

Influence of Neem (*Azadirachta indica* A. Juss) Seed Oil-Treatment on Static Bending Strength Properties of Wild Grown Split-Bamboo (*Bambusa vulgaris* Schrad.) in South-West Nigeria

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Abstract: In order to contribute to the efforts aimed at achieving sustainable environmentally benign methods of treating and preserving lignocellulosic materials, split samples of *Bambusa vulgaris* Schrad. ex J.C. Wendl. (a bamboo species prevalent in south-west Nigeria) with mean specific gravity of 0.89 and conditioned in the laboratory to 11.76% moisture content were treated, at two different temperature regimes, with mechanically extracted neem (*Azadirachta indica* A. Juss) seed oil. For this study, selected mechanical properties for the oil-treated and untreated bamboo samples were determined in conformity with modified ASTM D 143-83. Results showed that mean values for modulus of rupture and modulus of elasticity (MOR and MOE) for static bending strength test were lowest in samples soaked in hot oil at 60°C for 4 hours but higher in samples soaked in oil at room temperature of 25±2°C for 24 hours with control samples possessing higher values than those for the oil-treated samples. Analysis of variance also revealed statistical significant variation in the data obtained for MOR and MOE at 5% significance level. Fishers Least Significant Difference was used as a follow-up test to compare means also at 5% significance level.

Key words: Bamboo % Static bending % Modulus of rupture % Modulus of elasticity % Neem seed oil

INTRODUCTION

The use of wood and fibre materials and their products had been and is still important to different categories of users and this has necessitated series of studies globally, some of which have been on materials from wood, cotton, banana, flax, sisal, coir, wheat straw, sun hemp, Palmyra fibre, bamboo, rattan, among others [1-12].

There has been a recent intensification in research on bamboo in many parts of the world with series of outputs. Many of these studies showed that bamboo possess good potential not only for carbon sequestration, because of its fast growth and high biomass production within short period [13] but also because of the culms' comparatively high (er) physical and mechanical/strength properties when compared to many woody species.

Bamboos are ecologically, economically and socially important plants, with a wide spectrum of industrial and domestic applications [14]. It has long been traditionally utilized in rural life for ages, especially in Asia [15]. Relics from bamboo mats and baskets that were dated at the

Younger Stone Age, between about 3,300 and 2,800 BC had been obtained [16].

As important as this renewable natural resource is in many climes, it is known to possess low natural durability against agents of biodegradation thereby requiring preservatives to increase its service life. Suggestions has been made, in line with the clamour for environmental benign methods of treating and preserving wood and fibre products, that preservatives should be naturally sourced [e.g. ref. 17] particularly from plants that act as a reservoir for inexhaustible source of innocuous biocides, which are mammalian non-toxic and easily biodegradable than synthetic chemicals [18].

Since lignocellulosic material are utilized for different purposes by diverse categories of users, it is important to be acquainted with the influence(s)/effect(s) a particular preservative might have on wood and fibre properties of interest [19, 20]. This study was therefore carried out to investigate the influence of neem seed oil treatment on static bending strength properties of oil-treated wild grown split-bamboo samples in comparison with untreated control samples.

MATERIALS AND METHODS

Sourcing of Bamboo Culms and Neem Seeds:

The matured bamboo culms that were converted and experimented upon in this study were obtained in the month of October, 2008 from a forest in Eruwa town in Oyo State (Latitude 7°31'60N and Longitude 3°25'0E) about 64.8km west of Ibadan, Nigeria. This area is located in between the humid and sub-humid tropical climate. The mean annual rainfall ranges from 1,117.1 to 1,693.3mm. The harvested culms had no known age or history of management. Presently, there are no quantitative parameters established to identify the different growth stages of a bamboo culm for adequate harvesting purposes [21].

In order to ensure minimal influence of age, lack of management and other variables on the result of the research, only matured culms with mean circumferential length of 30cm at the second node from the base were harvested and cross cut in such a way that only the basal culm portion of 300 cm length were removed and placed in jute bags with nylon lined inner surface to avoid contamination from the soil. All the harvested culms in the bags were transported to and stored for 14 days in the wood workshop of the Department of Forest Resources Management, University of Ibadan, Ibadan, Nigeria for conversion to the test specimens.

