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Effect of Oil Heat Treatment on Physical properties of Semantan Bamboo (*Gigantochloa scortechinii* Gamble)

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Abstract

Effect of oil heat treatment on physical properties of 3 years old *Gigantochloa scortechinii* Gamble bamboo was investigated. The bamboo splits within epidermis were heat-treated using crude palm oil at temperature 140°C, 180°C and 220°C for duration 30 and 60 min. The objectives were to determine the effect of oil heat treatment on physical properties of the heat-treated bamboo and to assess any significant changes on physical properties of the heat-treated bamboo. Untreated bamboo was used as comparison for each treatment conditions. The results indicated equilibrium moisture content (EMC), density and volumetric shrinkage of heat-treated bamboo decreased as the treatment temperature and time increases. The EMC and density reduction were 4-27% and 11-18% approximately. This study indicated that bamboo became less hygroscopic when subjected to higher temperature and longer heat treatment time. Volumetric shrinkage of bamboo was also reduced by the treatment conditions (17-53%). The shrinkage properties of bamboo were inversely proportional to the treatment conditions, indicating that oil heat treatment successfully imparts the dimensional stability of the bamboo.

Keywords: Bamboo, Oil heat treatment, EMC, Density, Volumetric shrinkage

1. Introduction

Bamboo is regarded as eco-friendly plant which grows and matures quickly. It has a potential to be used as an alternative raw material to wood. Like wood, bamboo is susceptible to fungal and insect attacks. Heat treatment is one

of the potential treatments to enhance the durability and dimensional stability of bamboo. This process has been studied by several researchers in Europe, Africa and Asia. In Europe, the heat treatment process has long been used for timber treatment and in Asia it has been used for rattan. During the nineties and at present there are at least five different heat treatment methods developed in Europe. These methods were commercialized in response to the increased environmental awareness that drives the industry towards reducing the use of chemicals.

Oil heat treatment is another alternative way in treating bamboo without use of preservatives. This process is considered as eco-friendly treatment. Leithoff and Peek, 2001 reported that only temperature above 170°C was effective to enhance durability of bamboo however, Rafidah *et al.,* 2008 indicated that plasticization of lignin at this condition. Reduction of EMC of bamboo improved dimensional stability of bamboo. In this study, physical properties of bamboo after oil heat treatment at 140 to 220°C for 30 to 60 min were investigated. The objectives of this study were:-

- To determine the effect on physical properties of heat-treated bamboo and
- To assess any significant changes on physical properties of the treated bamboo at each condition applied

2. Material and methods

2.1 Preparation of Bamboo Samples

Bamboo culms of 3 years old were extracted from randomly selected clumps in Nami, Kedah in Malaysia. The culms were cut and split before conditioned at 20°C and 65% RH until constant weight. The sample were then subjected to heating at varies temperature and time.

2.1.1 Heat treatment Process

Palm oil which the boiling point of 320°C fulfilled 3/4 tank. Split bamboo samples were immersed in crude palm oils with original temperature in metallic cage of stainless steel tank. Temperature was rise gradually controlled by digital controller. Three electric heaters were generated heat from electricity power sources. Thermocouples connected to data logger were placed in the heated oil to record the oil temperatures. Data were recorded every 5-10°C interval. In this experiment, temperatures were applied at 140°C, 180°C and 220°C with duration 30 and 60 minutes. As the temperature reached the target, it was maintained for 30 or 60 min. Then, the samples were removed out and any excess of oil on the surface was removed by wiping with cloth. After boiling process, the splits were conditioned in a conditioning room at 20°C and 65% relative humidity (EMC=12%) for one weeks.

2.2 Evaluation of Physical Properties

Physical properties of treated bamboo were evaluated following the method described in Indian Standard of Testing Split Bamboos. The properties tested were Equilibrium Moisture Content (EMC), density at air dry volume and volumetric shrinkage from test after treatment to oven dry condition.

