

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

**Andrew A. Erakhrumen\* and Olukayode Y. Ogunsanwo\***  
**\*Ph.D**

Department of Forest Resources Management, Faculty of Agriculture and Forestry,  
University of Ibadan, Ibadan, NIGÉRIA

---

**Abstract.** This paper intends to contribute to the efforts aimed at achieving sustainable environmentally benign methods of treating and preserving lignocellulosic materials. For this study, split-bamboo samples, 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 seed oil. 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 moduli of rupture and 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. One way 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; rupture and elastic modulus; neem seed oil

### **A Influência do Tratamento com Óleo de Semente de *Azadirachta indica* nos Parâmetros de Resistência à Flexão Estática do Bambu Espontâneo (*Bambusa vulgaris* Schrad.) do Sudoeste da Nigéria**

**Sumário.** Este estudo pretendeu contribuir para o desenvolvimento de métodos ambientalmente benignos para o tratamento e preservação dos materiais lenhocelulósicos. Com este objectivo submeteram-se amostras de bambu de densidade média de 0,89, condicionadas em laboratório para obtenção de humidade de 11,76%, a tratamento com óleo extraído mecanicamente de sementes de *Azadirachta indica* sob dois regimes de temperatura. As propriedades mecânicas para caracterização dos provetes tratados e não tratados com óleo foram determinadas em conformidade com a norma ASTM D 143-83. Os valores médios dos módulos de ruptura e elasticidade (MOR e MOE) dos testes de resistência à flexão estática foram mais baixos nas amostras mergulhadas em óleo quente a 60°C durante 4 horas, e mais elevados em amostras mergulhadas em óleo à temperatura ambiente de 25±2°C durante 24 horas, sucedendo que os valores dos provetes testemunha foram mais elevados que os correspondentes aos provetes tratados com óleo. A análise de variância univariada também revelou diferenças estatisticamente significativas nos dados obtidos para MOR e MOE, para um nível de significância de 5%. A comparação das médias dos resultados foi realizada com

recurso ao teste de diferença de médias de Fisher.

**Palavras-chave:** Bambu; flexão estática; módulos de ruptura e elasticidade; óleo de sementes de *Azadirachta indica*

**Influence du Traitement avec de l'Huile de Graines de Neem sur les Propriétés Statiques de Résistance à la Flexion du Dédoubler-Bambou (*Bambusa vilgaris* Schrad.) Poussant à l'État Sauvage dans le Sud-Ouest du Niger**

**Résumé.** Ce travail a eu comme objectif de contribuer aux efforts de développement de méthodes bénignes pour l'environnement, pour traiter et préserver les matériaux lignocellulosiques. Pour cette étude, des échantillons de bambou, ayant une densité moyenne de 0.89 et conditionnés en laboratoire jusqu'à l'obtention d'une teneur en eau de 11.76%, ont été traités, à deux régimes différents de température, avec l'huile de graines de neem mécaniquement extraite. Les propriétés mécaniques choisies pour les échantillons en bambou huile-traitée et non traitée étaient déterminées conformément à ASTM modifié D 143-83. Les résultats ont prouvé que les valeurs moyennes pour des modules de la rupture et de l'élasticité (MOR et MOE) pour l'essai statique de résistance à la flexion étaient les plus basses dans les échantillons imbibés dans de l'huile chaude à 60°C pendant 4 heures, mais plus élevées dans les échantillons imbibés dans de l'huile à la température ambiante de 25±2°C pendant 24 heures, les échantillons témoins possédant des valeurs plus élevées que ceux des échantillons huile-traités. L'analyse de la variance à sens unique a aussi indiqué la variation statistiquement significative des données obtenues pour MOR et MOE au niveau de signification de 5%. Le test de «la moindre différence significative» de Fisher a été employé comme essai de suivi pour comparer les moyennes, également au niveau de signification de 5%.

**Mots clés:** Bambou; recourbement statique; modules de rupture et élasticité; huile de graines de neem

## Introduction

The use of wood and fibre materials and their products has been and is still important to different categories of users and this has necessitated series of global studies, some of which have been on materials from wood, cotton, banana, flax, sisal, coir, wheat straw, sun hemp, Palmyra fibre, bamboo, rattan, among others (MOCK, 1979; BEIMERS *et al.*, 1981; KULKARNI *et al.*, 1981; MANSUR and AZIZ, 1982; SATYANARAYANA *et al.*, 1982; KULKAMI *et al.*, 1983a; 1983b; JINDAL, 1986; VARADARAJULU *et al.*, 1998; DABADE *et al.*, 2005; 2006; ERAKHRUMEN *et al.*, 2008).

