ISSN 1996-3351

Asian Journal of Biological Sciences

Knowledgia
SCIENTIFIC
A Place to Publish Outstanding Research

Asian Journal of Biological Sciences 6 (3): 153-160, 2013
ISSN 1996-3351 / DOI: 10.3923/ajbs.2013.153.160

Effects of Chemical Treatments on Durability Properties of *Gigantochloa scortechinii* Strips and Ply-bamboo

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ABSTRACT

The aim of this study is to investigate the effect of some preservative treatment on the durability properties of bamboo (*Gigantochloa scortechinii*) strips and bamboo laminated product. The durability properties are examined by exposed the of bamboo samples to termite (*Coptotermes curvignathus*) for 4 weeks and white rot fungal (*Pycnophorous sanguineus* Wulfex Fries) for 12 weeks. The efficacy of treatments on bamboo strips and laminates against white rot and termite attacks were evaluated based on their weight loss after exposure to those biodeteriorating agents. All preservative-treated materials had resulted lower weight loss values compared to untreated and water-boiled bamboo treatment. The Water-Borne Preservatives (WBP) (5.80% weight loss) gave the best protection against termite whereas borax acid-treated (39.3%) materials had the least efficacy on protecting the strips. For the bamboo laminates, TBTO gave the best protection against termite attacks with only 8.9% of weight loss. The durability test against white rot fungal show that all preservative increased the resistance of bamboo strips and laminates. TBTO was found to be the best preservative to protect both bamboos strips (10.7% weight loss) and laminates (9.71% weight loss). Boiling in water for 30 minutes had decreased the resistance of the strips against white rot with the weight loss value for this strip was 21.8 while 22.4% for the laminates.

Key words: *Gigantochloa scortechinii*, preservation, termite, white rot fungus

INTRODUCTION

Bamboo is a fast growing plant; possess high mechanical properties among woody materials and being considered as an alternative to wood (Wahab *et al*., 2006). Anwar *et al*. (2005) reported that bamboo such as *G. scortechinii* are suitable for composite materials, laminated boards and plybamboo due to its fast growing ability and availability, as well as its attractive and unique appearance.

The weakness of bamboo is that, bamboo products cannot be placed outdoor or exposed under high moisture content. Like other lignocellulosic material bamboo served a very low resistance against bio-degradation agents. Therefore, fresh felled bamboo must be treated. The presence of large amount of starch makes it more susceptible fungal and insect attacks. Thus, there is a needed to treat bamboo culms to prolong it service life. Bamboo can be preserve either by using chemicals or non-chemicals method.

The chemical method ensures a longer service life for bamboo products and maintains its quality (Satish and Dobriyal, 1992; Anonymous, 2006) when compared to non-chemical methods. Nowadays, emerging of naturally derives preservatives gain a new approach to the industry. These naturally derived preservatives pose a better option towards environmental friendly products. An example, permethrin or cypermethrin is a pyrethroid insecticide, is a chlorinated which originally derived from the *pyrethrum* extract which is comes from the chrysanthemum plant. Permethrin is a broard spectrum non-systemic synthetic pyrethroid insecticide. It is a primarily a contact poison that depends on disturbance of axonic nerve impulse conduction and causing rapid paralysis followed by death (Imgrund, 2003). The current use of permethrin includes insecticide, termiticide and wood preservatives. A few of the target pests include alfalfa weevil, armyworms, leafhoppers, green fruitworm, European corn borer, flea beetles, stink bugs, termites, mosquitoes, ticks and lice (Meister, 2001; Thomson, 1997). Koike *et al.* (2000), reported that currently pyrethroids, organophosphorus and nitroguanidine insecticide are used as barriers for subterranean termites. Cox, (1996) indicated that pyrethroid insecticides (bifenthrin, cypermethrin, fenvelerate, permethrin) are highly repellent to termite. In fact, permethrin and particularly cypermethrin have low toxicity and are now extensively used.

The objective of this study is to evaluate the effects of chemicals and boiling treatments on durability of bamboo strips against termite and rotting fungus attacks. Prior to treatments all bamboo splits were dried in an air-dry condition for two weeks. The bamboo then was subjected to several chemicals treatments and boiling treatment and was tested for the resistance against termite (*Coptotermus curvignathus* Holmgren) and white rot (*Pycnophorous sanguineus* Wulfex Fries) attacks.

