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# Tensile strength properties of wild grown *Bambusa vulgaris* treated with neem seed oil in Southwest Nigeria

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**Abstract**: Tensile strength, a mechanical property of bamboo is less investigated. In this study, the moduli of rupture and elasticity (MOR and MOE) of neem seed oil-treated and control split-bamboo samples with specific gravity 0.89 and conditioned in the laboratory to 11.76 per cent moisture content were evaluated in conformity with modified ASTM D143-94 owing to bamboo's nature. The results showed that MOR for control samples, samples soaked in oil at room temperature for 24 h and samples soaked in hot oil at 60°C for 4 h were 157.40, 153.83, and 130.16 N $mm^{-2}$ respectively. MOE also followed the same trend with values for control samples, samples soaked in oil at room temperature for 24 h and samples soaked in hot oil at 60°C for 4 h being 3452.31, 2125.22, and 2018.18 N $mm^{-2}$ respectively. Energy at maximum load, load and extension at yield also followed this trend. Results of analysis of variance at 5 per cent level of significance showed that values for all the evaluated properties except those for energy at maximum load significantly varied between control and oil-treated samples. Fisher's Least Significant Difference was employed as a follow-up test to compare mean values at $P<0.05$.

*Keywords*: Bamboo, neem seed oil, tensile strength properties, rupture and elastic moduli.

## INTRODUCTION

Bamboo is a lignocellulosic material prone to easy degradation by fungi and insects (Liese, 1998; Razak *et al.*, 2004; Bhat *et al.*, 2005). This has necessitated the use of preservatives to enhance its durability and extend its service life. Even though, there has been clamours against the use of broad spectrum biocides for the preservation of lignocellulosic materials which has led to series of researches that are aimed at the use of environmental benign methods such as oil curing in linseed oil (Leithoff and Peek, 2001), palm oil (Razak *et al.*, 2004), virgin coconut oil (Manalo and Acda, 2009), among others. So far, information is meagre on the influence of oil curing on physical and mechanical properties of lignocellulosic material (Erakhrumen and Ogunsanwo, 2009). Bamboos possess excellent strength properties, especially tensile strength (Kumar *et al.*, 1994; Ghavami, 2005; Shyamasundar and Vengala, undated). Tensile strength is an

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important mechanical property of bamboos and if bamboo is to be used for furniture and construction purposes, its tensile strength has to be considered. It has been observed that some species of bamboo possess similar tensile strength as that for steel (Ghavami, 2005) while the specific ultimate tensile strength of certain bamboo species has also been found to be nearly six times that of mild steel (Anon., 2008) thus, it can be used for reinforcement in place of mild steel (Shyamasundar and Vengala, undated). The present study was carried out to investigate the influence of neem (*Azadirachta indica* A. Juss) seed oil treatment on tensile strength properties of *Bambusa vulgaris* Schrad. ex J.C. Wendl sourced from a forest in Eruwa, Oyo State, Southwest, Nigeria.

## MATERIALS AND METHODS

### Sourcing of bamboo culms and neem seeds

The 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°31'60 N and Longitude 3°25'0 E) about 64.8 km 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 1,693.3 mm.

Culms with mean girth of 30 cm at the second culm 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 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 *A. indica* trees located on Benue Road on the University of Ibadan Campus located on the northern edge of the city of Ibadan (Latitude 7°20'0 N and Longitude 3°50'0 E) of about 10.4 $km^2$. Ibadan lies at 200 m a.s.l. with a humid tropical climate (27°C average), a March – October rainy season (1250 mm) 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 to collect the seeds as they fall.

The seeds were sourced during 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 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 air dried daily 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, to obtain the bamboo timber with mean culm thickness of 5±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 of 20 mm (tangentially) x 20 mm (longitudinally) x 5mm (radially) were used for moisture content (MC) and specific gravity (SG) determination. Strips with dimensions of 20 mm (tangentially) x 200 mm (longitudinally) x 5 mm (radially) were oven-dried and stabilized in the laboratory to 11.76 per cent mean MC prior to testing for tensile strength properties.

