Journal of Applied Sciences

ISSN 1812-5654

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Journal of Applied Sciences 7 (8): 1145-1151, 2007
ISSN 1812-5654

Properties of Particleboard Made from Pretreated Particles of Rubberwood, EFB and Rubberwood-EFB Blend

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Abstract: The increasing use of low formaldehyde emission adhesives such as Melamine Urea Formaldehyde (MUF) for bonding particleboard and other wood composites has led researchers to find ways to improve the durability of these products against biodeterioration agents. A study on the treatment of particleboard through soaking of particles with 2% boric acid and 0.2% deltamethrin solutions was conducted. Particleboards were produced utilizing treated particles of rubberwood (clone RRIM 2002), Empty Fruit Bunches (EFB) and rubberwood-EFB blend (70:30). A low formaldehyde emission MUF resin (E1-grade) was used as a binder. The boards were evaluated for resistance against termite and fungal attack, static bending, internal bonding and dimensional stability. The properties were compared with those of untreated boards. The results of this study showed that the resistance of E1 grade MUF-bonded rubberwood and EFB particleboards against white rot fungus (*Pycnoporous sanguiness*) and termite (*Coptotermes curvignathus*) can be enhanced through the proposed treatment method. The particleboards made from both rubberwood and rubberwood-EFB blend require longer pressing time (> 6 min). Boric acid offered better protection against white rot wheras deltamethrin was more effective against termite. The bonding quality of both treated rubberwood and rubberwood-EFB blend boards was inferior compared to that of untreated board. Nonetheless, all treated EFB particleboards have higher IB. The strength and stiffness properties of rubberwood and rubberwood-EFB blend particleboards for both dry and wet conditions were markedly reduced by the treatments. The treatments increased the dry MOR and MOE values of EFB boards but lowered the wet MOR and MOE values. The study also indicated that the presence of preservatives had markedly decreased the stability of rubberwood and rubberwood-EFB blend particleboards.

Key words: Particleboard, melamine urea formaldehyde, deltamethrin, boric acid, *Pycnoporous sanguiness*, *Coptotermes curvignathus*

INTRODUCTION

Malaysia has proved itself to be one of the successful pioneers in utilizing rubberwood from rubber plantation as an alternative material for timbers from the natural forests. Rubberwood has been widely utilized in the manufacture of furniture and conventional composite products such as particleboard, Medium Density Fibre Board (MDF) and cement bonded particleboard. The progress in rubberwood utilization, however, does not auger with the supply of rubberwood in the country. One of the contributing factors is the significant decline in the total area of rubberwood plantations that were being converted into oil palm plantation. To ensure a continuous supply of rubberwood, Malaysian Rubber Board (MRB) has embarked on extensive research on new rubberwood materials comprising of new timber species and clones.

On the other hand, biomass from the oil palm industry has been gaining commercial importance for the past 10 years. It generates a large amount of residues and is the number one source for natural fibres (Rahim *et al.*, 1993). Extensive research on the conversion of oil palm trunks, Empty Fruit Bunches (EFB) and fronds into value added products such as particleboard, MDF, cement-bonded particleboard, fibre reinforced plastics and plyboards has been initiated with great commercial potentials (Chew and Ong, 1985; Chooi and Chan, 1998).

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Nonetheless, except for the production of MDF and particleboard using oil palm EFB fibres, the others remain as the laboratory-scale products.

Particleboards manufactured from admixture of rubberwood and oil palm EFB have been shown to have great potential (Chew and Ong, 1985; Rahim *et al.*, 1993; Abdul Karim *et al.*, 1994). However, the uncertainties of their properties have made them difficult to be accepted by the local particleboard manufacturers even though studies using such material have shown good results. To jump start the utilisation of oil palm EFB in the local particleboard plants, blending of these material with new clone rubberwood particles may provide a route to a wider usage. This approach would also help to reduce the cost of raw material in the particleboard mills.