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 (MAGEL *et al.*, 2005) 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 (SEKAR *et al.*, 1998). It has long been traditionally utilised in rural life for ages, especially in Asia (LIESE, 1999). 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 (DING, 1996).

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 have 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. SINGH *et al.*, 2006) 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 (VENMALAR and NAGAVENI, 2005).

Since lignocellulosic material are utilised 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 (ERAKHRUMEN, 2009; ERAKHRUMEN and OGUNSANWO, 2009). 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.

## 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 (LONDOÑO *et al.*, 2002).

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 culm from the base were harvested and cross cut in such a way that only the basal culm portion of 300cm 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 MITRA (1963), a method also applied by SOETAREDJO *et al.* (2008) 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  $5\pm 0.5$ mm for the tests. Bamboo timber, according to CHAND *et al.*, (2006) 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 (CHAND *et al.*, 2006).

After conditioning in the laboratory for 14 days, the strips were converted to test specimens. The specimens with dimensions 20mm (tangentially) x 20mm (longitudinally) x 5mm (radially) were for moisture content (MC) and specific gravity (SG) determination. Dimensions 20mm (tangentially) x 200mm (longitudinally) x 5mm (radially) were

oven-dried and stabilised 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 (PURI, 1999). Mechanical extraction is the most widely used method to extract neem oil from the seeds (FASINA and AJIBOLA, 1989; PURI, 1999) since this method is effective for seeds containing 30-70% oil (KETAREN, 1986) 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 (LIAUW *et al.*, 2008).

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 (31.03 Nmm<sup>-2</sup> or 31.03 MPa), as also done in similar studies by ERAKHRUMEN (2009); and ERAKHRUMEN and OGUNSANWO (2009).

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 (FASINA and AJIBOLA, 1989).

Bamboo samples for the mechanical property tests were sterilised by oven-drying at  $103^{\circ}\text{C}\pm 2^{\circ}\text{C}$  for 2 hours, cooled in a desiccator, 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  $60^{\circ}\text{C}$  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 weighted on a sensitive weighting 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 using the equation 1:

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

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*

Specific gravity (SG) of bamboo samples in this study was obtained based on the method described in ASTM D 2395-83. SG was calculated using equation 2:

$$SG = 1000WLwt[1+(MC/100)]^{-1} \quad \text{Equation 2}$$

where:

$W$  = Weight of specimen (g)

$MC$  = Moisture content of specimen in percentage

$L$  = Length of specimen (mm)

$w$  = Width of specimen (mm)

$t$  = Thickness of specimen (mm)

#### *Evaluation of selected mechanical properties*

The static bending strength test specimens of oil-treated and untreated samples with dimensions 25mm (tangentially) x 200mm (longitudinally) x 5mm (radially) were prepared with slight modification to ASTM D 143-83 owing to bamboo nature. The static bending test (with load introduced on the radial plane of the samples) was carried out using a computer controlled Instron 3363 Universal Testing Machine at cross-head speed of  $4.00\text{mm min}^{-1}$  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 (LI, 2004). The mean SG obtained for untreated samples in this research was in the range documented in literature (e.g. CHEW *et al.*, 1992; LEE *et al.*, 1994; YU *et al.*, 2008; ERAKHRUMEN, 2009). 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 were comparable to those published in literature (e.g. RAZAK *et al.*, 2007) on *Bambusa vulgaris*, although, lower in values as sample test dimension was smaller compared to those used by RAZAK *et al.* (2007). 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 were reduced in value compared to the control samples which were not treated with oil. This pattern of reduction has been documented in literature (e.g. RAZAK *et al.*, 2006; MANALO and ACDA, 2009).

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°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 ERAKHRUMEN (2009) for this species' tensile strength properties at the same temperature range and duration of treatment.

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. LEITHOFF and PEEK (2001); RAZAK *et al.* (2004; 2006); KUMAR (2007). 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 they are within the range of strength reduction of those bamboos or other lignocellulosic material that were chemically treated with preservatives (RAZAK *et al.*, 2004). 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 (RAZAK *et al.*, 2004; 2006).

Similar observation was experienced with heat treatment of other lignocellulosic material in the literature (VIITANIEMI, 1997; RAPP and SAILER, 2000). Reduction in strength properties were also reported in thermal

modification of wood at elevated temperature (BOONSTRA *et al.*, 1998; TJEERDSMA *et al.*, 1998). Studies in the past attributed this to the degradation of cell wall carbohydrates (BURMESTER, 1973; GIEBELER, 1983; TJEERDSMA *et al.*, 1998).

