EFFICACY OF PYRETHROID AND BORON PRESERVATIVES IN PROTECTING PARTICLEBOARDS AGAINST FUNGUS AND TERMITE

A. Zaidon[1,*], A. M. Norhairul Nizam[1], A. Faizah[1], M. T. Paridah[1], H. Jalaluddin[1], M. Y. Mohd Nor[2] & M. Y. Nor Yuziah[3]

[1]*Universiti Putra Malaysia, 43400, Serdang Selangor, Malaysia*
[2]*Forest Research Institute Malaysia, 52109 Kepong, Selangor, Malaysia*
[3]*Malaysian Adhesive & Chemicals Sdn. Bhd., PO Box 7086, 40702 Shah Alam, Malaysia*

Received January 2007

ZAIDON, A., NORHAIRUL NIZAM, A. M., FAIZAH, A., PARIDAH, M. T., JALALUDDIN, H., MOHD NOR, M. Y. & NOR YUZIAH, M. Y. 2008. Efficacy of pyrethroid and boron preservatives in protecting particleboards against fungus and termite. Pyrethroid-formulated preservatives were investigated for their efficacy in protecting rubberwood and empty fruit bunches (EFB) particleboards against fungi and termites. Timberlife®, Stoprot® and Cislin® solutions (5% w/w of particles) were incorporated in rubberwood (clone RRIM 2002), EFB and rubberwood–EFB blend (70:30) particleboards by spraying the solutions separately into the furnish during blending. Boric acid (0.5% w/w) was used for comparison. A low formaldehyde emission melamine urea formaldehyde (MUF) resin (E1 grade) was used as binder. The pressing time of each type of board was determined by studying the gelation time of the adhesive mixture with added preservatives. With the exception of Timberlife®, all preservatives markedly increased the gelation time of the resulting adhesive mixture. The gel time for control mixture (without preservative) was 360 s. The resistance of treated particleboards against biodeterioration agents was evaluated based on weight loss of testing blocks after exposure to white rot fungus *(Pycnoporus sanguineus)* and subterranean termite *(Coptotermes curvignathus)*. The resistance of particleboards either against white rot fungus or termite can be enhanced through incorporation of small amount of pyrethroid formulated preservatives through spraying during blending of furnish. Timberlife® provided the best protection of these particleboards against *P. sanguineus.* Cislin® offered the best protection for EFB particleboard against termite. Stoprot® gave fair protection to all particleboards against white rot fungus and termite, while boric acid still gave the best protection to rubberwood particleboard against termite.

Keywords: Panel, preservatives, boric acid, *Pycnoporous sanguineus, Coptotermes curvignathus*

ZAIDON, A., NORHAIRUL NIZAM, A. M., FAIZAH, A., PARIDAH, M. T., JALALUDDIN, H., MOHD NOR, M. Y. & NOR YUZIAH, M. Y. 2008. Keberkesanan bahan awet piretroid dan boron dalam melindungi papan serpai daripada kulat dan anai-anai. Bahan awet formulasi piretroid dikaji keberkesanannya melindungi papan-papan serpai kayu getah dan hampas kosong kelapa sawit (EFB) daripada serangan kulat dan anai-anai. Larutan Timberlife®, Stoprot® dan Cislin® (5% w/w serpai) dicampurkan ke dalam papan serpai kayu getah (klon RRIM 2002), EFB dan papan serpai adunan kayu getah–EFB (70:30) melalui semburan larutan bahan awet semasa proses adunan serpai. Asid borik (0.5% w/w) digunakan sebagai perbandingan. Resin melamin urea formaldehid (MUF) jenis pelepasan formaldehid rendah (gred–E1) digunakan sebagai perekat. Masa tekanan untuk setiap jenis papan ditentukan dengan mengkaji tempoh pengegelan campuran perekat dan bahan awet. Semua bahan awet kecuali Timberlife® meningkatkan tempoh pengegelan campuran perekat. Masa gel untuk campuran kawalan (tanpa bahan awet) ialah 360 s. Kerintangan papan serpai yang dirawat terhadap agen pereput dinilai berdasarkan kehilangan berat blok ujian selepas didedahkan kepada kulat reput putih *(Pycnoporus sanguineus)* dan anai-anai bawah tanah *(Coptotermes curvignathus)*. Kerintangan papan serpai sama ada terhadap kulat reput putih atau anai-anai boleh ditingkatkan melalui campuran formulasi bahan awet piretroid dalam kuantiti yang rendah melalui semburan semasa adunan serpai. Timberlife® memberi perlindungan terbaik kepada semua jenis papan serpai terhadap *P. sanguineus.* Cislin® memberi perlindungan terbaik kepada papan serpai EFB terhadap anai-anai. Stoprot® memberi perlindungan sederhana kepada semua papan serpai terhadap kulat reput putih dan anai-anai sementara asid borik masih lagi terbaik bagi melindungi papan serpai kayu getah daripada anai-anai.