Laboratory studies (Chew and Ong 1985; Rahim *et al.*, 1993; Abdul Karim *et al.*, 1994) indicated that oil palm EFB can be combined with rubberwood in the manufacture of particleboard. In these studies, the oil palm EFB particles were used as core material in a three-layered rubberwood particleboard. The results indicate that except for the thickness swelling, other properties are satisfactory meeting the minimum standards of JIS A 5908 (Rahim *et al.*, 2001). Improvements are being made on the bonding quality of these panels through the use of other resins such as Melamine Urea Formaldehyde (MUF) and Isocyanate-base.

The increasing use of low formaldehyde emission adhesive such as E1-grade MUF (maximum formaldehyde emission <0.01 ppm) for bonding particleboard and other wood composites has led researchers to find ways to improve the durability of the products against biodeterioration agents. Improving the durability of the board by preservative treatment is one way of extending its end uses. The addition of such chemicals is necessary to increase the little inherent resistant to decay and insect attack possessed by this kind of material.

A study on treatment of single layer particleboard made from rubberwood (clone RRIM 2002), EFB and rubberwood-EFB blends through soaking of particles with boric acid and deltamethrin-based preservative solutions was undertaken. This study reports the resistance of the treated board against fungal and termite attacks. The mechanical and physical properties of the boards are also discussed.

MATERIALS AND METHODS

Preparation of particles: The material used in this study were four-year-old rubber tree from clone RRIM 2002 which was extracted from RRIM plantation, Besut, Terengganu and Empty Fruit Bunches (EFB), supplied by SABUTEK Sdn. Bhd, Telok Intan, Perak. Both materials were chipped, flaked and screened into particles of size ranging from 0.5-2.0 mm in size. Immediately after screening, the particles were soaked separately in solutions of 0.2% (w/v) Cislin® (a.i. deltamethrin) and 2% (w/v) boric acid (Orthoboric acid, H_3BO_3) for 2 min. The treated and untreated particles were dried to 5% Moisture Content (MC) in a standard industrial oven maintained at 60°C. 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.

Manufacture of particleboard: Single layered particleboards 340×340×10 mm with a target density of 650 kg m^{-3} and final MC of *ca.* 12% were fabricated. Pre-weighed particles, untreated and treated with preservatives, were blended separately with 11% (w/w of od particles) MUF-E1 resin and 1% (w/w of od particles) wax. Six boards from each treated and untreated rubberwood, EFB and rubberwood-EFB blend (70 parts rubberwood and 30 parts EFB) were made. The furnish was then formed in a former, pre-pressed and subsequently pressed in a hot press maintained at 160°C for 6 min (as specified by the resin supplier). Prior to the property evaluations, all boards were conditioned in a conditioning room maintained at 20°C and 65% relative humidity for one week before they were cut into testing specimens. The number of particleboards and treatment combinations used for this study are summarized in Table 1.

Resistance of particleboards against fungal and termite attack: The test on resistance against white rot fungus (*Pycnoporous sanguiness* Wulfex Fries) and termite (*Coptotermes curvignathus* Holmgren) was carried out in the laboratory using the method specified in the American Wood Preserver's Association (AWPA M10-77) (Anonymous, 1977) and American Society of Testing Material (ASTM D3345-74) (Anonymous 1972), respectively. The efficacy of the treatment was evaluated based on the percent weight loss caused by fungus degradation and termite attack. For each fungus and termite tests, six test blocks, i.e., 16×16×10 mm for fungus

Table 1: Number of particleboards and treatment combinations used in this study

Raw materials	Untreated	Soaking in 0.2% w/v deltamethrin	Soaking in 2% w/v boric acid
Rubberwood	6	6	6
EFB	6	6	6
Rubberwood-EFB blend (70:30)	6	6	6
Total boards	18	18	18

test and 25×25×10 mm for termite test, were cut from the treated and untreated particleboards. The blocks were conditioned in a conditioning room until they reached constant weight. Their weights were measured and the blocks were then placed in culture bottles containing either white rot mycelium or termites. The bottles with the fungus were left in an incubating room maintained at 25±2°C and 65% humidity, while for the bottles with termites were left in the dark at room temperature. At the end of the test period, i.e., 12 and 4 weeks for fungus and termite tests, respectively, the test blocks were removed from the bottles and all mycelium or sand that adhered on the surface of the blocks were brushed off. They were again left in the conditioning room until their weights were constant. The percent weight loss from the conditioned weight before and after exposure was calculated using Eq. 1:

$$\text{Weight loss (\%)} = [\,W1 - W2)/W1\,] \times 100 \quad (1)$$

where,

W1 = Conditioned weight before exposure to fungus or termite
W2 = Conditioned weight after exposure to fungus or termite

