

## Effects of Hot Pressing on Resistance of Compressed Oil Palm Wood to Subterranean Termite (*Coptotermes gestroi* Wasmann) Attack

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Oil palm trunks are a by-product of oil palm plantations and provide raw material to the woodworking industries. However, their resistance against degradation by termites needs to be improved; this study investigated hot pressing as a chemical-free method to improve resistance. The main objective was to assess resistance to termites conferred to oil palm wood by hot pressing at various temperatures (140, 180, and 220 °C) for a fixed duration of 8 min and maximum pressure of 2 MPa. The samples were the only available nutrition to subterranean termites (*Coptotermes gestroi* Wasmann) in a 4-week no-choice test. The thermally compressed oil palm wood did not show any significant effect of the pressing temperature on mass loss, but the surface damage to the samples with treatment at 220 °C indicated improved resistance to subterranean termites based on visual observation.

**Keywords:** *Oil palm wood; Compressed wood; Subterranean termite; No-choice test*

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### INTRODUCTION

Oil palm wood is the main agricultural waste from oil palm plantations, with an estimated 41 tons per hectare (oven dry) produced annually. At 25 to 30 years of age, the palm becomes too tall for economic harvest of the fruit, and its yield decreases (Khalid *et al.* 1999), so the palm tree is felled. Most oil palm trunks in Thailand are left in the field to rot and are not used as lumber. As lumber, the bending and ultimate strengths of oil palm are poor in comparison to commercially common tree species due to the low density of oil palm wood. The wood density in an oil palm trunk gradually increases radially outwards, and decreases slightly in the axial direction from the bottom to the top (Ratnasingam and Ioras 2010; Choowang 2012). Erwinsyah (2008) reported that the density of an oil palm trunk, at 12% moisture content, is 0.16 to 0.19 g/cm<sup>3</sup> at the inner zone, 0.17 to 0.23 g/cm<sup>3</sup> at the central zone, and 0.37 to 0.43 g/cm<sup>3</sup> at the peripheral zone. Preprocessing is required to make oil palm trunk an alternative to other solid wood in value-added products (Jumaat *et al.* 2006).

Several prior studies have reported modification of the mechanical properties of low-density woods by compression with heat, sometimes supplied as steam. The density increase with compression is expected to improve the mechanical properties of wood. The respective processes for modifying wood have been varyingly named as thermo-mechanical (TM), thermo hydro-mechanical (THM), and viscoelastic thermal compression (VTC) processes (Navi and Girardet 2000; Yoshihara and Tsunematsu 2007; Boonstra and Blomberg 2007; Kutnar *et al.* 2008). Kunar and Kamke (2012) report that compression at high temperature under saturated steam increases the oven-dry density of

hybrid poplar wood from 0.38 g/cm<sup>3</sup> to 1.16 g/cm<sup>3</sup> and increases the modulus of rupture and modulus of elasticity. Oil palm wood properties can also be similarly improved (Sulaiman *et al.* 2012). Choowang (2013) reports that hot pressing of oil palm increases the average oven-dry density from 0.34 g/cm<sup>3</sup> to 0.71 g/cm<sup>3</sup>, partly due to the collapse of vessel and parenchyma cells. This improves the bending strength of thermally compressed oil palm wood. Heat during compression is essential to enable deformation of cell walls and to provide permanence to the transformed shapes (Inoue *et al.* 2008). On the other hand, heat treatment can improve the durability of wood by inhibiting biological attack, as a chemical-free wood-preserving technology (Unsal *et al.* 2009; Bami and Mohebbi 2011). Thermally modified aspen and jack pine treated at 210 °C for 15 min had better resistance to brown-rot fungus and subterranean termites than untreated wood. However, for some wood species, thermal treatment does not protect against subterranean termite attacks (Shi *et al.* 2007). Usually, the resistance to termites of thermally modified wood improves with treatment temperature and duration (Duarte *et al.* 2012).

Subterranean termites cause significant damage to wooden construction elements and other wood products. In Thailand, *Coptotermes gestroi* Wasmann has the highest economic impact of wood-damaging species (Sornnuwat *et al.* 1996). Therefore, the objective of this study was to assess resistance to subterranean termite attack of hot-pressed oil palm wood, specifically against *C. gestroi* in a no choice test.