*E-mail: zaidon@putra.upm.edu.my

INTRODUCTION

A series of researches were conducted to fabricate wood composites using the new latex timber rubber clone (RRIM 2002) and oil palm empty fruit bunches (EFB) blend at Universiti Putra Malaysia. Both rubberwood and EFB are the main fibre resources available and are considered residues of agricultural activities (Norini *et al.* 1998, Paridah & Zaidon 2000). EFB are fibrous biomass left behind from the fruit bunches of oil palm which have been extracted for oil production. One of the products understudied was development of particleboard from EFB.

Wood composites are generally less susceptible to biodeterioration compared with solid wood (Behr 1972, Zaidon *et al.* 2003). However, with the utilization of non-durable raw materials such as rubberwood coupled with the use of low formaldehyde emission adhesives such as melamine or urea formaldehyde as binders would encourage microorganism attack especially if the product is exposed to moisture. Previous researches showed that the resistance of rubberwood composites to fungi and termites could be enhanced through incorporation of small amounts of boron compound and CCA (Zaidon *et al.* 1998, Zaidon *et al.* 2002, Zaidon *et al.* 2003). Since boron compound and CCA are becoming less popular nowadays due to their hazard to human beings, new and more environment friendly preservative formulations are sought after. Pyrethroids are potential groups of chemical preservatives that may replace boron and CCA preservatives.

Earlier studies revealed that the treatment of low formaldehyde emission MUF-bonded particleboards made from rubberwood (latex timber clone RRIM 2002), EFB and rubberwood–EFB blend through soaking of particles with 0.2% deltamethrin and 0.2% boric acid solutions could enhance the resistance of the product against white rot fungus *(Pycnoporus sanguineus)* and termite *(Coptotermes curvignathus)* (Zaidon *et al.* 2007). Most of the strength and physical properties, however, were reduced except for particleboard fabricated from EFB. The cause of poor board performance was probably attributed to improper curing of the adhesive which may be interfered by dry salt retention during manufacturing of the board. It was thought that the pressing time employed in the previous study as recommended by the resin supplier was not long enough to fully cure the resin.

This study attempted to incorporate small amounts of pyrethroid-based and boric acid preservatives into particleboard made from rubberwood, empty fruit bunch (EFB) and rubberwood–EFB blend. The efficacy of these treatments was evaluated based on the resistance of the treated particleboards to fungal and termite attack.

MATERIALS AND METHODS

Materials

Four-year-old rubber tree, *Hevea brasiliensis* (latex timber clone RRIM 2002) extracted from RRIM plantation, Besut Terengganu and oil palm (*Elaeis guineensis*) EFB, supplied by SABUTEK Sdn. Bhd, Telok Intan, Perak, were used. The adhesive used was a low formaldehyde emission type (E1-grade resin) (MUF-E1, maximum permissible formaldehyde emission < 0.1 ppm). New formulation pyrethroid-based preservatives (Timberlife®, Stoprot® and Cislin®) were used as treating solutions. The active ingredient and concentration of each chemical compound are listed in Table 1. Timberlife® is an organic solvent-based preservative, while Stoprot® and Cislin® are water-based preservatives. Analytical grade boric acid (orthoboric acid, H_3BO_3) was used for comparison.