The ripe neem seeds from which oil was mechanically extracted in this study were obtained from *Azadirachta indica* trees located on the University of Ibadan Campus located on the northern edge of the city of Ibadan (Latitude 7°20'0N and Longitude 3°50'0E) of about 10.4 square kilometres. Ibadan lies at 200m above sea level with a humid tropical climate (27°C average), a March-October rainy season (1250mm) followed by a mild dry season. Collection of the seeds was done by placing nylon sheets around the stems in such a way that it covered a substantial cross sectional area of the crown in order to collect the seeds as they fall.

The seeds were sourced in the months of June to early August of 2008. The neem seeds obtained from the field were thoroughly washed using distilled water to remove dirt and other impurities and then air dried in an open space with regular movement for aeration for proper drying as suggested by [22], a method also applied by [23] to reduce the moisture content for proper crushing and to facilitate high oil volume recovery during mechanical extraction.

The seeds were stored in a nylon lined jute bags at room temperature and kept away from the reach of organisms such as rodents and other animals that can consume the seeds and also to prevent contamination and daily air dried with proper monitoring to prevent damage as a result of possible moisture fluctuations.

Conversion of Bamboo Culms to Test Samples:

The selected culms were carefully sawn with circular and vertical breakdown sawing machine longitudinally into strips. Each strip was planed on both the inner and outer surface, using a planing machine, in order to obtain the bamboo timber with mean culm thickness of 5 ± 0.5 mm for the tests. Bamboo timber, according to Chand *et al.* [24] is the part between the bamboo skin and the pith. Bamboo skin is the outermost part of cross-section of stem wall, where no vascular bundles are seen while pith is the part of stem wall next to bamboo cavity and it also does not contain vascular bundles [24].

After conditioning in the laboratory for 14 days, the strips were converted to test specimens. The specimens with dimensions 20 mm (tangentially) x 20 mm (longitudinally) x 5 mm (radially) were for moisture content (MC) and specific gravity (SG) determination. Dimensions 20 mm (tangentially) x 200 mm (longitudinally) x 5 mm (radially) were oven-dried and stabilized in the laboratory to 11.76% mean MC prior to testing for static bending strength properties.

Extraction of Neem seed Oil: There are several methods of obtaining oil from the seeds of neem e.g. mechanical pressing, supercritical fluid extraction and solvent extraction [25]. Mechanical extraction is the most widely used method to extract neem oil from the seeds [25-26] since this method is effective for seeds containing 30-70% oil [27] although, the oil produced with this method may have a low price, since it is turbid and contains a significant amount of water as compared to those obtained by supercritical fluid extraction and solvent extraction [28].

The shells were decorticated from the neem seeds kernels, cleaned from dirt, then dried in the open air. Dried kernels were carefully ground into paste using seed grinder to smaller particles ensuring no significant loss of seed's oil. Mechanical extraction of oil was performed by cold pressing. This method of oil extraction under cold pressing was adopted in this research at maximum pressure of 4500psi, as also done in similar studies by [19, 20].

Mechanical extraction was performed at this pressure until the oil stopped flowing out. This is to allow for easy adoption by most of the target end-users particularly those in the rural areas. The mechanical extraction has several advantages compared to the other methods, such as simple equipment and low investment, low operating cost and the oil does not undergo solvent separation process, among others [26].

Bamboo samples for the mechanical property tests were sterilized by oven-drying at $103^{\circ}\text{C}\pm 2^{\circ}\text{C}$ for 2 hours, cooled in a dessicator and subjected to two neem seed oil treatment temperature regimes i.e. soaking a set of samples in oil for 24 hours at room temperature of $25\pm 2^{\circ}\text{C}$ and soaking another set in hot neem seed oil at 60°C for 4 hours and allowed to cool at room temperature with untreated samples serving as control.