2.2.1 Evaluation of EMC and Density

A total of thirty specimens (25 mm x 20 mm x original thickness) from each treatment group were used for the determination of EMC. All conditioned samples were weighed and measured. All treated and untreated samples was conditioned in a conditioning room maintained at 25 ± 2°C and 65 ± 2% relative humidity (approximately 12% MC) until constant weight. The samples were then dried in an oven 103 ± 2°C until constant weight. Oven-dry weighed were recorded and these values were used to determine the EMC and density of the treated and untreated bamboo using Equation 3.1 and 3.2 respectively.

$$MC = [(W_i - W_{OD})/ W_{OD}] X 100 \qquad \text{Equation 3.1}$$

where, MC = Moisture content, %,

W_i = Initial weight of sample, g

W_{OD} = Oven-dry weight of the sample, g.

$$\rho = [(Wo/Vg)] \qquad \text{Equation 3.2}$$

where, ρ = Density of bamboo, kg/m^3

Wo = Oven dry weight, kg

Vg = Green volume, m^3

2.2.2 Evaluation of Shrinkage

The heat-treated blocks were evaluated for shrinkage from green to oven-dry conditions. All treated blocks were immersed in water for 24 hour until it's fully saturated. For the untreated bamboos, it was evaluated from green to oven-dry condition. In this test, samples of 25 mm x 20 mm x thickness were used. Each of the samples was measured

in three plane directions (length x width x thickness). Each direction was marked with waterproof ink and measured before and after samples were dried for 48 hours at 103±2°C in an oven. The shrinkage value was then calculated using the Equation 3.3.

$$\text{Shrinkage} = [(D_i - D_o)/ D_i] \times 100 \qquad \text{Equation 3.3}$$

where, D_i = Initial dimension, mm,

D_o = Final dimension, mm.

3. Statistical Analysis

All data were statistically analyzed using one-way analysis of variance (ANOVA) and the mean value of each property was separated using Least Significant Difference (LSD) test to determine the differences between treatment levels. The analysis was carried out using the statistical analysis software (SAS).

4. Results and Discussion

4.1Evaluation of Physical properties of heat-treated G. scortechnii

Table 4.1 shows the equilibrium moisture content, density and the maximum volumetric shrinkage (from just after treatment to oven dry conditions) of treated and untreated *Gigantochloa scortechinii* after heating in crude palm oil at different temperatures and times.

4.1.1 Equilibrium Moisture Content (EMC)

From Table 4.1, it can be seen that EMC of heat-treated bamboo gradually decreased with increasing in the treatment temperatures. Untreated bamboo had the highest EMC value i.e. 13.69% followed by bamboo treated at temperature 140°C/60 min (13.2%), at 180°C/60 min (12.2%) and at 220°C/60 min (10.05%). At the same temperature (180°C), EMC of bamboo which was treated for 30 min (12.6%) was slightly higher than those treated for 60 min (12.2%). This result would indicate that, treatment at high temperature markedly influenced the hygroscopic of the bamboo

Figure 4.1 exhibits the percent EMC reduction against the untreated bamboo after treatment at various temperatures and times. It can be seen that the percent reduction of EMC increased as the temperature of treatment increased. At 140°C/60 min heating conditions, the percent EMC was reduced by 3.9% and while at 180°C/30 min and 180°C/60 min heating conditions, they were reduced by 7.8 and 10.7%, respectively. A highest percent EMC reduction was recorded for bamboo treated at 220°C/60 min (26.6%).

Heat treatment of wood produces a material that is less hygroscopic than gently dried wood (Tjeerdsma *et al.,* 1998a; Obataya *et al.,* 2000). There may be considerable variation among them with respect to the absolute values of hygroscopicity (Rowell and Banks, 1985). The change in hygroscopicity has been attributed to chemical changes in wood components or physical changes in crystallinity and the microsurface (Bourgois and Guyonnet 1988; Obataya *et al*., 2000). This can be noted as a reduced swelling and shrinkage, up to 50% for treatments at higher temperatures (>200°C) and longer times. Kortelainon *et al*. (2005), stated that heat treatment decreased the water absorption of spruce and pine heartwood. They found that the higher the temperature of treatment in wood the lower the amount of moisture adsorbed.

Rapp and Sailer (2001) reported that, wood which was heated in oil at 220°C for 4 hour had a fibre saturation point of 14% compared to 29% for those untreated samples. The equilibrium moisture content (EMC) of heat treated wood was reduced by 40% compared to untreated wood (Viitaniemi and Jamsa, 1996).