Preparation of materials

The materials were chipped, flaked and screened into particles ranging from 0.5 to 2.0 mm in size. The particles were dried to 5% moisture content (MC) in a standard industrial oven maintained at 60 °C. Single layered particleboards with dimensions 340 × 340 × 10 mm with targeted density of 650 kg m^{-3} and final MC of ca. 12% were fabricated. The parameters used to manufacture the particleboards are summarized in Table 2. Boards from each treated and untreated rubberwood (Rw), EFB and rubberwood–EFB blend in the ratio 70:30 were made. The preservative solutions of various concentrations (see Table 2) were sprayed onto the furnish which was first blended with 11% MUF-E1 and 1% wax.

Table 1 Active ingredients and concentrations of preservatives

Trade name	Composition	Concentration (%)
[1]Timberlife®	Tributyltin naphthenate	3.5
	Permethrin	0.2
	Dichlofuanid	0.1
	Organic solvent	96.2
	(Total active ingredient)	(3.8)
[2]Stoprot®	Disodium octaborate	10
	Benzalkonium chloride	2.0
	Permethrin	0.2
	Water	87.8
	(Total active ingredient)	(12.2)
[3]Cislin®	Deltamethrin	0.2
	Water	99.8
	(Total active ingredient)	(0.2)
Boric acid	Orthoboric acid	100 (solid)

[1, 2, 3]Anonymous (2000, 2003, na)

Table 2 Parameters used in the particleboard manufacture

Raw materials	Rubberwood (Clone PRIM 2002) Empty fruit bunches (EFB) Rubberwood–EFB blend (70:30)
Target board density	650 kg m^{-3}
Target board MC	12%
Board size	(340 × 340 × 10) mm^3
Adhesive	
MUF-E1 GRADE (55.8% solid)	11% (w/w of particles)
Industrial grade Hardener, (NH_4Cl)	11% (w/w of solid resin)
Wax	11% (w/w of particles)
Preservatives	
Timberlife®	5% solution (w/w of particles) or 0.19% a.i.
Stoprot®	5% solution (w/w of particles) or 0.61% a.i.
Cislin®	5% solution (w/w of particles) or 0.01% a.i.
Boric acid	0.5% solution (w/w of particles) or 0.5% a.i.

The solution concentrations were calculated to obtain loading of active ingredients in each board as recommended by the producers (Anonymous 2000, 2003, NA). For boric acid treatment, a pre-weighed solid salt was dissolved in distilled water. The treated furnish was blended for approximately 15 min to ensure uniform distribution of active ingredients. The furnish was then formed in a former, pre-pressed and subsequently pressed in a hot press at 15 kg cm^{-2} maintained at 160 °C. The time of hot pressing was dependent on the results of the gelation time of the admixture of adhesive and preservatives (Table 3). A total of four boards for each treatment combination were made. All boards were conditioned at 20 ± 2 °C and 65 ± 5% relative humidity for one week before they were cut into testing blocks.

Determination of gelation time of the adhesives

In this study, the gelation time for the adhesive mixed with preservatives was determined. The same amount of adhesive formulation (resin + hardener [NH4Cl] + wax) and preservatives to be used in fabricating the particleboard was prepared. The first formulation comprised 69.02% MUF-E1, 0.62% hardener (NH4CL) and 30.36% of each pyrethroid solution, while the second formulation comprised 94.8% MUF-E1, 0.85% hardener and 4.3% solid boric acid. The formulation was mixed in a 100 ml beaker. The beaker and its contents were submerged in boiling water and stirred until the adhesive hardened and gelled. The pH of the adhesive mixture and time taken for it to gel was recorded. The experiment was replicated three times.

Table 3 Gelation of adhesive mixtures with added preservatives

Adhesive/ Preservatives	pH at 30 °C	Adhesive mixture[a]	pH at 30 °C	Gelation time[b] (s)	Estimated pressing time
MUF-E1	9.7[c]	MUF-E1	9.0	361	6 min 1 s
Boric acid	6.7	MUF-E1 + boric	12.7	439	7 min 19 s
Cislin®	7.0	MUF-E1 + Cislin®	10.2	466	7 min 46 s
Timberlife®	7.8	MUF-E1 + Timberlife®	11.2	370	6 min 10 s
Stoprot®	8.0	MUF-E1 + Stoprot®	11.5	520	8 min 40 s

[a] Ammonium chloride was added at 1% w/w resin solid.
[b] Gelation time at 100 °C
[c] Mean of three replicates