Moisture Content Determination for Bamboo Samples:

Ten (10) test specimens each of 20 mm x 20 mm x 5mm were first weighed on a sensitive weighing balance and the weight were recorded as initial weight W_m . The test specimens were then oven-dried at $103^{\circ}\text{C}\pm 2^{\circ}\text{C}$ using UNISCOPE SM 9053 forced air laboratory oven until a constant weight was achieved. These constant weights were tabulated as W_o . The moisture content was calculated in accordance with ASTM D 4442-84 [30] using the equation:

$$MC = [(W_m - W_o) / W_o] \times 100 \quad (1)$$

Where:

- MC = Moisture content
- W_m = Weight of specimens before oven-drying (g)
- W_o = Weight of specimens after oven-drying (g)

Determination of Specific Gravity of Bamboo Samples:

The SG of bamboo samples in this study was obtained based on the method described in ASTM D 2395-83 [29]. The MC of samples for SG were first obtained in accordance with ASTM D 4442-84 [30] (Equation 1) and recorded. SG was calculated using equation 2.

$$SG = KW [1+(MC/100)]G^1 Lwt \quad (2)$$

Where:

- W = Weight of specimen
- MC = Moisture content of specimen in percentage
- L = Length of specimen
- w = Width of specimen
- t = Thickness of specimen
- K = Constant = 1000 (since weight was in g and volume in mm^3)

Evaluation of selected mechanical properties: The static bending strength test specimens of oil-treated and untreated samples with dimensions 25 mm (tangentially) x 200 mm (longitudinally) x 5 mm (radially) were prepared with slight modification to ASTM D 143-83 [31] owing to bamboo nature. The static bending test (with load introduced on the radial plane of the samples) was carried out using a 5 kN computer controlled Instron 3363 Universal Testing Machine at cross-head speed of 4.00 mm min^{-1} at the Material Testing Laboratory of the Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife, Nigeria.

RESULTS AND DISCUSSION

Mean Specific Gravity Value for Control Bamboo Samples:

Specific gravity is a measure of the density of a substance. The SG of a substance is a comparison of its density to that of water at a particular temperature and pressure. The SG of bamboo varies between 0.4 and 0.8 depending mainly on the anatomical structure [32]. The mean SG obtained for untreated samples in this research was in the range documented in literature [19, 33-35]. Density/SG is the major factor that influences the mechanical properties and it is closely related to the proportion of vascular bundles in the cell wall.

Mean Static Bending Strength Values of Both Oil-treated and Untreated Bamboo Samples:

The mean values tabulated in Table 1 was comparable to those published in literature [36] on *Bambusa vulgaris*, although, lower in values as sample test dimension was smaller compared to those used by [36]. This might imply that there are many strength properties of this species of bamboo from this part of the world that need to be investigated. The mean values showed that the selected static bending strength properties (MOR and MOE) for the treated bamboo samples reduced in value as compared to the control samples which were not treated with oil. This pattern of reduction has been documented in literature [37, 38].

The result obtained in the static bending test for oil-treated and untreated bamboo samples showed that the selected strength properties i.e. MOR and MOE reduced in values with increase in oil temperature. The properties were higher in value for the samples used in the control experiment while they were lower in samples soaked in oil at room temperature of $25\pm 2^{\circ}\text{C}$ for 24 hours and lowest in samples soaked in hot oil at 60°C for 4 hours, a similar trend was also observed by [19] for this species' tensile strength properties at the same temperature range and duration of treatment.

Table 1: Mean values obtained for selected static bending strength and other related properties for the oil-treated and untreated bamboo samples

Treatment	MOR (Nmm ⁻²)	MOE (Nmm ⁻²)	Energy at Maximum Load (kJ)	Load at Yield (Zero Slope) (N)	Extension at Yield (Zero Slope) (mm)
Control	103.20±1.65	9850.39±68.78	0.20±0.01	27266±98.21	15.88±1.04
Samples soaked in oil at room temperature of 25±2°C for 24 hours	98.17±1.48	8910.11±50.89	0.18±0.01	25419±117.11	15.74±1.22
Samples soaked in hot oil at 60°C for 4 hours	83.05±1.21	7892.69±35.38	0.16±0.01	22542±95.87	15.61±1.19

Values are means for 10 test samples per each treatment

Table 2: Summary of ANOVA results for data obtained for the selected mechanical properties evaluated for static bending strength test for treated and untreated bamboo samples