## EXPERIMENTAL

### Materials

Oil palm wood samples sawed from the outer parts of trunks were hot pressed at three press surface temperatures (140, 180, and 220 °C) while maintaining a pressure of 2 MPa. Results were compared with those of uncompressed oil palm wood control samples. The physical properties of hot pressed oil palm wood specimens with dimensions 50 mm (longitudinal) x 50 mm (tangential) and 6 mm (radial) are given in Table 1.

**Table 1.** Physical Properties of Hot Pressed Oil Palm Wood and Untreated Control Samples

Properties	Thermally compressed oil palm wood (60% compression ratio)			Control
	Press temperature			
	140 °C	180 °C	220 °C	
Oven-dry density (g/cm <sup>3</sup> )	0.72 (0.03)*	0.68 (0.6)	0.73 (0.03)	0.34 (0.03)
Water absorption 2 h (%)	83.86 (3.03)	57.12 (5.83)	24.89 (1.32)	34.63(1.95)
Thickness swelling 2 h (%)	44.58 (0.60)	42.85 (0.98)	10.40 (4.08)	1.59(0.50)

\* values in parentheses are S.D.

### Testing Resistance to Termites

Termite resistance testing of oil palm wood specimens followed the American Society of Testing Materials standard method (ASTM D-3345-74, 1999), with minor modifications. The hot pressed oil palm wood lumber, with press temperatures 140 °C, 180 °C, 220 °C, and untreated control, were cut to dimensions of 25 mm x 25 mm x 6 mm in longitudinal, tangential, and radial directions, with five replicates for each

treatment. Subterranean termites (*Coptotermes gestroi* Wasmann) were collected from a wood building in the Phthalung province of Thailand. Approximately 200 g of dried sand and 35 mL of distilled water were put into a cleaned plastic box, and  $1 \pm 0.05$  g of subterranean termites was added (90% workers and 10% soldiers). An oven-dry wood specimen was then placed onto the sand, one in each box. All plastic boxes were kept in a dark room at 25 to 27 °C and the average relative humidity at 82%. The wood specimens were removed from their boxes and cleaned after exposure to termites for 4 weeks. Resistance to subterranean termite attack was quantified by both mass loss and subjective visual rating.

The percent mass loss was calculated from Eq. 1,

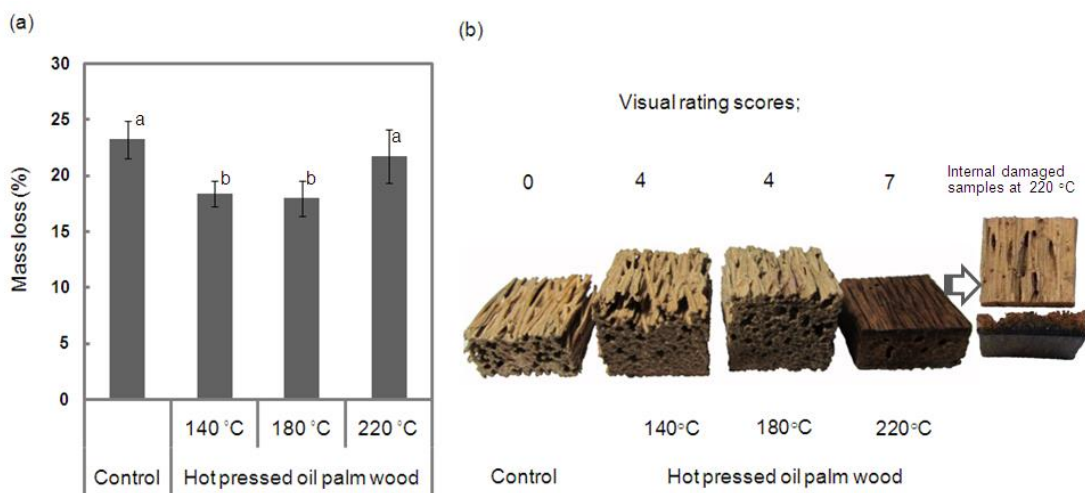
$$\text{Mass loss \%} = [(w_1 - w_2) / w_1] \times 100 \quad (1)$$

where  $w_1$  is the oven-dry weight of test specimens before exposure to the termites (g) and  $w_2$  is the oven-dry weight of test specimens after exposure to the termites (g).