Wang and Cooper (2005) also reported a similar result for wood treated at 220°C for 4h. The EMC was reduced about 50%. The decrement in EMC was mainly attributed to the decomposition of the most hygroscopic hemicelluloses (Kollmann and Scheneider 1963; Price and Koch, 1980).

4.1.2 Density

Heat treatment also significantly affects the density of the treated bamboo. As it can be seen from Table 4.1, the density of *G. scortechinii* decreased as the heating condition increases. Untreated bamboo had a density of 719 kg/m^3 while those treated at 220°C/60 min conditions had the lowest density 587 kg/m^3. At 140°C/60 min to 180°C/60 min, the density values ranged from 639-613 kg/m^3. The reduction of density was possibly attributed to the degradation of hemicelluloses and degradation of cellulose. Kortelainen *et al*. (2005), reported wood treated at high temperature (130-230°C) loss some of its weight and at the same time reduced its density.

Figure 4.2 exhibits the percent density reduction from untreated bamboo after treatment at various heating conditions. It can be seen that the percent reduction of density increased as the boiling condition increases. At 140°C/60 min heating conditions, the percent reduction of density was 11.4% while at 180°C/30 min and 180°C/60 min heating conditions, the reduction were 12.3 and 14.7%, respectively. A highest percent reduction of density (18.3%) was recorded for bamboo treated at 220°C/60 min.

4.1.3 Volumetric shrinkage

Table 4.1 and Figure 4.3, shows the volumetric shrinkage of heat treated and untreated *G. scortechinii* from green to oven dry conditions. It can be seen that the shrinkage is inversely proportional to the temperature of treatments. The shrinkage of the heated material is lesser when the heating temperature is higher.

The volumetric shrinkage of heat treated *G. scortechinii* at 220°C/60 min was 7.4% (i.e., 52.6% reduction from untreated). At 180°C/60 min and 180°C/30 min, the volumetric shrinkage were 10.7% (31.4% reduction) and 11.9% (23.7% reduction), respectively. The volumetric shrinkage for this bamboo at 140°C/60 min was 12.9% (17.3% reduction).

Syrjanen (2001) found that heat treatment at temperature over 150°C reduced the shrinkage and swelling of wood and improved the equilibrium moisture content. Heat treatment caused slower water uptake and wood cell wall absorbed less water due to the reduction of hydroxyl groups in the wood (Jamsa and Viitaniemi, 2001). They also stated that the decrement in shrinkage can also be attributed to the reduction in the hemicellulose content, which would possibly improved the dimensional stability of the wood.

In the previous research, Tjeerdsma *et al.* (1998b), found that the hygroscopicity of heat treated wood reduced to 60% compared to those untreated and the dimensional stability improved to 50%. Improvement of dimensional stability of heat treated wood was also reported by Seborg *et al.* (1953). They stated that the improvement was due to the loss of constitutional water in wood.

Kamden *et al*. (2002) and Tjeerdsma *et al*. (2000) revealed that heat treatment enhanced cross-linking reactions of formaldehyde generated during the decomposition of wood organic acids and the phenol units of wood lignin. This theory may partially explain the dimensional stability of heat treated wood.

Stamm (1964), found that an anti-shrink efficiencies (ASE) of 40% to 50% can be obtained by heating wood at 320°C for 1 min or at 150°C for 1 week (Rowell and Banks, 1985). Bekhta and Niemz (2003), found that Spruce wood heated at 200°C become more dimensionally stable than wood heated at 20°C. They also concluded that treatment time significantly affect this property. Tjeerdsma and Militz (2005), simplified that esterification reactions were found to occur at elevated temperature in the heating which contributes to a decrease of hygroscopicity of wood and consequently improve of dimensional stability and durability.

Hemicellulose is highly hygroscopic while high temperature affects the hemicellulose content in wood for increase in dimensional stability. High temperature drying also contributed to result in more dimensionally stable material. Sandland and Edvardsen (1999), indicated that wood is more dimensionally stable when it has been exposed to high temperature compared with exposed to low temperature

5. Conclusions

With regard to physical properties, equilibrium moisture content of heat-treated bamboo decreased as the treatment conditions increased. The highest EMC reduction was recorded for bamboo treated at 220°C/60 min followed by at 180°C/30 min and 60 min. Treatment at 140°C/60 min had the least EMC reduction. This study indicated that bamboo when subjected to higher temperature and longer heat treatment time became less hygroscopic.