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 SALIM *et al.* (2009). 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 (LYBEER and KOCH, 2005).

The strength of bamboos is 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 (RAZAK *et al.*, 2006), 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  $60^\circ\text{C}$  for 4 hours while LSD showed that all the mean values for MOE were significantly different.

**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 <sup>-2</sup> )	MOE (Nmm <sup>-2</sup> )	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 $25 \pm 2^\circ\text{C}$ 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 $60^\circ\text{C}$ 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*	
	MOE	3338.58*	
	Energy at Maximum Load	0.29ns	3.35
	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 <sup>-2</sup> )	MOE (Nmm <sup>-2</sup> )	Energy at Maximum Load (kJ)	Load at Yield (Zero Slope) (N)	Extension at Yield (Zero Slope) (mm)
Control	103.20 <sup>a</sup>	9850.39 <sup>a</sup>	0.20 <sup>a</sup>	27266 <sup>a</sup>	15.88 <sup>a</sup>
Samples soaked in oil at room temperature of 25±2°C for 24 hours	98.17 <sup>a</sup>	8910.11 <sup>b</sup>	0.18 <sup>a</sup>	25419 <sup>a</sup>	15.74 <sup>b</sup>
Samples soaked in hot oil at 60°C for 4 hours	83.05 <sup>b</sup>	7892.69 <sup>c</sup>	0.16 <sup>a</sup>	22542 <sup>b</sup>	15.61 <sup>c</sup>

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

## 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 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

- ASTM, 1983a. Standard Methods of Testing Small Clear Specimens of Timber. ASTM D 143-83. *American Society for Testing and Materials* vol. 04.09: 37-78.

- ASTM, 1983b. Standard Test Methods for Specific Gravity of Wood and Wood-Base Materials. ASTM D 2395-83. *American Society for Testing and Materials* vol. 04.09: 382-389.
- 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* vol. 04.09: 514-518.
- BEIMERS, H., BERRERA, A., CASTILLO, E., VERHEUGEN, E., MONJARAS, M., PATFOORT, G.A., BUCQUEYE, M.E.N., 1981. Development of Composite Material with Palm Fibres. *Ind. Eng. Chem. Prod. Res. Dev.* **20**: 555-561.
- BOONSTRA, M.J., TJEERDSMA, B.F., GROENEVELD, H.A.C., 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.
- BURMESTER, A., 1973. Einfluß einer Wärme-Druck-Behandlung halbtrockenen Holzes auf seine Formbeständigkeit. *Holz als Roh- und Werkstoff* **31**: 237-243.
- CHAND, N., JAIN, D., NIGRAWAL, A., 2006. Investigations on Gradient a.c. Conductivity Characteristics of Bamboo (*Dendrocalamus strictus*). *Bulletin of Material Science* **29**(2): 193-196.
- CHEW, L.T., RAHIM, S., JAMALUDIN, K., 1992. *Bambusa vulgaris* for Urea and Cement-bonded Particleboard Manufacture. *Journal Tropical Forest Science* **4**(3): 249-256.
- DABADE, B.M., RAMACHANDRA R.G., CHAVAN, U.K., 2005. Tensile Properties of Short Sunhemp Fibre Reinforced Composites, In: *Proceeding of 3<sup>rd</sup> International Conference on Advanced Fibre/ Textile Materials at Ueda, Japan*, pp. 175-176.
- DABADE, B.M., REDDY, G.R., RAJESHAM, S., KIRAN, C.U., 2006. Effect of Fibre Length and Fibre Weight Ratio on Tensile Properties of Sun Hemp and Palmyra Fibre Reinforced Polyester Composites. *Journal of Reinforced Plastics and Composites* **25**(16): 1733-1738.
- DING, Y., 1996. *Phyllostachys* in China and its Utilization. *Belgian Bamboo Society Newsletter* **12**: 7-15.
- ERAKHRUMEN, A.A., 2009. Tensile Strength Properties of Wild Grown *Bambusa vulgaris* Treated with Neem Seed Oil in Southwest Nigeria. *Journal of Bamboo and Rattan* **8**(1&2): 95-102.
- ERAKHRUMEN, A.A., AREGHAN, S.E., OGUNLEYE, M.B., LARINDE, S.L., ODEYALE, O.O., 2008. Selected Physico-Mechanical Properties of Cement-Bonded Particle-board made from Pine (*Pinus caribaea* M.) Sawdust-Coir (*Cocos nucifera* L.) Mixture. *Scientific Research and Essays* **3**(5): 197-203.
- ERAKHRUMEN, A.A., OGUNSANWO, O.Y., 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. *BioResources* **4**(4): 1417-1429.
- FASINA, O.O., AJIBOLA, O.O., 1989. Mechanical extraction of oil from conophor nut (*Tetracarpadium conophorum*). *Journal of Agric. Engng. Res.* **44**: 275-287.
- GIEBELER, E., 1983. Dimensionsstabilisierung von Holz durch eine Feuchte/Wärme-/Druck-Behandlung. *Holz als Roh- und Werkstoff* **41**: 87-94.
- GIELIS, J., 2002. Future Possibilities for Bamboo in European Agriculture. Oprins Plant Sint-Lenaartsesteenweg 91 B-2310 Rijkvorschel.
- JINDAL, U.C., 1986. Development and Testing of Bamboo Fibre Reinforced Plastic Composites. *Journal of Composite Materials* **20**: 19-29.
- KETAREN, S., 1986. Pengantar Teknologi Minyak dan Lemak Pangan. Jakarta: UI-Press. p. 201.
- KULKARNI, A.G., SATYANARAYANA, K.G., ROHATGI, P.K., 1981. Fabrication and Properties of Coir Based Composites. *J. Sci. Ind. Res.* **40**: 222-226.
- KULKARNI, A.G., SATYANARAYANA, K.G., ROHATGI, P.K., VIJAYAN, K., 1983a. Breaking Stress of Banana Fibres of Different Lengths. *Journal of Materials Science* **18**: 2290-2296.