MATERIALS AND METHODS

Bamboo culms were split and the epidermis was removed. Then the bamboo strips of 150×20×4 mm were vacuum treated with borax (5%), tributyltin-oxide (TBTO, 1%), LOSP (a.i Tributyltin naphthenate (3.5%), Permethrin (0.2%)), WBP (a.i Disodium octaborate (10%), Benzalkonium chloride (2%), permethrin (0.2%). The strips were dries in kiln drying for 1 week. Another batch of the treated and untreated strips were then fabricated into laminates using Phenol Formaldehyde (PF) as binder. Laboratory accelerated test on durability of the treated bamboo against termite (*Coptotermus curvignathus*) was determined using standard specified in ASTM (1999). A total of 48 testing samples were prepared for the termite test. The samples sizes of 25×25× 4 mm were cut from bamboo strips and 25×2×12 mm for bamboo laminates. Prior to testing, all samples were conditioned at 25±2°C and 65% RH until their weights are constant. The samples were then exposed to termite for four weeks. Testing on durability against fungi (*Pycnophorous sanguineus* Wulfex Fries) was carried out according to the method specified in the American Wood Preservatives Associations Standard (AWPA) -M10-77 Standard Method of Testing Wood Preservatives by Laboratory Soil-Block Cultures (AWPA, 2001). The treated and untreated bamboo strips and laminates were cut into 16×16 by 5 mm of dimension size. Rubberwood (*H. brasiliensis*) samples of 16×16×5 mm were cut for reference blocks. Sixty samples were prepared for the testing including 20 reference samples. The test was completed when the reference samples lost 50% of their weight. All blocks were exposed to white rot fungus for 12 weeks. The specimens were weighed after conditioned in a conditioning room at 20±2°C and 65±3% RH before and after exposure to the fungus.

RESULTS AND DISCUSSION

The highest retention gained was the bamboo strips treated with TBTO which gained 0.55% chemicals. This is followed by LOSP with 0.48%, WBP (0.36%) and Borax (0.22%). Zaidon *et al.* (2000) was found the same trend in chemicals loading in *G. scortechinii* strips where treated with 5% borax was attained more than the threshold limit (0.2%). However, boiled treatment removed off some component in bamboo which is a result in reduction in weight of the bamboo strips.

Resistance of bamboo strips and laminates after treatment with chemicals against termite (*Coptotermes curvignathus*): The durability was measured according to the weight loss of samples after exposure to termite (*Coptotermes curvignathus*) for 4 weeks. The least weight loss value indicates the highest resistance to termite attack. The percentage of increment in resistance of treated bamboo laminates was calculated against the untreated samples. The mean weight losses of treated and untreated samples summarized in Table 1.

Among the treatments, strips which were treated with WBP had the least weight loss (5.8%) compared to others. This is followed by LOSP (18.2%), TBTO (22.9%), borax (39.2%), untreated (45.3%) and boil-treated (72.9%) respectively. The percentage of weight loss for the bamboo laminates was 8.9% for TBTO, followed by LOSP and WBP (9.7%), Borax (17.2%), untreated (23.6%) and boiled-treated (26.1%).

The decrement in resistance for boiled-treated samples was probably attributed to the removal of some of toxic extractives during boiling treatment. This is because of after boiling treatment extractives, starch, organic acids, hemicelluloses and other mineral substances were dissolved in water (Bujanovic *et al.*, 2000; Mollekopf and Ledig, 2002). Cellulose is a primary source of food for termite (Bowyer *et al.*, 2003) and the absence of the toxic substances in boiled-treated samples makes the bamboo prone to attack by termite compared to other treatment and untreated samples. This is supported that the durability of bamboo, against mold, fungal and borers attack is strongly associated with its chemical composition.

Observation on bamboo strips, found that the inner part of the strips was severely attacked by termite. The bamboo samples were eaten by termite and scattered everywhere sooner than the surface. According to Bhat *et al.* (2005) this is probably due to high starch content was found in the inner part comparedto the outer part of the culm. The authors also revealed that inner portion of *Bambusa bambos* was severely attacked by termite while the outer portion remained nearly sound without much tunneling.