Mechanical and physical properties of the particleboard: The boards were trimmed at the edges and cut into required dimensions for the physical and mechanical tests as shown in Fig. 1. 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 5908A 1994) (Anonymous, 1994). Density and moisture content for each of the test specimens were recorded. Since the final density of the boards fabricated varies considerably (approximately 10% variation), all strength and physical property values were adjusted to a target density of 650 kg m^{-3} using Eq. 2:

$$\text{Adj P} = \Delta P\,(\rho_t \,.\, \rho_a) + P_a \quad (2)$$

where,

Adj P = Adjusted property to target density
ΔP = Slope of regression of property against density
ρ_t = Target density
ρ_a = Actual density
P_a = Actual property

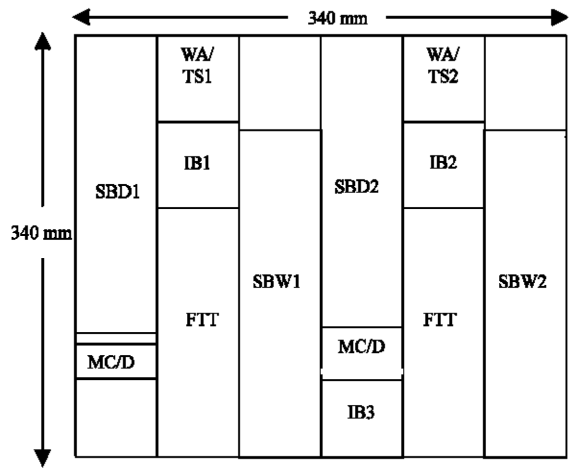

Fig. 1: Cutting patterns of the testing specimens from each board, SB = Static Bending, IB = Internal Bond, TS = Thickness Swelling and water absorption, MC/D = Moisture Content and Density and FTT = Fungus and Termite Tests

Statistical analysis: All data were statistical analysed using one-way analysis and the mean value of each property was separated using Least Significant Difference (LSD) test to determine the differences between treatment levels.

RESULTS AND DISCUSSION

Resistance of particleboards against fungal and termite attack: The results on the mean weight loss and increase in resistance of treated boards after exposure to white rot fungus and termite are summarized in Table 2. Lower weight loss values indicate higher resistance against deteriorating agents. Percent increase in resistance of treated boards was calculated against the untreated. All control (untreated) blocks were completely covered with mycelium, while very little was seen on the surface of the treated blocks. As a whole, the preservative treatments successfully increased the resistance against white rot and termite attacks. Among the untreated particleboards, those made from rubberwood had the highest weight loss (37.19%) followed by boards made from EFB (29.16%) and Rubberwood/EFB blend (27.2%). However, the statistical analysis shows that the values for both EFB and Rubberwood-EFB particleboards did not differ significantly at $p<0.05$.

The weight loss values for untreated rubberwood particleboard were slightly higher than the values reported in an earlier study, i.e., 30.34% (Zaidon *et al.*, 2001). Nevertheless, in the earlier study the adhesive used in fabricating the board was MUF-E2 type (MUF-E2,

Table 2: Mean weight loss of treated and untreated boards and percent increase in resistance of treated particleboards when subjected to *Pycnoporous sanguiness* and *Coptotermes curvignathus*