Resistance of particleboards to fungal decay

The decay resistance against the white rot fungus, *P. sanguineus,* was carried out in the laboratory using the method specified in ASTM D2017-81 (ASTM 1996). The efficacy of the treatment was assessed based on the per cent of weight loss caused by fungal degradation. Eight test blocks, 16 × 16 × 10 mm, were cut from each treated and untreated boards. The blocks were stabilized in a conditioning room maintained at 25 ± 2 °C and 65 ± 5% relative humidity until they reached constant weight. The test bottles were prepared according to ASTM D2017-81 (ASTM 1996). Rubberwood feeder strips of dimensions 3 × 20 × 30 mm were laid flat on the soil surface in the test bottles. The bottles were loosely capped and steamed sterilized at 121 °C for 30 min. After cooling and keeping overnight, the feeder strip in each bottle was inoculated with the white rot fungus. The fungus was allowed to grow and cover the feeder strip before the pre-weighed test block was introduced. The bottles together with the contents were left in an incubating room maintained at 25 ± 2 °C and (70 ± 5)% relative humidity. At the end of 12 weeks, the test blocks were removed from the bottles and all mycelium adhered on the surface of the blocks were brushed off. They were again left in the conditioning room until their weights were constant. The per cent weight loss [(Wa – Wb)/Wa] × 100 from the conditioned weight before (Wa) and after exposure (Wb) was calculated.

Resistance of particleboards to termite attack

The test on resistance of treated boards against termite *(C. curvignathus)* was carried out in the laboratory in accordance with ASTM D3345-74 (ASTM 1998). Eight blocks of 25 × 25 × 10 mm were randomly cut from each of the untreated and treated boards and conditioned in the conditioning room until they reached constant weights. The weights were measured and the blocks were placed in test bottles filled with sand. The test bottles and the sand were prepared according to ASTM D3345-74 (ASTM 1998). The bottles, together with their contents, were sterilized at 120 °C for two hours. Approximately (1.0 ± 0.05) g termites comprising 10% soldiers and 90% workers were introduced in each of the test bottles. The bottles were covered with black paper and kept at room temperature 26 ± 1 °C for four weeks. The activities of the termites were observed and the mortality recorded at the end of 1st, 2nd and 4th week of exposure. At the end of four weeks, the blocks were removed, cleaned and conditioned in a conditioning room until their weights were constant. The resistance to termite attack was calculated based on percentage weight loss [(W1 – W2)/W1] × 100 from the conditioned weight before (W1) and after exposure (W2). The percentage mortality of termites (No / Ni) × 100 in the test bottles was also calculated based on the number of dead (No) and the original number (Ni).

Statistical analyses

All data were statistically analysed using one way analysis of variance (ANOVA) and the mean values of weight loss was separated using Least Significant Difference (LSD) to determine the differences between groups.

RESULTS AND DISCUSSION

Gelation time of adhesive formulation

With the exception of Timberlife®, all preservatives markedly increased the gelation time of the resulting adhesive mixture (Table 3). The control mixture (without preservative) had relatively shorter gelation time, i.e. 361 s. This increment may be attributed to the increase in the pH of the adhesive mixture after addition of preservative. Since MUF resin requires an acidic condition to cure, normally pH < 4.5 (Pizzi 2003), higher pH slows down the rate of polymerization, thus longer time or higher temperature is required to fully cure the resin. This information is crucial for setting the press time to ensure enough time to complete cross-linking of the adhesive. Hence, in this study, different press times were used to manufacture the treated boards.

In an earlier study, Zaidon *et al.* (2007) reported that the press time used to fabricate particleboards made from Cislin®- and boric acid-treated particles of rubberwood and rubberwood–EFB blend was insufficient to fully cure the resin. In the study 360 s of press time was used for fabricating treated and untreated boards, whereas the exact press time for Cislin® -added and boric acid-added adhesives were 466 and 439 s respectively (Table 3).

Rubberwood particleboard

All the rubberwood particleboards were attacked by white rot fungus (Table 4). Untreated blocks showed significantly higher weight loss (35.14%) when compared with the range of treated blocks (5.56–25.58%). Among the preservatives, Timberlife® provided the best protection against white rot fungus (5.56%). The per cent change in weight loss over untreated blocks was 84.2% (Figure 1). The least effective preservative was Cislin® whereby it only increased the resistance of the rubberwood particleboard to the fungus by 27.2%. The weight loss values were 7.82 and 12.02%, for Stoprot-® and boric acid-treated boards respectively. This means that the increment in resistance to fungal attack were 77.7% for Stoprot® and 65.8% for boric acid.