The subjective visual rating scale was as follows: 0, failure; 4, heavy; 7, moderate attack (penetration); 9, light attack; and 10, sound sample with surface nibbles permitted, following appropriate standards (ASTM D3345-74 1999).

## RESULTS AND DISCUSSION

The results in Fig. 1 show an average 23% mass loss of control specimens, in agreement with Loh *et al.* (2011). An ANOVA analysis indicated that the press temperature had no significant effect on the mass loss. The average mass losses were 18.34%, 17.97%, and 21.72% for hot pressed oil palm wood with press temperatures 140 °C, 180 °C, and 220 °C, respectively. The compressed wood had high thickness swelling when compared to the control, a negative characteristic that improved with temperature of heat treatment in accordance with prior work (Salim *et al.* 2013), as listed in Table 1. The specimens treated at 140 °C and 180 °C had higher spring-back than with treatment at 220 °C, when they absorbed water from the wet sand during termite testing, as illustrated in Fig. 1(b), effectively increasing the volume and decreasing the density.



**Fig. 1.** % Weight loss (a) and visual rating score (b), of control and hot pressed oil palm wood after exposure to *Coptotermes gestroi* Wasmann for 4 weeks

In this experiment it was observed that the subterranean termites mainly destroy the parenchyma cells in oil palm wood, especially with compression at 140 °C, 180 °C, and without treatment, from the samples in Fig. 1(b). The parenchyma cells are thin-walled cells with a higher content of starch granules than in vascular bundle cells (Hashim *et al.* 2011); starch is an attractive food easily extracted by mandibles and digested into glucose in the guts of termites (Fujita *et al.* 2010). In comparison, oil palm wood impregnated with phenol formaldehyde had a good resistance from *C. gestroi* attack, such as 0.71% mass loss with 75% phenol formaldehyde resin content, because the food source was covered by resin, especially in parenchyma cells (Abdullah *et al.* 2013; Abdul Khalil *et al.* 2012). The scores from superficial visual ratings after subterranean termite attacks were 0 for control, 4 for treatments at 140 °C and 180 °C, and 7 for treatment at 220 °C. When the specimen treated at 220 °C was split, the internal damage from termites was considerable, despite the superficial appearance, as shown in Fig. 1 (b). However, both surfaces that had been in contact with the hot plates at 220 °C had slight damage from termites. The chemical composition on the surfaces of oil palm wood samples may change with hot pressing at high temperatures. Prior studies have found degradation of hemicelluloses and their cross-linking to lignin during thermal treatments, causing an apparent increase in lignin content (Wikberg and Maunu 2004; Tjeerdsma and Militz 2005; Brosse *et al.* 2010). Potentially the termite resistance of wood was improved by the lignin polymer, which is known to inhibit termite attacks (Geib *et al.* 2008). In addition, the surface layers had higher density and hardness than the material inside of the samples (Rautkari *et al.* 2013), which may have conferred resistance to the hot pressed surfaces treated at 220 °C. Manalo and Garcia (2012) examined bamboo's resistance to termites after treating in hot oil at 200 °C, and the treatment duration had no significant effect on damage rating. Spruce and beech wood samples had improved resistance against termites after heat treatments at 220 °C over longer periods of time, but the mechanical properties were degraded (Duarte *et al.* 2012).

## CONCLUSIONS

1. Hot pressing temperatures in the range from 140 °C to 220 °C had no significant effect on termite resistance of oil palm wood as indicated by mass loss. However, the highest 220 °C press temperature gave the highest density, least spring-back with moisture and termite attack, and hardest most consolidated surfaces. These surface effects may have conferred improved resistance based on superficial visual evaluation, against subterranean termites (*Coptotermes gestroi* Wasmann), while internal damage was considerable in all samples.
2. Visual observations confirmed that subterranean termites damaged primarily the parenchyma cells of oil palm wood. These cells are soft and have a high content of food sources, primarily starch.
3. The effects of pressing duration, moisture content at start of hot pressing, and further elevated press temperatures, could be further examine experimentally. Potential effects on the chemical composition of hot pressed oil palm wood might provide insights into the mechanisms conferring termite resistance, and might be addressed in further research.

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