Preservatives	Weight loss due to white rot (%)	Increase in resistance against white rot (%)	Weight loss due to termite (%)	Increase in resistance against termite[1] (%)
Rubberwood (Clone RRIM 2002)				
Control	37.19±10.29[a]		26.42±6.11[a]	
(untreated)	N = 6	-	N = 6	-
Deltamethrin	Sample failed[2]	na	8.69±5.13[c]	67.27
(0.2% w/v)			N = 6	
Boric acid	11.93±8.24[b]	67.91	12.12±6.01[b]	54.14
(2% w/v)	N = 6		N = 6	
	(67.9)			
Empty fruit bunches (EFB)				
Control	29.16±6.50[a]		15.12±4.26[a]	
(untreated)	N = 6	-	N = 6	-
Deltamethrin	18.52±9.23[b]	36.5	7.82±3.70[c]	48.3
(0.2% w/v)	N = 6		N = 6	
Boric acid	9.09±7.89[c]	69.0	10.26±1.78[b]	32.2
(2% w/v)	N = 6		N = 6	
	(69.0)			
Rubberwood and EFB blend				
Control	27.2±7.16		21.7±5.31[a]	
(untreated)	N = 6		N = 6	-
Deltamethrin			10.33±3.55[b]	
(0.2% w/v)			N = 6	52.4
Boric acid			7.79±2.56[b]	64.1
(2% w/v)			N = 6	

[1]Calculated based on weight loss of treated boards against untreated, [2]Majority of test blocks disintegrate during removing from the culture bottles, Means in a column followed by the same letter is not significantly different at $p<0.05$. Analysed separately for each raw material

maximum permissible formaldehyde emission >0.1 ppm). These findings suggest that the amount of formaldehyde emission may have significant effect on the resistance against white rot fungus. The current results also revealed that EFB is more resistance against white rot fungus than rubberwood clone RRIM 2002.

Treatments with boric acid and deltamethrin increased the resistance of rubberwood and EFB particleboards against *P. sanguiness*. The resistance values (recorded as percent weight loss) of boric acid-treated rubberwood (11.93%) and EFB (9.09%) boards when subjected to a white rot fungus were increased by 67.9 and 69.0%, respectively. However, when pre-treated with deltamethrin, the EFB boards exhibited a smaller increment in resistance (36.5%). The average weight loss value for this board was only 18.53%. For deltamethrin-treated rubberwood and admixture particleboards, most of the blocks were broken during removing the blocks from the culture bottles, thus the weight loss data cannot be determined. The fragility of the specimens was probably attributed to the low bonding quality of the material. The bonding property of the treated boards is discussed in the next section.

When tested against *C. curvignathus*, EFB particleboard was the most resistant against termite while rubberwood particleboard was the least. The weight loss for EFB particleboard was 15.2%, while for rubberwood and admixture particleboard had the weight loss values of 26.4 and 21.7%, respectively. Generally deltamethrin treatment increased the resistance for rubberwood, EFB and admixture boards against termite by 67.2, 48.3 and 52.4%, respectively. While boric acid treatment increased the resistance of rubberwood board by 54.1%, EFB board 32.2% and admixture board 64.1%. Zaidon *et al.* (2003) found that the resistance of MUF-bonded rubberwood particleboard when spray treated with 0.5% BAE solution against termite increased by 55.9% and the resistance increased as the retention of BAE in the board increases. Observations were also made on termite activities during the 28 day exposure period. After 15 days of exposure, 100% mortality of termites was noted in the culture bottles containing treated blocks. For untreated rubberwood and blend particleboard, at least 15% of termites survived throughout the test. Grace *et al.* (1992) reported that Douglas fir blocks treated with 0.35% Boric Acid Equivalent (BAE) killed all the termites within 3 weeks and resulted in a 10% weight loss of the blocks. The low mortality of termites for the treated blocks at the early stage of exposure was probably due to the availability of suppliants in the termites which enable them to survive. At the later stage, the mortality was attributed to the reaction of the toxicant which was ingested by the termites (Mauldin and Karl, 1996).

The variability in the resistance of the particleboards against the degradation agents is possibly due to the extractive contents in the material. Some extractives like starch is a source of food for fungus and insects while others like hydrolysable and condensed tannins, lignins, alkaloids, terpenoids, flavanoids and a few others impart decay resistance (Eaton and Hale, 1995). The amount of these compounds may vary between rubberwood and EFB. The above results reveal that, between the treatments, soaking of particles in 2% boric acid solution provides better protection for MUF-bonded particleboard against white rot, while soaking in 0.2% deltamethrin solution serves better control against termite.