Source of variation	Selected properties	(F-cal)	(F-tab)
Treatment	MOR	468.99*	3.35
	MOE	3338.58*	
	Energy at Maximum Load	0.29ns	
	Load at Yield	1004.54*	
	Extension at Yield	22.86*	

* denotes significance, ns denotes not significant (p < 0.05)

Table 3: Fisher's Least Significant Difference of pair of means for static bending strength and other related properties for the oil-treated and untreated bamboo samples

Treatment	MOR (Nmm ⁻²)	MOE (Nmm ⁻²)	Energy at Maximum Load (kJ)	Load at Yield (Zero Slope) (N)	Extension at Yield (Zero Slope) (mm)
Control	103.20 ^a	9850.39 ^a	0.20 ^a	27266 ^a	15.88 ^a
Samples soaked in oil at room temperature of 25±2°C for 24 hours	98.17 ^a	8910.11 ^b	0.18 ^a	25419 ^a	15.74 ^b
Samples soaked in hot oil at 60°C for 4 hours	83.05 ^b	7892.69 ^c	0.16 ^a	22542 ^b	15.61 ^c

Mean values with same superscript in same column are not significantly different (p < 0.05)

This particular trend which showed that these strength properties of split-bamboo samples reduced as the temperature and intensity of treatment increased has been reported in series of similar experiments and reports on bamboo culms e.g. [39, 37, 40, 41]. The MOR values reduced by 4.87% for soaked bamboo samples in neem seed oil at room temperature of 25±2°C for 24 hours while it reduced by 19.22% for samples treated with hot oil at 60°C for 4 hours. This pattern of reduction was also observed in MOE as it reduced by 9.55% for soaked split-bamboo samples in neem seed oil at room temperature of 25±2°C for 24 hours and 19.87% for samples treated with hot oil at 60°C for 4 hours.

These reductions in strength properties may still be acceptable as these percentage reductions are within the range of strength reduction of those bamboos or other lignocellulosic material that were chemically treated with preservatives [40]. It is important to note that the reduction in these strength properties are dependent on the condition of bamboo samples, types and concentration of preservatives applied, penetration and retention in the bamboo, amount of heat applied, duration of treatment, among other factors [37, 40].

Similar observation was experienced with heat treatment of lignocellulosic material in literature [42, 43].

Reduction in strength properties were also reported in thermal modification of wood at elevated temperature [44, 45]. Studies in the past attributed this to the degradation of cell wall carbohydrates [45-47].

The trend observed in this experiment might also be as a result of the comparative reduction in the quantity of holocellulose, hemicellulose, cellulose, starch and lignin present in the samples as the treatment temperature increased as observed in studies such as [48]. For instance, lignin is a major component of the cell wall of fibres, parenchyma cells and vessels in bamboo tissue and is responsible for many of its mechanical properties [49].

The strength of bamboos are associated with their anatomical structures and composition particularly the fibres and parenchyma. It relies to a large extent on the quantity and quality of fibres [37], although, the strength varies with respect to species, age, moisture content, position along the culm, among other factors. It was also noticed that energy at maximum load also reduced as the temperature of oil increased, thus, indicating that energy required in bringing the samples to failure also reduced in like manner with increased intensity of treatment temperature. This trend was also recorded for load at yield and the extension at yield.

On subjecting the data obtained from the static bending test for the selected properties to one-way ANOVA ($p < 0.05$), result showed that all except the data on energy at maximum load were significant (Table 2). Comparing the mean values using Fisher's Least Significant Difference (LSD) in Table 3, it was observed that the mean values of MOR for control and samples soaked in oil at room temperature of $25 \pm 2^\circ\text{C}$ for 24 hours experiment has values within the same range but differed significantly from those obtained from samples soaked in hot oil at 60°C for 4 hours while LSD showed that all the mean values for MOE were significantly different.

CONCLUSIONS

The results of this study showed that MOR and MOE for static bending strength property reduced in values as the oil treatment temperature increased as also observed in many other studies on bamboo treatment with other vegetable oils at varied temperatures. The likely implication of this is that if this oil is to be used, particularly at high temperature range, as a preservative for bamboo to extend its service life, the use to which the bamboo will be put should be an important determining factor.