Table 1: Mean weight loss of sample of untreated and treated bamboo strips and laminates after 4 weeks of exposure to termite (*Coptotermes curvignathus*)

	Strip		Bamboo Laminates	
Treatment	Weight loss(%)	Increment in resistance (%)	Weight loss (%)	Increased in resistance (%)
Untreated	45.3±6.38[b]		23.6±4.55[bcd]	
Boiling (water)	72.9±37.2[a]	-60.9	26.1±3.10[b]	-10.3
Borax (5% w/v)	39.3±26.2[bc]	13.3	17.2±1.14[cd]	27.4
LOSP (Total a.i 3.8% w/v)	18.2±9.10[cd]	59.9	9.7±2.15[d]	58.9
WBP (Total a.i 12.2% w/v)	5.80±2.65[d]	87.2	9.7±5.09[d]	58.8
TBTO (1% w/v)	22.9±7.13[bcd]	49.4	8.9±2.09[d]	62.5
Rubberwood	41.6±11.6[bc]			

No. of samples = 48, Values in parentheses are standard deviations. Mean followed by the same letter in a column is not significantly difference at $p \leq 0.05$, (-) sign were indicates the decrement in resistance to termite attack

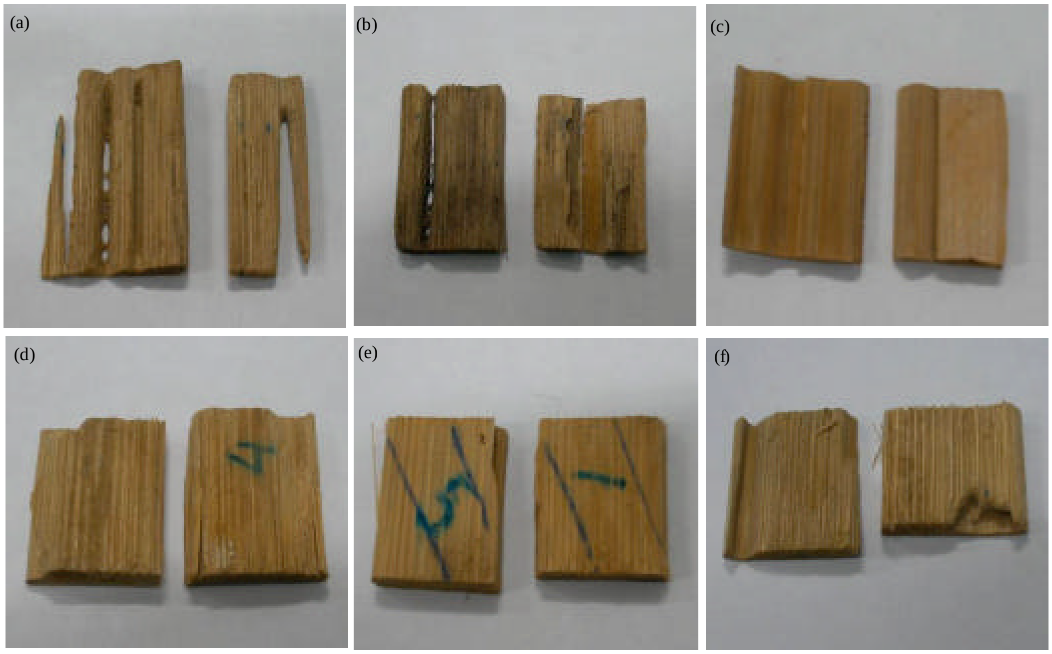

Fig. 1(a-f): Typical ratings on termite damaged at inner part of the bamboo strip samples following rating value specific in ASTM standard ASTM, 1999, (a) Untreated samples (Mostly the inner part of the sample were severely attacked by termite), Rating: 4 , (b) Boiling (Damage by termite is shows less severe than untreated), Rating: 5, (c) Boric acid (The damages were moderate as shown from the slight attack from termite), Rating: 7, (d) Loght Organic Solvent Preservatives (LOSP), (The damages was moderate as shown from the slight attack by the termite), Rating: 7, (e) Water-borne Preservatives (WBP) (Minimum damage occurred as shown from the slight attack by the termite), Rating: 9, (f) TBTO (The damage was moderate as shown by the slight attack from termite), Rating: 7

Figure 1 shows the damaged the bamboo sample after exposure to termite for four weeks. The samples evaluation was based on ASTM standard (ASTM, 1996) Standard Method of Laboratory of Wood and Other Cellulosic Materials for Resistance to Termite. Untreated and boiled-treated bamboo strips were rated number four (4) and based on the weight loss of these samples strips were 45-75%. For borax acid-treated, LOSP-treated and TBTO treated bamboo, the strips were rated seven (7). The samples were moderately attacked by termite with the weight loss of 20-40%. WBP-treated bamboo strips was rated as nine (9) which was slightly attacked by termite. The bamboo weight loss of this sample was 10%.