Physical and mechanical properties of particleboards: A great variation of density was recorded in the boards. The values ranged from 599-669 kg m^{-3} for untreated boards and 583-787 kg m^{-3} for treated boards. Lehmann (1974) stated that the final density greatly influenced the physical and mechanical properties of the boards. Owing to this, all the properties tested in this study were adjusted to a density of 650 kg m^{-3}. The adjustment was carried out by performing a regression analysis for each of the treatment (refer to Eq. 2). The adjusted values for Internal Bonding (IB), Modulus of Rupture (MOR), Modulus of Elasticity (MOE), Thickness Swelling (TS) and Water Absorption (WA) are listed in Table 3. Figure 2 exhibits the change in properties as compared to the untreated boards.

The following discussion assumes that all the treated specimens have a uniform distribution of preservatives. The results show that strength and stiffness as well as the bonding quality of rubberwood and admixture particleboards were significantly affected by the preservative treatments. However, the properties of EFB board were improved. The deltamethrin treatment was found to reduce the IB of rubberwood particleboard from 0.91 to 0.40 N mm^{-2}, i.e., 56% reduction in IB property, while boric acid treatment reduced the IB by 37% to 0.57 N mm^{-2}. For blended particleboard, the boric acid and deltamethrin treatments reduced the IB of the boards from 0.80 to 0.61 N mm^{-2} (24% reduction) and 0.39 N mm^{-2} (51% reduction), respectively. The IB values for treated EFB particleboards were improved from 0.80 to 0.91 and 0.92 N mm^{-2} for boric acid and deltamethrin treatments, respectively. The increments in IB were 14-24%. The significant reduction of IB in treated rubberwood and admixture boards may be attributed to insufficient curing of adhesive. This lack of curing is obviously seen on the tested tensile specimens where the fibers are easily detached upon pulling. Internal bond measures the particleboard efficiency and indicates the compatibility of resin adhesive. The preservative contained in the particles before fabricating into particleboard may change the compatibility of the resin adhesive. In the previous study, incorporation of 0.5% w/w (od particles) boric acid by spraying during blending in MUF and UF-bonded rubberwood particleboard did not significantly affect the IB of the board (Zaidon *et al*., 1998, 2001). However, when higher amount of the preservative was added in the board the IB of the boards reduced. Similar effect was observed in this study where soaking of particles in preservative solution lead to higher retention of the dry salt, hence the board properties containing the treated materials were affected.

Table 3: Adjusted mean mechanical and physical properties of untreated and preservative treated particleboards made from rubberwood (clone RRIM 2002), EFB and rubberwood and EFB blend