EFB particleboard

Among the untreated blocks a lower weight loss was recorded for EFB blocks (25.16%), compared with those from rubberwood and admixture blocks (35.14%, 25.47%).The least weight loss recorded for EFB particleboard may be probably due to the reduction of starch content in fibres of empty fruit bunches during the steaming process to extract fruits from the fruit bunch in palm oil mill. As in rubberwood particleboards, preservative treatments to this board produced a similar trend of resistance to white rot decay. Timberlife® (Figure 1) was the best formulation to protect against white rot (65.8% increment in resistance) and Cislin® formulation was the least (16.8% increment). The other two preservative formulations increased the resistance by 51.5 and 56.7% for boric acid and Stoprot® respectively.

Rubberwood–EFB blend particleboard

The untreated blended boards had a quite similar mean weight loss (25.47%) compared with those of untreated EFB blocks (25.16%). In terms of efficacy, except for Cislin®-treated blocks, all treated blocks had higher mean weight loss values compared with those of the other two groups. Timberlife® still recorded the best protection with resistance increment of 61.6% (Figure 1). This was followed by boric acid and Stoprot®. Even though the increment in resistance were merely 48.5 and 42.3% respectively, the difference, however, was not significant. Cislin® treatment did not significantly increase the resistance to fungal attack as reflected by the lower value of per cent change in weight loss against that of untreated (2.1%).

Table 4 Mean weight loss of untreated and treated particleboards after 12 weeks of exposure to *Pycnoporus sanguineus*

	Weight loss (%) ± SD				
	Control	Timberlife®	Stoprot®	Cislin®	Boric acid
Active ingredient in a board		0.19% a.i. or 0.93 kg m^{-3}	0.61% a.i. or 2.98 kg m^{-3}	0.01% a.i. or 0.005 kg m^{-3}	0.5% a.i. or 2.64 kg m^{-3}
Rubberwood	35.14 ± 9.61 a n = 8	5.56 ± 0.37 d n = 5	7.82 ± 1.68 d n = 5	25.58 ± 10.16 b n = 7	12.02 ± 2.74 c n = 7
EFB	25.16 ± 6.75 a n = 9	8.60 ± 0.77 d n = 6	10.9 ± 3.24 cd n = 6	20.94 ± 8.25 b n = 7	12.21 ± 3.06 c n = 7
Rubberwood–EFB blend	25.47 ± 6.05 a n = 7	9.78 ± 3.03 c n = 8	14.70 ± 1.66 b n = 8	24.94 ± 13.37 a n = 8	13.12 ± 3.67 b n = 8

n = Number of samples
Means within a row followed by the same letter are not significantly different at $p < 0.05$. Analysed separately for each raw material.

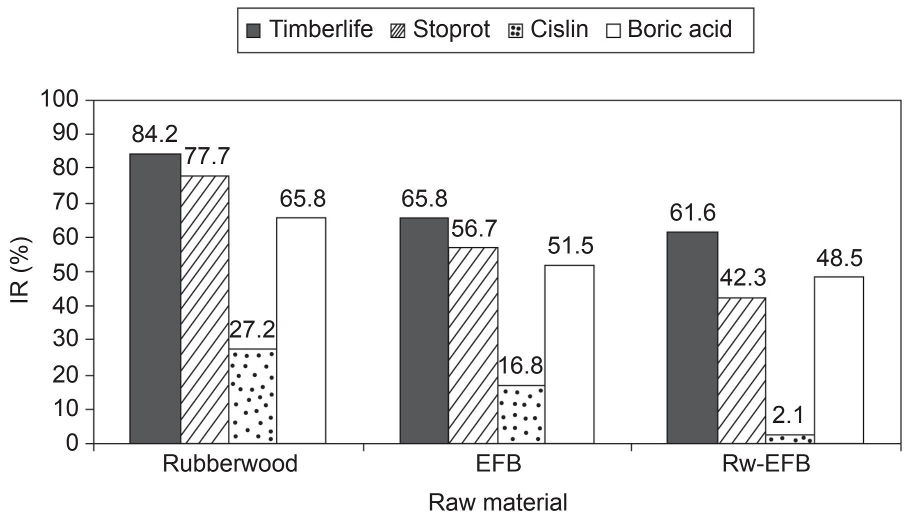

Figure 1 Increment in resistance (IR) of treated blocks due to *P. sanguineus* decay calculated against untreated blocks