WBP offers the best protection against termite attack for bamboo strips after being exposed to termite for 4 weeks. The presence of insecticidal and fungicidal active ingredients, a,i (10% disodium octaborate, 2% benzalkonium chloride and 0.2% permethrin) in their ready used formulation in WBP was strongly responsible for this superior performance. The total of 12.2% a.i. contain in WBP are greatly influenced the efficacy of the treatment compared to LOSP 3.8, TBTO 1 and borax 5% a.i.

As a whole, it was observed that the trend of using chemical treatment increased 50% resistance against termite compared to untreated bamboo sample. In contrast, boiling treatment was not the suitable method in increasing bamboo resistance against termite attacks because it doesn't offer the best protection to the bamboo samples. The study shows that, bamboo sample were severely attacked by termites and the bamboo strips samples lost more than 60% loss of its weight. This suggested that this treatment was not effectively protecting the bamboo samples.

In bamboo laminates, protection against termites was more effective compared to bamboo strips. Chemicals that used to treat the bamboo strips were incorporated with the formaldehyde that derived from phenol formaldehyde resin. Aldehydes in certain concentrations have a narcotic effect on the central nerveous system which gives local irritation on the mucous membrane (Roffeal, 1999). Formaldehyde irritation is also mainly centered on the upper respiratory tract.

Efficacy of chemical treatments on bamboo strips toward

Fungal (*Pycnoporous sanguineus*) attack: Table 2 summarized the efficacy of chemical and non-chemical treatments on bamboo strips and laminates against white rot fungus (*Pycnoporous sanguineus*) based on percentage weight loss of the samples after exposure to the fungus.

From Table 2, it shows that except for boiling in water, the resistance against fungal attack on the strips and laminates were increased. The weight loss value for untreated and treated bamboo strips were in the ranged 10.69 to 21.81% and for bamboo laminates 9.71 to 22.88%. Samples treated with TBTO were the least deteriorated by the fungi with 10.69% weight loss for strips and 9.71% weight loss for bamboo laminates. The is followed by Borax-treated strips with weight loss 11.23% and laminates (10.49%), WBP-treated bamboo had weight loss of 11.04 and 11.49% for strips and laminates, respectively. Next, LOSP-treated strips was loss 12.66% for strips and 12.71% for laminates, 21.81% weight loss for boiled-treated strips and 22.38% for laminates and lastly, for untreated strips 23.4% weight loss and 22.9% for laminates.

TBTO-treated samples recorded the highest increment in resistance against the fungus with the percent increment of 39.2 and 57.6% for strips and laminates, respectively. This is followed by WBP-treated strips with 37.2%, borax-treated (36.1%) and LOSP-treated (27.9%) strips. However, the resistance against fungal attack decreased when the bamboo was boiled in water. The value recorded was 8.81 and 24.1%. As a whole, regardless of treatment, after TBTO-treated, borax-treated 54.2% increment followed by WBP-treated laminates with 49.7%, LOSP®-treated (44.5%) and lastly boiling treated bamboo laminates with 2.18%.

Table 2: Mean weight loss of untreated and treated bamboo strips and laminates after exposure to white rot fungus (*Pycnoporous sanguineus*)

	Strip		Laminates	
Treatment	Weight loss (%)	Increment in resistance (%)	Weight loss (%)	Increment in resistance (%)
Untreated	17.57±13.6^{bc}	-	22.88±18.3^{a}	-
Boiling in water	21.81±10.0^{a}	-24.1	22.38±14.4	2.18
Borax (5% w/v)	11.23±1.68^{ab}	36.1	10.49±4.89^{ab}	54.2
LOSP (Total a.i 3.8% w/v)	12.66±2.43^{ab}	27.9	12.71±0.81^{ab}	44.5
WBP (Total a.i 12.2% w/v)	11.04±2.13^{ab}	37.2	11.49±1.48^{ab}	49.7
TBTO (1% w/v)	10.69±3.49^{b}	39.2	9.71±6.16^{b}	57.6
Rubberwood	58.57±16.01^{a}			

No. of sample, 80, Values in parentheses are standard deviations. Mean with the same letter with a column are not significantly different at $p \leq 0.05$, (-) sign were indicates the decrement in resistance against termite attack

The used of TBTO may control the oxidative phosphorylation of mitochondria to control the whole metabolic activity of animal and plant cells (Li and Shi, 1994). Its toxicological mechanism against fungus has not been ascertain but is supposed to be analogous (Cui and Kamdem, 2000). TBTO demonstrated excellence efficacy as antiseptic for wood decaying fungi, blue-stain fungi and mildew infestations (Yang, 1994; Li and Shi, 1994). According to experiments, TBTO at concentration of 0.5% shows the same effect on wood rot fungi as Pentachlorophenol (PCP) at 5% and with 1/16 toxicity to animals of PCP.