Thus, if the bamboo so treated will be applied in the static bending load bearing mode, it is important to be acquainted with this information, in order for the lofty objective of treating bamboo or any other lignocellulosic material with such an environmentally friendly means not to be defeated. Further studies are expected to increase the potential of using the oil as wood and fibre preservative and also improve the efficacy of the oil in this regard.

REFERENCES

1. Mock, J.A., 1979. Development of Plastic Laminates with Wooden Core. *Materials of Engineering*, 89: 60-63.
2. Beimers, H., A. Berrera, E. Castillo, E. Verheugen, M. Monjaras, G.A. Patfoort and M.E.N. Bucqueye, 1981. Development of Composite Material with Palm Fibres. *Ind. Eng. Chem. Prod. Res. Dev.*, 20: 555-561.
3. Kulkarni, A.G., K.G. Satyanarayana and P.K. Rohatgi, 1981. Fabrication and Properties of Coir Based Composites. *J. Sci. Ind. Res.*, 40: 222-226.
4. Mansur M.A. and M.A. Aziz, 1982. Study of Jute Fibre Reinforced Composites. *International Journal of Chemical Composite Light Weight Concrete*, 4: 75-82.
5. Satyanarayana, K.G., C.K.S. Pillai, S.G.K. Sukumaran, K. Vijayan and P.K. Rohatgi, 1982. Structure and Properties of Fibres from Various Parts of Coconut Tree. *J. Materials Sci.*, 17: 2453-2462.
6. Kulkarni, A.G., K.G. Satyanarayana, P.K. Rohatgi and K. Vijayan, 1983a. Breaking Stress of Banana Fibres of Different Lengths. *J. Materials Sci.*, 18: 2290-2296.
7. Kulkarni, A.G., K.G. Satyanarayana, P.K. Rohatgi and K. Vijayan, 1983b. Mechanical Properties of Banana Fibre. *J. Materials Sci.*, 18: 2292-2296.
8. Jindal U.C., 1986. Development and Testing of Bamboo Fibre Reinforced Plastic Composites. *J. Composite Materials*, 20: 19-29.
9. Varadarajulu, A., S. Allahbakash, R.G. Ramachandra and K. Narasimhachary, 1998. Chemical Resistance and Tensile Properties of short Bamboo Fibre Reinforced Epoxy Composites. *J. Reinforced Plastics and Composites*, 17: 1507-1512.
10. Dabade, B.M., R.G. Ramachandra and U.K. Chavan, 2005. Tensile Properties of Short Sunhemp Fibre Reinforced Composites, In: *Proceeding of 3rd International Conference on Advanced Fibre/ Textile Materials at Ueda, Japan*, pp: 175-176.
11. Dabade, B.M., G.R. Reddy, S. Rajesham and C.U. Kiran, 2006. Effect of Fibre Length and Fibre Weight Ratio on Tensile Properties of Sun Hemp and Palmyra Fibre Reinforced Polyester Composites. *J. Reinforced Plastics and Composites*, 25(16): 1733-1738.
12. Erakhrumen, A.A., S.E. Areghan, M.B. Ogunleye, S.L. Larinde and O.O. Odeyale, 2008. Selected Physico-Mechanical Properties of Cement-Bonded Particleboard made from Pine (*Pinus caribaea* M.) Sawdust-Coir (*Cocos nucifera* L.) Mixture. *Scientific Research and Essays*, 3(5): 197-203.
13. Magel, E., S. Kruse, G. Lütje and W. Liese, 2005. Soluble Carbohydrates and Acid Invertases involved in the Rapid Growth of Developing Culms in *Sasa palmata* (Bean) Camus. *Bamboo Science and Culture*, 19(1): 23-29.
14. Sekar, T., A. Balasubramanian and V. Manimekalai, 1998. Vegetative Propagation of an Ornamental Bamboo, *Bambusa vulgaris* cv. Wamin McClure, by branch cuttings. *Bamboo Science and Culture*, 12(1): 30-36.
15. Liese, W., 1999. Bamboo: Past-Present-Future. *American Bamboo Society Newsletter* 20(1): 9.
16. Ding, Y., 1996. *Phyllostachys* in China and its Utilization. *Belgian Bamboo Society Newsletter*, 12: 7-15.