- KULKARNI, A.G., SATYANARAYANA, K.G., ROHATGI, P.K., VIJAYAN, K., 1983b. Mechanical Properties of Banana Fibre. *Journal of Materials Science* **18**: 2292-2296.
- KUMAR, S., 2007. Bamboo Protection Research: Contributions from India. Paper prepared for the 38<sup>th</sup> Annual Meeting of the International Research Group on Wood Protection. Session 4: Processes and properties held at Jackson Lake Lodge, Wyoming, USA from 20<sup>th</sup> to 24<sup>th</sup> May, 2007. IRG/WP 07-40355, 14pp.
- LEE, A.W.C., XUESONG, B., PERRY, N.P., 1994. Selected Physical and Mechanical Properties of Giant Timber Bamboo Grown in South Carolina. *Forest Products Journal* **44**(9): 40-46.
- LEITHOFF, H., PEEK, R.D., 2001. Heat Treatment of Bamboo. IRG/WP 01-40216. Prepared for the 32<sup>nd</sup> Annual Meeting of the International Research Group on Wood Preservation Nara, Japan from May 20<sup>th</sup> to 25<sup>th</sup>, 2001, 10pp.
- LIAUW, M.Y., NATAN, F.A., WIDIYANTI, P., IKASARI, D. INDRASWATI, N., SOETAREDOJO, F.E., 2008. Extraction of Neem oil (*Azadirachta indica* A. Juss) using N-Hexane and Ethanol: Studies of Oil Quality, Kinetic and Thermodynamic. *ARPJ Journal of Engineering and Applied Sciences* **3**(3): 49-54.
- LIESE, W., 1999. Bamboo: Past-Present-Future. *American Bamboo Society Newsletter* **20**(1): 9.
- LONDOÑO, X., CAMAYO, G.C., RIAÑO, N.M., LÓPEZ, Y., 2002. Characterization of the anatomy of *Guadua angustifolia* (Poaceae: Bambusoideae) culms. *Bamboo Science and Culture* **16**(1): 18-31.
- LYBEER, B., KOCH, G., 2005. Lignin Distribution in the Tropical Bamboo Species *Gigantochloa levis*. *IAWA Journal* **26**(4): 443-456.
- MAGEL, E., KRUSE, S., LÜTJE, G., LIESE, W., 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.
- MANALO, R.D., ACDA, M.N., 2009. Effects of Hot Oil Treatment on Physical and Mechanical Properties of Three Species of Philippine Bamboo. *Journal of Tropical Forest Science* **21**(1): 19-24.
- MANSUR, M.A., AZIZ, M.A., 1982. Study of Jute Fibre Reinforced Composites, *International Journal of Chemical Composite Light Weight Concrete* **4**: 75-82.
- MITRA, C.R., 1963. Neem. Indian Central Oil Seeds Committee, Hyderabad, India, 190pp.
- MOCK, J.A., 1979. Development of Plastic Laminates with Wooden Core. *Materials of Engineering* **89**: 60-63.
- PURI, H.S., 1999. Neem: The Divine Tree. *Azadirachta indica*. Harwood Academic Publications, Amsterdam. ISBN 90-5702-348-2.
- RAPP, A.O., SAILER, M., 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.
- RAZAK, W. SAMSI, H.W., SUDIN, M., MOKTAR, J., 2004. Strength and Durability of Bamboo Treated Through an Oil-curing Process. *Journal of Biological Sciences* **4**(5): 658-663.
- RAZAK, W., MOKTAR, J., SUDIN, M., SAMSI, H.W., 2006. Strength Properties of Preservative Treated *Gigantochloa scortechinii* after Vacuum Impregnation process. *International Journal of Agricultural Research* **1**(1): 8-13.
- RAZAK, W., SAMSI, H.W., SULAIMAN, O., 2007. Properties of Oil-Cured Cultivated *Bambusa vulgaris*. *International Journal of Agricultural Research* **2**(9): 820-825.
- SALIM, R., WAHAB, R., ASHAARI, Z., SAMSI, H.W., 2009. Chemical Constituents of Oil-Cured Tropical Bamboo *Gigantochloa scortechinii*. *Journal of Applied Sciences* **9**(1): 149-154.
- SATYANARAYANA, K.G., PILLAI, C.K.S., SUKUMARAN, S.G.K., VIJAYAN, K., ROHATGI, P.K., 1982. Structure and Properties of Fibres from Various Parts of Coconut Tree. *Journal of Materials Science* **17**: 2453-2462.