Heating of bamboo significantly reduced the density of *G. scortechinii.* The density of *G. scortechinii* decreased as the temperature of the treatment increased. The highest percentage reduction of density was recorded for bamboo treated at 220°C/60 min and the least was at 140°C/60 min.

Volumetric shrinkage of bamboo was also reduced by the treatments. The shrinkage properties of bamboo were inversely proportional to the treatment conditions, indicating that heat treatment successfully imparts the dimensional stability of the material.

References

Bekhta, P. and Niemz, P. (2003). *Effect of High Temperature on the Change in Color, Dimensional Stability and Mechanical Properties of Spruce Wood*. Journal of Holzforschung: Vol. 57, 539-546.

Bourgois, P.J. and Guyonnet, R. (1988). Characterization and analysis of torrefied wood. Wood science and Technology: Vol. 22, 143-155.

Jamsa, S. and Viitaniemi, P. (2001). *Heat treatment of wood. Better durability without chemicals.* In: Review on Heat treatment of wood. Rapp AO (ed) Proceedings of Special Seminar in Antibes, France.

Kamden, D.P., Pizzi, A. and Jermannaud, A. (2002). *Durability of heat-treated wood.* Journal of Holz als Roh-und Wekstoff. Vol 60: 1-6.

Kollman, F. and Schneider, A. (1963). *On the sorption behaviour of heat stabilized wood*. Holz als Roh- und Werkstoff: Vol. 21, 77-85.

Kortelainen, S.M., Antikainen, T. and Viitaniemi, P. (2005). *The water absorption of sapwood and heartwood of Scots pine and Norway spruce heat-treated at 170℃, 190℃ and 230℃.* Journal of Holz als Roh-und Wekstoff.

Leithoff, H. and Peek, R.D. (2001). Heat treatment of Bamboo. The International Research Group on Wood Preservation. Section 4. Paper prepared for the 32nd Annual Meeting Nara, Japan on May 20-25th, 2001. IRG/WP 10-40216.

Obataya, E., Tanaka, F., Norimoto, M. and Tomito, B. (2000). Hygroscopicity of heat-treated wood 1. Effects of after treatments on the hygroscopicity of heat-treated wood. Journal of the Japan Wood Research Society: Vol. 46, 77-87.

Rafidah S., Razak, W. and Zaidon, A. (2008). *Effect of Oil Heat Treatment on Chemical Constituents of Semantan Bamboo (Gigantochloa scortechinii Gamble).* Journal of Sustainable Development Vol 1: 91-98.

Rapp, A.O. and Sailer, M. (2001). *Oil heat treatment of wood – process and properties*. Drvna Industrija: Vol.52, 63-70.

Rowell, R.M. and Banks, W.B. (1985). *Water Repellency and Dimensional Stability of Wood,* USDA Forest Service, General Technical Report FPL 50, Forest Product Laboratory, Madison, WI.

Stamm, A.J. (1964) Wood and Cellulose Science. The Ronald Press Co., New York.

Syrjänen, T. (2001). COST E 22 *Production and Classification of Heat-Treated Wood in Finland.* Review on Heat Treatments of Wood. Rapp AO (ed) Proceedings of Special Seminar in Antibes, France

Tjeerdsma, B.F. and Militz, H. (2005). Chemical changes in hydrothermal treated wood: FTIR analysis of combined hydrothermal and dry heat-treated wood. Journal of Holz als Roh-und Wekstoff. Vol 63: 102-111.

Tjeerdsma, B.F., Boonstra, M. and Militz, H. (1998a). Thermal modification of non-durable wood species 2. Improved wood properties of thermally treated wood. International research group on wood preservation, Maastricht, The Netherlands, June, 14-19

Tjeerdsma, B.F., Boonstra, M. and Militz, H. (1998b). Thermal modification of non-durable wood species. 2. Improved wood properties of thermally treated wood. International Research Group on Wood Preservation, Document no. IRG/WP 98-40124.