As a whole, Timberlife® was the best preservative formulation for the protection of rubberwood, EFB and rubberwood–EFB blend particleboards. The presence of active ingredient fungicide tributyltin naphthenate (3.5%) in the formulation may be responsible for its superior performance. Benzalkonium chloride which is the active ingredient present in the Stoprot® formulation is also a fungicide but in lower content (2.0%). This may be the reason for its lower efficacy than Timberlife® in protecting against *P. sanguineus*. Cislin® preservative contains only insecticide, i.e. pyrethroid compound (0.2% deltamethrin), while boric acid is known to have fungicidal and insecticidal properties.

Resistance of particleboards to termite attack

During the test period, termite activities were observed daily. After introducing termites into the culture bottles, they were very active on the sand and started digging tunnels downward either in the preservative-treated blocks or in the untreated blocks. The presence of tunnels indicates the vigour of the termites (ASTM 1998). After one week, the termites in treated blocks started to move upwards to the surface, indicating the response of termites towards the repellency effects of the preservative (ASTM 1998). After the second week, 100% mortality was noted in the treated blocks and untreated EFB blocks and about 75% in untreated admixture blocks. For untreated rubberwood blocks, less than 50% termite mortality was recorded. At the end of the test period 85.3% mortality of termite was recorded in the rubberwood blocks. Mauldin and Karl (1996) stated that the low mortality of termites for 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, mortality was attributed to the reaction of the toxicant which was ingested by the termites.

Rubberwood particleboard

All treatments significantly reduced the weight loss of this board (Table 5). The mean weight loss value for untreated rubberwood block was 31.1%. Boric acid provided the best protection against termites whereby it increased the resistance of the board by 79.9%. Timberlife® and Stoprot® increased the resistance by 76.9 and 75.0% respectively, while Cislin®, by 61.5%.

EFB particleboard

For untreated blocks, the weight loss value (17.75%) was relatively lower compared with untreated rubberwood blocks. A different trend of resistance against termite was observed in treated EFB particleboards. In this case (Figure 2), Cislin® exhibited the best protection against termite with 65.7% increment of resistance, followed by boric acid (60.5%), Timberlife® (44.3%) and Stoprot® (32.0%). However, the weight loss values for Cislin-® and boric acid-treated blocks did not differ significantly.

Rubberwood–EFB blend particleboard

The untreated admixture blocks had slightly higher weight loss value (18.29%) than EFB blocks but the difference was not significant. Compared with rubberwood blocks, the weight loss value for these blocks was significantly lower. Like the treated particleboard, Timberlife® showed the best protection against termites (57.5% increase in resistance), while the other three preservative formulations increased the resistance in 51–52% only. The weight loss values for these preservative-treated blocks did not differ significantly.

In general, the rubberwood particleboard was the most susceptible to termite attack. The EFB fibres were harder and stiffer (Paridah & Zaidon 2000) and therefore less attractive to termites. In addition, EFB fibre contains less carbohydrate due to steaming during palm oil extraction which makes it much less preferred compared with the starch rich rubberwood. It is also interesting to note that the weight loss value for untreated rubberwood particleboard (31.10%) was higher than those reported, i.e. 26.30% (Zaidon *et al.* 2003). In previous studies, particles were screened from matured stem of rubberwood tree. Juvenile wood which has more sapwood and contains higher hemicellulose (Haygreen & Bowyer 1996) may be more attractive to termites. The variability of resistance of treated particleboards to termite attack was probably attributed to one of two possibilities. Firstly, the level of toxicity of the component in the formulation and secondly, the retention of active ingredients in the board. Timberlife® which is an organic solvent-based pyrethroid compound (0.2% permethrin) was the best formulation to protect rubberwood–EFB blend particleboards against *C. curvignathus*. Cislin®, a formulation containing another pyrethroid compound (0.2% deltamethrin) was able to give the best protection to EFB particleboard even with a small amount of active ingredient retention (0.01%) (Table 5). Boron compound was still the best preservative for the protection of rubberwood particleboard.

