were more stable than rubberwood particleboards (17.2%). Only OSP-treated blended boards showed a significant increase ($p \leq 0.05$) in thickness swelling (by 25.6%). Boric-acid treated boards showed a reduced dimensional stability of the board by 41.2%. In general, all preservative treatments reduced the water absorption of these boards. The WA values for treated boards were in the range of 41.4 to 51.1% as compared to the untreated board which had a higher WA value of 56.4%.

Among the three types of particleboards, the mechanical properties of EFB particleboards were affected most by the pyrethroid treatments. This was indicated by significant reductions found in IB, MOR (except for deltamethrin-treated board) and MOE. The mechanical and physical properties of rubberwood and admixture particleboards that were treated with pyrethroid preservatives were comparable or better than those of untreated boards. When treated with boric acid, all the three types of particleboards showed a reduction in strength as reflected by lower MOR values. Such reduction may be attributed to the thermal degradation of cellulose during hot pressing under acidic conditions.

CONCLUSIONS

The findings from this study revealed that the pyrethroid treatments did not significantly affect bonding quality of rubberwood and rubberwood + EFB blend particleboards, but significantly reduced the IB of EFB particleboards. Strength of rubberwood boards (as reflected by MOR values) was improved by the treatments, while for boards from rubberwood + EFB blend, the strength was not affected. In the case of EFB boards, only deltamethrin treatment increased the strength but organic solvent-based and water-based permethrin treatments reduced the strength. Stiffness (MOE values) of pyrethroid-treated rubberwood and admixture boards was either increased or equal to the untreated boards. However, the stiffness of treated EFB boards decreased. Deltamethrin treatment increased the strength of admixture board, while organic solvent-based permethrin treatment increased the stiffness. The presence of pyrethroid preservatives markedly increased the stability of rubberwood and EFB particleboards. The thickness swelling of admixture board decreased only when it was treated with organic solvent-based permethrin. As a whole, regardless of raw material, pyrethroid-treated particleboards achieved the minimum requirement for IB, MOR and TS of Type 13 board of JIS 5908.

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