Tjeerdsma, B.F., Stevens, M. and Militz, H. (2000). Durability aspects of hydrothermal treated wood. International Research Group on Wood Preservation, Document no. IRG/WP 00-4.

Viitaniemi, P. and S. Jämsä. (1996). *Modification of wood with heat treatment* Espoo, Finland: VTT Building Technology

Table 4.1 Mean physical properties of heat treated and untreated *G. scortechinii*.

Heating conditions	[1]N	EMC at 25°C, RH 65% (%)	Density, ρ kg/m^3	Volumetric shrinkage after treatment from green to ovendry conditions (%)
Untreated	30	13.69 [a 2]	719 [a]	15.6 [a]
		(0.71) [3]	(58.6)	(2.4)
140°C/60	30	13.16 [b]	639 [b]	12.9 [b]
		(0.86)	(61.8)	(1.4)
		{-3.9}	{-11.2}	{-17.2}
180°C/30	30	12.62 [c]	630 [b]	11.9 [b]
		(0.67)	(76.8)	(2.4)
		{-7.8}	{-12.3}	{-23.5}
180°C/60	30	12.22 [d]	613 [bc]	10.7 [c]
		(0.64)	(62.5)	(2.9)
		{-10.7}	{-14.7}	{-31.3}
220°C/60	30	10.05 [e]	587 [c]	7.4 [d]
		(0.62)	(86.9)	(1.1)
		{-26.6}	{-18.3}	{-52.6}

Note: [3] Values in parentheses are standard deviations

[2] Means followed with the same letter are not significantly different ($p<0.05$)

[1]N = number of sample

{ } = % change from untreated

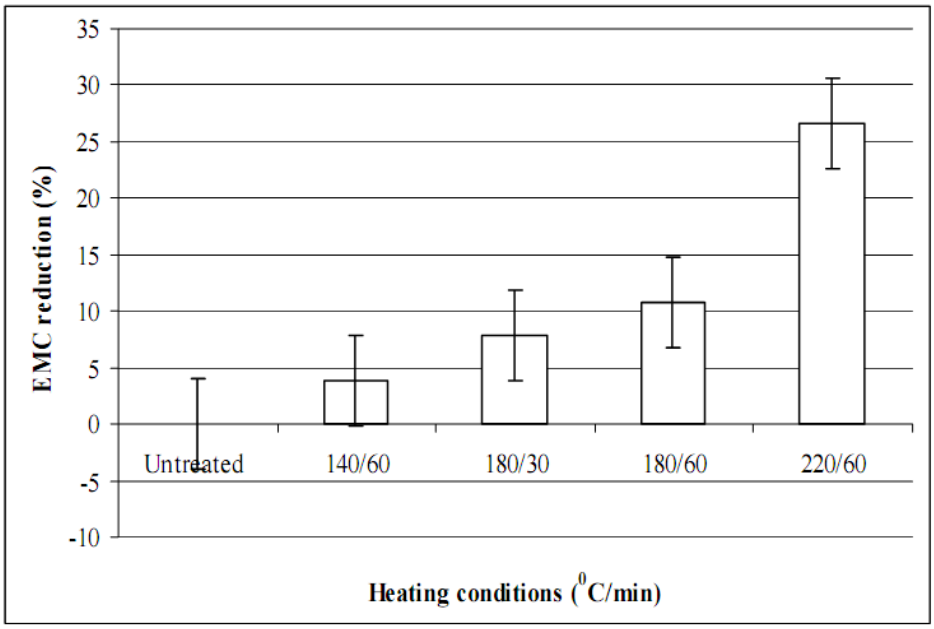

Figure 4.1 Percent reduction in EMC of treated bamboo blocks calculated against untreated