		Dry condition		Wet condition		Physical properties	
Treatments	IB (N mm^{-2})	MOR (N mm^{-2})	MOE (N mm^{-2})	MOR (N mm^{-2})	MOE (N mm^{-2})	TS (%)	WA (%)
Rubberwood (clone RRIM 2002)							
Control	0.91 ± 0.30^{a}	16.80 ± 2.68^{a}	1721 ± 411^{a}	4.00 ± 2.40^{a}	497 ± 206^{a}	17.2 ± 4.94	71.9 ± 14.0^{a}
(Untreated)	N = 16	N = 12	N = 12	N = 14	N = 14	N= 14	N = 14
Deltamethrin	0.40 ± 0.06^{c}	7.40 ± 1.97^{c}	900 ± 320^{b}	1.50 ± 0.40^{b}	669 ± 399^{a}	Failed	88.0 ± 16.7^{b}
(0.2% w/v)	N = 16	N = 16	N = 16	N = 6	N = 6	(>100%)	N = 16
Boric acid	0.57 ± 0.11^{b}	9.63 ± 1.36^{b}	1076 ± 257^{b}	2.50 ± 0.72^{ab}	662 ± 182^{a}	Failed	71.8 ± 13.97^{a}
(2% w/v)	N = 16	N =16	N = 16	N = 7	N = 7	(>100%)	N = 16
Empty Fruit Bunches (EFB)							
Control	0.80 ± 0.27^{b}	21.99 ± 3.62^{b}	1276 ± 188^{a}	9.64 ± 1.61^{a}	366 ± 118^{a}	11.28 ± 2.84^{a}	75.0 ± 17.7^{a}
(Untreated)	N = 16	N = 10	N = 10	N = 14	N = 14	N = 14	N = 14
Deltamethrin	0.10 ± 0.11^{a}	25.1 ± 2.37^{a}	1439 ± 166^{a}	7.05 ± 1.05^{b}	212 ± 98^{b}	11.95 ± 0.78^{a}	71.0 ± 3.5^{a}
(0.2% w/v)	N = 12	N = 12	N = 12	N = 6	N = 6	N = 12	N = 12
Boric acid	0.91 ± 0.20^{ab}	22.45 ± 1.6^{b}	1415 ± 294^{a}	5.6 ± 1.1^{c}	215 ± 68^{b}	10.84 ± 1.1^{a}	61.0 ± 6.3^{b}
(2% w/v)	N = 16	N = 16	N = 16	N = 7	N = 7	N = 16	N = 16
Rubberwood + EFB (70:30)							
Control	0.80 ± 0.20^{a}	19.45 ± 1.8^{a}	1292 ± 183^{a}	7.57 ± 0.50^{a}	497 ± 38^{a}	12.46 ± 1.2	56.0 ± 5.8^{b}
(Untreated)	N = 6	N = 4	N = 4	N = 4	N = 4	N = 4	N = 4
Deltamethrin	0.39 ± 0.14^{c}	17.02 ± 1.6^{b}	1022 ± 209^{b}	2.56 ± 0.20^{b}	150 ± 84^{b}	Failed	74.9a±7.5
(0.2% w/v)	N = 16	N = 16	N = 16	N = 6	N = 6	(>100%)	N = 16
Boric acid	0.61 ± 0.18^{b}	18.26 ± 1.6^{ab}	870 ± 223^{b}	2.99 ± 0.20^{b}	148 ± 11^{b}	Failed	55.2 ± 4.7^{b}
(2% w/v)	N = 16	N = 16	N = 16	N = 5	N = 5	(>100%)	N = 16

Means in a column followed by the same letter is not significantly different at $p<0.05$. Analysed separately for each raw material, N, is a number of sample

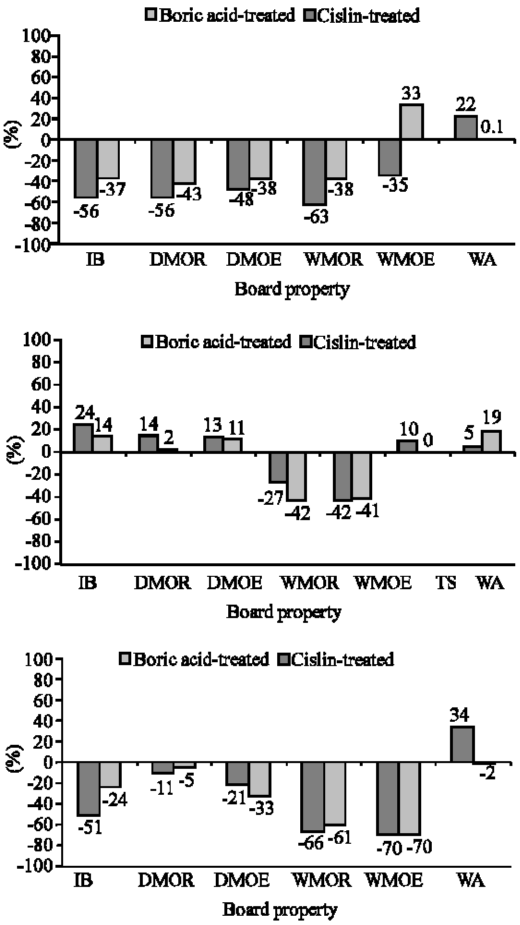

Fig. 2: Percent relative change in properties against untreated. Top: Rubberwood particleboard; Middle. EFB particleboard and Bottom: Rubberwood and EFB blend