CONCLUSIONS

The addition of Cislin®, Stoprot® and boric acid in the adhesive mixture increased the curing time of the resin. A longer pressing time was needed for particleboards treated with these preservative formulations. As a consequence of longer pressing time in board fabrication, the production yield may be reduced. The resistance of rubberwood, EFB and rubberwood–EFB blend particleboards against *P. sanguineus* or *C. curvignathus* could be enhanced through the incorporation of small amounts of pyrethroid-formulated preservatives through spraying during blending of furnish. Timberlife® provided the best protection to rubberwood, EFB and admixture particleboards against

Table 5 Mean weight loss of sample blocks of untreated and preservative-treated particleboards after four weeks of exposure to *Coptotermes curvignathus*

	Weight loss (%) ± SD				
	Control	Timberlife®	Stoprot®	Cislin®	Boric acid
Active ingredient in a board		0.19% a.i. or 0.96 kg m^{-3}	0.61% a.i. or 3.10 kg m^{-3}	0.01% a.i. or 0.005 kg m^{-3}	0.5% a.i. or 2.64 kg m^{-3}
Rubberwood	31.10 ± 3.30 a n = 8	7.17 ± 1.07 bc n = 5	7.77 ± 0.82 bc n = 5	11.97 ± 5.70 b n = 7	6.25 ± 3.67 c n = 7
EFB	17.75 ± 7.05 a n = 8	9.89 ± 1.21 c n = 5	12.07 ± 1.64 b n = 5	6.09 ± 4.77 d n = 8	7.01 ± 4.41 cd n = 8
Rubberwood–EFB blend	18.29 ± 4.81 a n = 6	7.78 ± 2.12 b n = 8	8.78 ± 4.63 b n = 8	9.03 ± 3.49 a n = 8	8.94 ± 4.50 b n = 8

n = Number of samples
Means within a row followed by the same letter are not significantly different at $p < 0.05$. Analysed separately for each raw material.

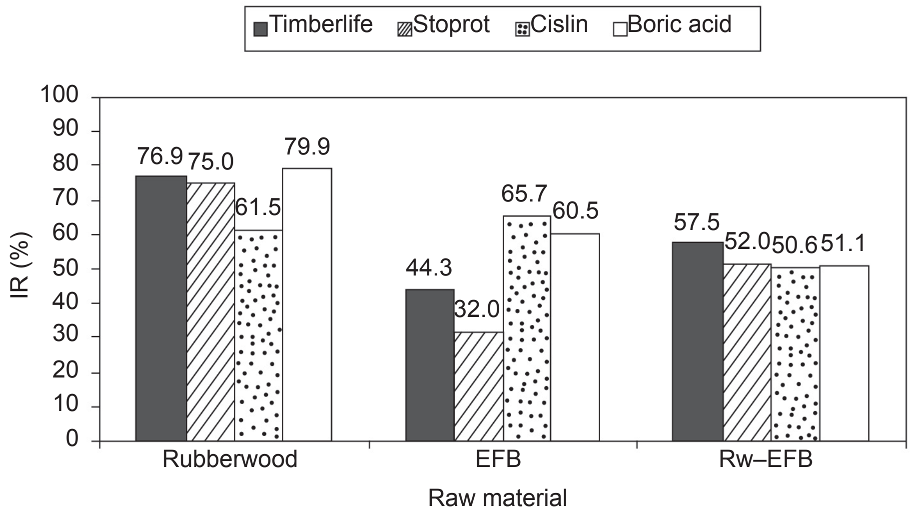

Figure 2 Increment in resistance (IR) of treated blocks due to *C. curvignathus* attack calculated against untreated blocks

P. sanguineus and admixture particleboard against *C. curvignathus.* Cislin® offered the best protection to EFB particleboard against termite even with a small amount of active ingredient retained in the board. However, it is least effective to protect all particleboards against white rot. Stoprot® gave fair protection to all particleboards against white rot and termites, while boric acid was still the best protection for rubberwood particleboard against termites.