- SEKAR, T., BALASUBRAMANIAN, A., MANIMEKALAI, V., 1998. Vegetative Propagation of an Ornamental Bamboo, *Bambusa vulgaris* cv. Wamin McClure, by branch cuttings. *The Journal of the American Bamboo Society* **12**(1): 30-36.
- SINGH, T., CHITTENDEN, C., VESENTINI, D., 2006. *In vitro* Antifungal Activity of Chilli against Wood Degrading Fungi. IRG/WP 06-10572. A Paper prepared for the 37<sup>th</sup> Annual Meeting of The International Research Group on Wood Protection held in Tromsø, Norway from 18 to 22 June 2006, 11 pp.
- SOETAREDO, F.E., BUDIJANTO, G.M., PRASETYO, R.I., INDRASWATI, N., 2008. Effects of Pre-treatment Condition on the Yield and Quality of Neem Oil obtained by Mechanical Pressing. *ARPN Journal of Engineering and Applied Sciences* **3**(5): 45-49.
- TJEERDSMA, B.F., BOONTRA, M., PIZZI, A., TEKELY, P., MILITZ, H., 1998. Characterization of thermal modified wood: molecular reasons for wood performance improvement. *Holz als Roh-und Werkstoff* **56**: 149-153.
- VARADARAJULU, A., ALLAHBAKASH, S., RAMACHANDRA, R.G., NARASIMHACHARY, K., 1998. Chemical Resistance and Tensile Properties of short Bamboo Fibre Reinforced Epoxy Composites. *Journal of Reinforced Plastics & Composites* **17**: 1507-1512.
- VENMALAR, D., NAGAVENI, H.C., 2005. Evaluation of Copperised Cashew Nut Shell Liquid and Neem Oil as Wood Preservatives. IRG/WP 05-30368. Prepared for the 36<sup>th</sup> Annual Meeting of the International Research Group on Wood Protection held in Bangalore, India from April 24<sup>th</sup> to 28<sup>th</sup>, 2001, 20 pp.
- VIITANIEMI, P., 1997. Thermowood - Modified wood for improved performance. In: Trätekt Rapport No. 9709084, 1997: Proceedings of the 4<sup>th</sup> Eurowood Symposium "Wood - The Ecological Material" 22-23 September, Stockholm, Sweden. ISSN 1102-1071, pp. 67-69.
- YU, H.Q., JIANG, Z.H., HSE, C.Y., SHUPE, T.F., 2008. Selected Physical and Mechanical Properties of Moso Bamboo (*Phyllostachys pubescens*). *Journal of Tropical Forest Science* **20**(4): 258-263.

Entregue para publicação em Abril de 2010  
 Aceite para publicação em Agosto de 2010