17. Singh, T., C. Chittenden and D. Vesentini, 2006. *In vitro* Antifungal Activity of Chilli against Wood Degrading Fungi. IRG/WP 06-10572. A Paper prepared for the 37th Annual Meeting of The International Research Group on Wood Protection held in Tromsø, Norway from 18 to 22 June 2006, 11.
18. Venmalar, D. and H.C. Nagaveni, 2005. Evaluation of Copperised Cashew Nut Shell Liquid and Neem Oil as Wood Preservatives. IRG/WP 05-30368. Prepared for the 3rd Annual Meeting of the International Research Group on Wood Protection held in Bangalore, India from April 24th to 28th, 2001, 20.
19. Erakhrumen, A.A., 2009. Tensile Strength Properties of Wild Grown *Bambusa vulgaris* Treated with Neem Seed Oil in Southwest Nigeria. J. Bamboo and Rattan, 8(1and2): 95-102.
20. Erakhrumen, A.A. and O.Y. Ogunsanwo, 2009. Water Absorption, Anti-Swell Efficiency and Dimensional Stability Properties of Neem Seed Oil-Treated Wild Grown *Bambusa vulgaris* Schrad ex J.C. Wendl. in Southwest Nigeria. Bio Resources, 4(4): 1417-1429.
21. Londoño, X., G.C. Camayo, N.M. Riaño and Y. López, 2002. Characterization of the anatomy of *Guadua angustifolia* (Poaceae: Bambusoideae) culms. Bamboo Science and Culture, 16(1): 18-31.
22. Mitra, C.R., 1963. Neem. Indian Central Oil Seeds Committee, Hyderabad, India, pp: 190.
23. Soetaredjo, F.E., G.M. Budijanto, R.I. Prasetyo and N. Indraswati, 2008. Effects of Pre-treatment Condition on the Yield and Quality of Neem Oil obtained by Mechanical Pressing. ARPN J. Engineering and Appl. Sci., 3(5): 45-49.
24. Chand, N., D. Jain and A. Nigrawal, 2006. Investigations on Gradient a.c. Conductivity Characteristics of Bamboo (*Dendrocalamus strictus*). Bulletin of Material Sci., 29(2): 193-196.
25. Puri, H.S., 1999. Neem: The Divine Tree. *Azadirachta indica*. Harwood Academic Publications, Amsterdam. ISBN, 90-5702-348-2.
26. Fasina, O.O. and O.O. Ajibola, 1989. Mechanical extraction of oil from conophor nut (*Tetracarpidium conophorum*). J. Agric. Engng. Res., 44: 275-287.
27. Ketaren, S., 1986. Pengantar Teknologi Minyak dan Lemak Pangan. Jakarta: UI-Press. pp: 201.
28. Liauw, M.Y., F.A. Natan, P. Widiyanti, D. Ikasari, N. Indraswati and F.E. Soetaredjo, 2008. Extraction of Neem Oil (*Azadirachta indica* A. Juss) using N-Hexane and Ethanol: Studies of Oil Quality, Kinetic and Thermodynamic. ARPN J. Engineering and Appl. Sci., 3(3): 49-54.
29. ASTM 1983a. Standard Test Methods for Specific Gravity of Wood and Wood-Base Materials. ASTM D 2395-83. American Society for Testing and Materials. **Volume** 04.09. pp: 382-389.
30. ASTM. 1984. Standard Test Methods for Direct Moisture Content of Wood and Wood-Base Materials. ASTM D 4442-84. American Society for Testing and Materials. **Volume** 04.09. pp: 514-518.
31. ASTM. 1983b. Standard Methods of Testing Small Clear Specimens of Timber. ASTM D 143-83. American Society for Testing and Materials. **Volume** 04.09. pp: 37-78.
32. Li, X., 2004. Physical, Chemical and Mechanical Properties of Bamboo and its Utilization Potential for Fibreboard Manufacturing. M.Sc. Dissertation, the School of Renewable Natural Resources, Louisiana State University and Agriculture and Mechanical College, U.S. pp: 76.
33. Chew, L.T., S. Rahim and K. Jamaludin, 1992. *Bambusa vulgaris* for Urea and Cement-bonded Particleboard Manufacture. J. Tropical Forest Sci., 4(3): 249-256.
34. Lee, A.W.C., B. Xuesong and N.P. Perry, 1994. Selected Physical and Mechanical Properties of Giant Timber Bamboo Grown in South Carolina. Forest Products J., 44(9): 40-46.
35. Yu, H.Q., Z.H. Jiang, C.Y. Hse and T.F. Shupe, 2008. Selected Physical and Mechanical Properties of Moso Bamboo (*Phyllostachys pubescens*). Journal of Tropical Forest Sci., 20(4): 258-263.
36. Wahab, R., H.W. Samsi and O. Sulaiman, 2007. Properties of Oil-Cured Cultivated *Bambusa vulgaris*. *International J. Agri. Res.*, 2(9): 820-825.
37. Wahab, R., J. Moktar, M. Sudin and H.W. Samsi, 2006. Strength Properties of Preservative Treated *Gigantochloa scortechinii* after Vacuum Impregnation process. *International J. Agri. Res.*, 1(1): 8-13.
38. Manalo, R.D. and M.N. Acda, 2009. Effects of Hot Oil Treatment on Physical and Mechanical Properties of Three Species of Philippine Bamboo. J. Tropical Forest Sci, 21(1): 19-24.
39. Leithoff, H. and R.D. Peek, 2001. Heat Treatment of Bamboo. IRG/WP 01-40216. Prepared for the 32nd Annual Meeting of the International Research Group on Wood Preservation Nara, Japan from May 20th to 25th, 2001, pp: 10.
40. Wahab, R., W., H.W. Samsi, M. Sudin and J. Moktar, 2004. Strength and Durability of Bamboo Treated Through an Oil-curing Process. J. Biological Sci., 4(5): 658-663.