ACKNOWLEDGEMENTS

The authors wish to thank the Director of the Rubber Research Institute Malaysia, General Manager of Sabutek Sdn. Bhd, Manager of the Research and Development, Malaysian Adhesive & Chemicals Sdn. Bhd., Shah Alam and Manager of Research and Development, Protim Solignum Sdn. Bhd. Petaling Jaya for the supply of raw materials, adhesive and preservatives. A special thank is also extended to the Ministry of Science, Technology and Innovation for financial support.

REFERENCES

Anonymous. 2000. *Protim® Timber Life Exterior: Water Repellent Organic Solvent Based Fungicidal and Insecticidal Preservative.* Tech. Data Sheet. Osmose Co., Malaysia.

ANONYMOUS. 2003. Osmose® *Stop Rot: Colourless Fungicidal and Insecticidal Preservative*. Tech. Data Sheet. Osmose Co., Malaysia.

ANONYMOUS. Not available. Cislin® *Wood Protectant: The Welcome Solutions for Wood Protection Against All Insect Pests*. Tech. Data Sheet. Bucks, UK.

ASTM (American Society for Testing and Materials). 1996. ASTM D2017-81 (reapproved 1994). Standard test method of accelerated laboratory test of natural decay resistance of woods. Pp. 348–352 in *Annual Book of ASTM Standards. Vol. 04.09*. ASTM, Philadelphia.

ASTM (American Society for Testing and Materials). 1998. ASTM D3345-74. Standard test method for laboratory evaluation of wood and other cellulosic materials for resistance to termites. Pp. 430–432 *in Annual Book of ASTM Standards, Vol. 04.10*. ASTM, Philadelphia.

BEHR, F. A. 1972. Decay and termite resistance of medium density fiberboards made from wood residue. *Forest Products Journal* 22: 48–51.

HAYGREEN, J. G. & BOWYER, l. 1996. *Forest Products and Wood Science*. Third edition. Iowa State University Press, Ames.

MAULDIN, J. K. & KARL, B. M. 1996. Disodium octaborate tetrahydrate treatments to slash pine for protection against Formosan subterranean termite and Eastern subterranean termite (Isoptera: Rhinotermitidae). *Journal Economic Entomology* 89: 682–687.

NORINI, H. I., WAN ASMA, W. I. & MOHD. AZMI, I. 1998. Availability of oil palm residues in Peninsular Malaysia. Pp. 146–152 in Jalaluddin, H. *et al.* (Eds.) *Proceedings of the Seminar on Utilization of Oil Palm Tree Residues*. 29 April–1 May 1997, Kuala Lumpur.

PARIDAH, M. T. & ZAIDON, A. 2000. Oil palm tree residues for fibre-reinforce composite material—an overview. *Malaysian Forester* 63: 69–76.

PIZZI, A. 2003. Melamine formaldehyde adhesives. Pp. 653–679 in Pizzi, A. & Mittal, K. L. (Eds.) *Handbook of Adhesive Technology*. Second edition. Marcel Dekker, New York.

ZAIDON, A., KAMARUL AZLAN, M., FAIZAH, A. H. & MOHD. HAMAMI. S. 2002. Resistance of some forest plantation timbers against rotting fungus and their durability in ground contact. *Pertanika Journal Tropical Agriculture Science* 25: 69–73.

ZAIDON, A., MOY, C. S., SAJAP, A. S. &. PARIDAH, M. T. 2003. Resistance of CCA and boron-treated rubberwood composites against termites, *Coptotermes curvignathus* Holmgren. *Pertanika Journal Science and Technology* 11: 65–72.

ZAIDON, A., NORHAIRUL NIZAM, A. M., MOHD NOR, M. Y., FAIZAH, A., PARIDAH, M. T., NOR YUZIAH, M. Y. & JALALUDDIN, H. 2007. Properties of particleboard made from pretreated particles of rubberwood, EFB and rubberwood–EFB blend. *Journal Applied Science* 7: 1145–1151.

ZAIDON, A., RAYEHAN, H. PARIDAH, M. T. & NOR YUZIAH, M. Y. 1998. Incorporation of preservative in particle board: properties and durability. *Pertanika Journal Tropical Agriculture Science* 21: 88–92.