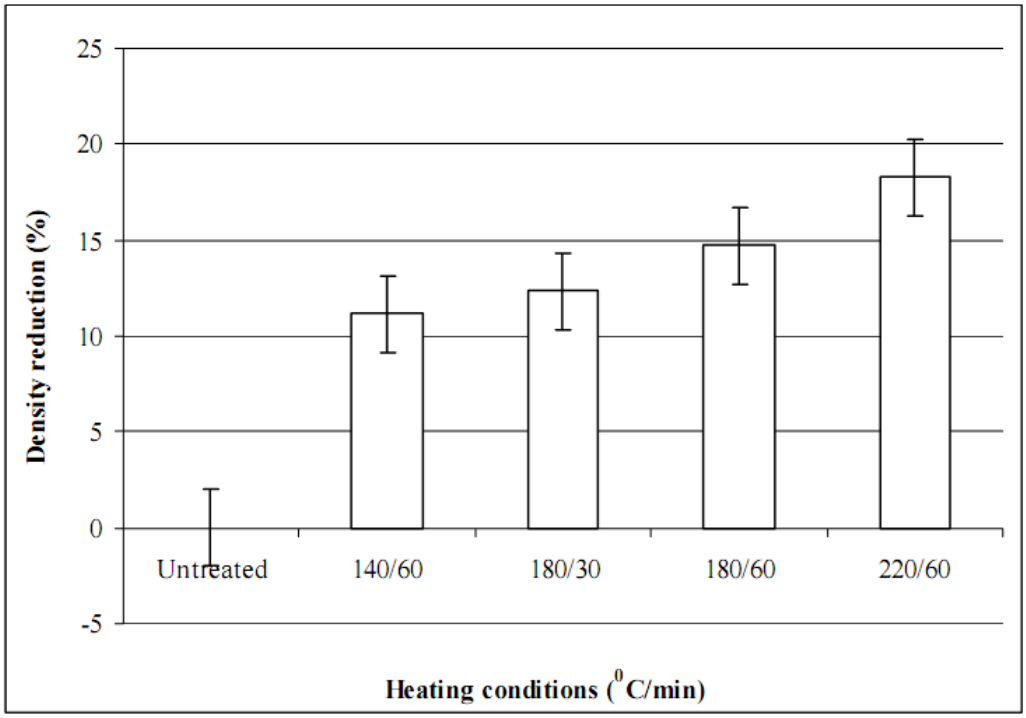

Figure 4.2 Percent reduction in density of treated bamboo blocks calculated against untreated

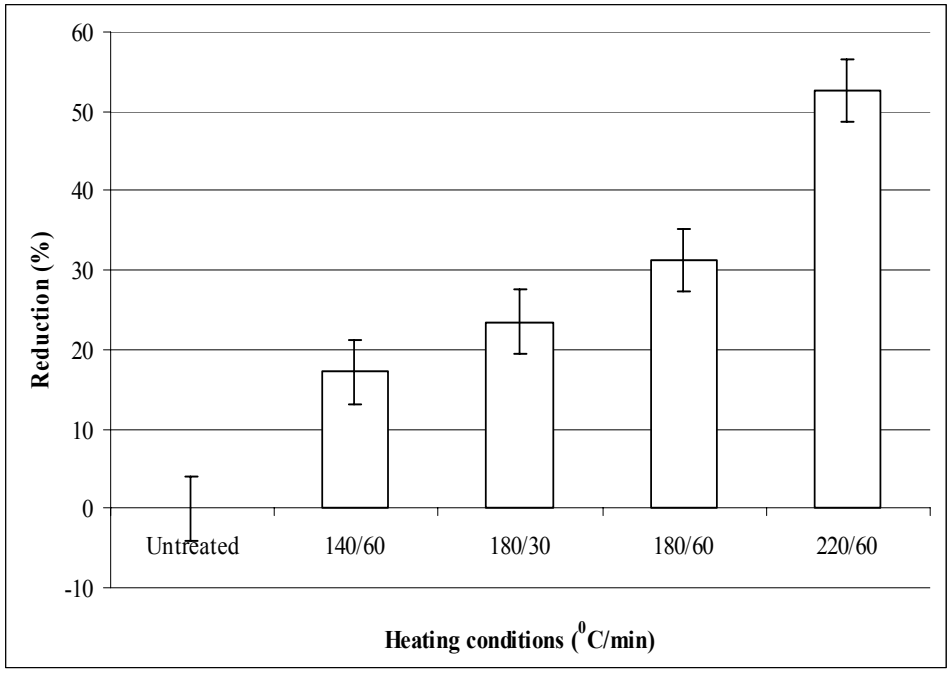

Figure 4.3 Percent reduction in volumetric shrinkage of treated bamboo blocks calculated against untreated