41. Kumar, S., 2007. Bamboo Protection Research: Contributions from India. Paper prepared for the 38th Annual Meeting of the International Research Group on Wood Protection. Session 4: Processes and properties held at Jackson Lake Lodge, Wyoming, USA from 20th to 24th May, 2007. IRG/WP 07-40355, pp: 14.
42. Viitaniemi, P., 1997. Thermowood - Modified wood for improved performance. In: Trätek Rapport No. 9709084, 1997: Proceedings of the 4th Eurowood Symposium "Wood - The Ecological Material" 22-23. September 1997, Stockholm, Sweden. ISSN 1102-1071, pp: 67-69.
43. Rapp A.O. and M. Sailer, 2000. Heat Treatment in Germany - State of the Art. Nordic Wood, Nordic Wood Seminar om varmebehandlet tre, Scandic Hotel Triaden, Lorenskog 22.11.2000, pp: 81-95.
44. Boonstra, M.J., B.F. Tjeerdsma and H.A.C. Groeneveld, 1998. Thermal Modification of Non-durable Wood Species. 1. The PLATO Technology: Thermal Modification of Wood. Document No. IRG/WP 98-40123. International Research Group on Wood Preservation, Stockholm.
45. Tjeerdsma, B.F., M. Boonstra, A. Pizzi, P. Tekely and H. Militz, 1998. Characterization of thermal modified wood: molecular reasons for wood performance improvement. Holz als Roh- und Werkstoff, 56: 149-153.
46. Burmester, A., 1973. Einfluß einer Wärme-Druck-Behandlung halbtrockenen Holzes auf seine Formbeständigkeit. Holz als Roh- und Werkstoff, 31: 237-243.
47. Giebeler, E., 1983. Dimensionsstabilisierung von Holz durch eine Feuchte/Warmer/Druck-Behandlung. Holz als Roh- und Werkstoff, 41: 87-94.
48. Salim, R., R. Wahab, Z. Ashaari and H.W. Samsi, 2009. Chemical Constituents of Oil-Cured Tropical Bamboo *Gigantochloa scortechinii*. J. Appl. Sci., 9(1): 149-154.
49. Lybeer, B. and G. Koch, 2005. Lignin Distribution in the Tropical Bamboo Species *Gigantochloa levis*. IAWA J., 26(4): 443-456.