A significant reduction in MOR (43-56%) and MOE (38-48%) values when rubberwood particleboards were treated with both preservatives in which the deltamethrin-treated board showed a markedly reduction in the properties. There was a slight to moderate reduction of MOR (5-11%) and MOE (21-33%) for treated rubberwood+EFB blend particleboard. On the other hand, treatment of EFB particles increased the strength and stiffness of the boards in dry condition. The IB increased significantly by 24% to 0.1 N mm^{-2} and 14% to 0.91 N mm^{-2} when treated with deltamethrin and boric acid, respectively. The MOR values for the untreated EFB board was 21.99 N mm^{-2} and this property increased to 22.5 N mm^{-2} for boric acid-treated and 25.1 N mm^{-2} for deltamethrin-treated boards. In wet condition, the MOR and MOE values of EFB were significantly reduced. For deltamethrin and boric acid treatments the MOR reduced from 9.64 to 7.05 and 5.6 N mm^{-2}, respectively, while the stiffness was lowered by approximately 42% for both deltamethrin-treated and boric-acid treatments. The wet MOE value for the untreated EFB boards was 366 N mm^{-2}.

The significant reduction in strength for treated rubberwood and rubberwood-EFB blend particleboards may be attributed to one of the two possibilities. Firstly, it was possibly due to the bonding quality of the board as reflected by the lower IB values. Secondly, the thermal degradation of juvenile cellulose of the rubberwood. The presence of boric acid and deltamethrin in the board coupled with heat (160°C) from the hot press to bond the particles will hydrolyse the bonds between the glucose units and will effectively rupture the micrifobrils and creating shorter chains. Ifju (1964) stated that most of the strength properties of wood are closely related to cellulose microfibril integrity, the degradation of cellulose will reduce the bending strength.

Thickness Swelling (TS) measures the dimensional stability of the boards. The lower the TS, the better the dimensional stability of the board. TS tests for treated rubberwood and rubberwood-EFB blend particleboard failed since the specimens swelled enormously (>100%). This results correspond well with the IB strength obtained for these boards. The low IB values indicate that the particles were not effectively bonded together, hence cannot prevent the water from penetrating into the particles. A better result was observed for EFB boards. The TS of treated and untreated were about the same. i.e., 11-12%. The WA value for untreated and boric acid-treated rubberwood boards was approximately 72% and for the rubberwood+EFB blend boards was 55-56%. For EFB board. The water absorption of the boards from 75% to 71% for deltamethrin-treated board and 61% for boric acid-treated boards.

CONCLUSIONS

The findings from this study revealed that the resistance of MUF-E1 bonded particleboard made from rubberwood and EFB against white rot fungus and termite can be enhanced through soaking the particles with small amount of boric acid (2% w/v) and deltamethrin (0.2%) solutions prior to fabricating into particleboard. However, for manufacturing rubberwood and rubberwood+EFB blend particleboards using the preservative-treated particles, the hot pressing parameters employed in this study as recommended for the commercial particleboard is not suitable and requires modification. Boric acid offered better protection for particleboard against *P. sanguiness*, whereas deltamethrin is more effective against *C. curvignathus*.

With regard to the bonding quality, the preservative treatments significantly lowered the IB strength of rubberwood and rubberwood-EFB blend particleboards, but the treatments increased the IB of EFB board.

Strength and stiffness of rubberwood and rubberwood-EFB blend particleboards either in dry or wet conditions were slightly and markedly reduced by the treatments. The treatments increased the dry MOR and MOE values of EFB boards but lowered the wet MOR and MOE values. The presence of preservatives markedly decreased the stability of rubberwood and rubberwood-EFB blend particleboards.

As a whole, the treatment system used in this study may be suitable for the manufacturing of particleboard from empty fruit bunches of oil palm. A comprehensive study on the compatibility of resin adhesive and the treated particles of rubberwood and treatment method are currently being conducted and will be reported in the next series of paper.

ACKNOWLEDGMENTS

The authors wish to thank the Director of Rubber Research Institute, Malaysia, General Manager of Sabutek Sdn. Bhd, Telok Intan, Perak and Manager of Research and Development, Malaysian Adhesive and Chemicals Sdn. Bhd., Shah Alam for the supply of raw materials and adhesive. A special thank is also extended to the Ministry of Science, Technology and Innovation for their financial support through the Priority Research- IRPA grant.

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