The least weight loss after exposure to fungi suggested that the chemical had a good toxicity against fungi. It also suggested that the bamboo strips have a better chemical penetration into the cell walls throughout the bamboo blocks (Wahab *et al.,* 2006). Less growth of white rot fungus (*Pycnoporous sanguineus*) were observed on bamboo strips and ply-bamboo treated with TBTO, LOSP and WBP. Those chemicals were successfully impeding the growth of the white rot fungi. Generally, there are slightly differences in the presence of weight loss among treatment; however, the value was not significant different.

White rot causing fungi degrade all major components of the wood, including lignin. Decayed wood is soft, moist and light colored (Hickman, 2002). Degradation of hemicellulose and cellulose results in reduction of the wood strength. Previous studies (Winandy and Morrell, 1993; Curling *et al.*, 2000) have demonstrated a relationship between the degradation of hemicellulose components such as arabinose and mannose and wood strength losses.

According to Bowyer *et al.* (2003), white rot fungi have the ability to degrade both lignin and cellulosic component of the cell although the lignin is usually utilized at a somewhat faster rate. During the degradation process, white rots usually retain its shape but may eventually become a fibrous spongy mass. White rots may changes the color of wood only slightly but more often give it a bleached or whitish color inherent to de-lignified cellulose. According to Rowell (2005), white rot fungi decompose the entire structural component (i.e cellulose, hemicellulose and lignin) from wood. As the wood decays it becomes bleached (in part of lignin removal) or white with black zone lines. The degraded wood does not crack across the grain until it is severely degraded. It keeps its outward dimensions but feels spongy. White rot fungi have complete cellulose complex and the ability to degrade lignin.

TBTO (1% w/w) offers the best protection against fungus attack for both strips and bamboo laminates. This is followed by borax with 5% a.i., WBP with active ingredients (a.i) 12.2%, LOSP with 3.8% a.i,. Thus there is a distinct danger that internal decay can occur if the preserved zone is relatively shallow and this danger is normally avoided by using a much higher retention of TBTO. In fact, wood impregnated with TBTO is effectively protected against fungi and insects. This is because of the very low solubility of TBTO in water. Wood preservation was carried out with TBTO dissolved in organic solvents such as kerosene (Thoonen *et al.*, 2004).

Boiling in water for 30 mins had decreased the resistance against white rot for bamboo strips by 24.1%. Lack of chemicals substance which helps bamboo retain its durability makes bamboo prone to white rot attacks. However, for bamboo laminates the resistance was increased by 2.18%. The presence of phenol formaldehyde in the adhesive gave an additional chemical protection to bamboo laminates. Overall, it was observed that by chemical treatments, the resistance against fungus was increased up to 50% compared to untreated bamboo strips and laminates. The trend was same as in the durability test against termite.

Observation on the damage between strips and bamboo laminates found that bamboo strips were severely deteriorated by fungus. Bamboo laminates were the least degraded by both termites and fungus attack. The presence of formaldehyde in adhesive helps to increase the resistance against biodegradation agents. According to Rowell (1998), very little or no weight loss occurred in flakeboard made using either phenol or isocyanates adhesive with acetylated flakes. It was observed that the development of mycelial was significantly slower in phenol formaldehyde flakeboards. Therefore, the degradation was delayed and less severe.

CONCLUSION

Preservatives treatment apparently increased the durability of bamboo strips and laminates against termite (*Coptotermes curvignathus*) and white rot fungus (*Pycnoporous sanguineus*) attacks. The durability against termite attacks was increased up to 39.2% (strips) and 57.6% (bamboo laminates) when treated with TBTO. Next, the resistance against white rot fungus, the bamboo strips which are treated with WBP increased 87.2 and 62.5 % for bamboo laminates treated with TBTO. Durability rate of bamboo laminates was also boost up with the presence of formaldehyde components consists in the adhesive.

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