**Extraction of neem seed oil**

Several methods of obtaining oil from the seeds of neem exist *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 per cent oil (Ketaren, 1986) although, the oil produced with this method may have a low price, as it is turbid and contains a significant amount of water as compared to those obtained by solvent and supercritical fluid extraction (Liauw *et al.*, 2008). The neem seeds were manually cracked and separated from the shell, cleaned from dirt, then air-dried. Dried kernels were carefully ground into paste using seed grinder to smaller particles ensuring no significant loss of oil. Mechanical extraction of oil was performed by cold pressing at maximum pressure of 4500 psi. Mechanical extraction was performed at this pressure until the oil stopped flowing out.

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

**Moisture content determination for bamboo samples**

Ten test specimens each of 20 mm x 20 mm x 5 mm 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±2°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 4442-07 (ASTM

2007 a,b) using the equation:
$MC = [(W_m - W_o) / W_o] \times 100$ ———————— ———————— 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

The SG of bamboo samples in this study was obtained based on the method described in ASTM D 2395-07 (ASTM 2007 b). The MC of samples for SG were first obtained in accordance with ASTM D 4442-07 (Equation 1) and recorded. SG was calculated using equation 2.
$SG = KW / [1+ (MC/100)] Lwt$ ———————————————— Equation 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

Tensile 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 143-94 (ASTM, 1994) owing to bamboo's nature. Tensile strength test (with tension force introduced longitudinally) was carried out using a 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

SG is a measure of the density of a substance. The SG of a substance is a comparison of its density to that of water. The SG of bamboo varies between 0.4 and 0.8 depending mainly on the anatomical structure (Li, 2004). The mean SG obtained in this study (0.894) was in the range documented in literature (Chew *et al.*, 1992; Lee *et al.*, 1994; Yu *et al.*, 2008). 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 tensile strength values of both oil-treated and untreated bamboo samples

The selected tensile strength properties (MOR and MOE) for the treated bamboo samples had lower values as compared to that of control samples which were not treated with oil. The results also showed that the evaluated tensile strength properties

(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 for 24 h and lowest in samples soaked in hot oil at 60°C for 4 h (Table 1).

Earlier, reduction in strength/mechanical properties of bamboos treated with preservatives has been reported (Razak *et al.*, 2004; Kumar, 2007). Similar results in which strength properties of bamboo reduced as a result of treatment with preservatives and increase in treatment temperature were also reported (Leithoff and Peek, 2001; Manalo and Acda, 2009). Studies attributed reduction in strength properties of lignocellulosic material as a result of increase in temperature to the degradation of cell wall carbohydrates (Burmester, 1973; Giebeler, 1983; Tjeerdsma *et al.*, 1998). It might also be as a result of the comparative reduction in the quantity of holocellulose, hemicellulose and lignin present in the cell wall of the samples as the treatment temperature increased as observed in studies such as Salim *et al.* (2009).

It was also noticed that energy at maximum load 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 tensile strength test for the selected properties to one-way ANOVA ($P<0.05$), result showed that all except the data on energy at maximum load significantly varied (Table 2). Comparing the mean values using LSD, it was observed that the mean values of MOR and MOE for control and treated samples differed significantly with only extension at yield having mean values for control and samples soaked in oil at room temperature for 24 h which were not significantly different (Table 3).

**Table 1.** Mean values obtained for selected tensile strength and other related properties for the oil-treated and untreated split-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 | 157.40 | 3452.31 | 0.15 | 25019 | 10.98 |
| Samples soaked in oil at room temperature for 24 h | 153.83 | 2125.22 | 0.14 | 23338 | 10.92 |
| Samples soaked in hot oil at 60°C for 4 h | 130.16 | 2018.18 | 0.13 | 20637 | 10.84 |

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 tensile strength test for treated and untreated split-bamboo samples

| Source of variation | Selected properties | (F-cal) | (F-tab) |
|---|---|---|---|
| Treatment | MOR | 3252.60* | |
| | MOE | 5.5E+04* | |
| | Energy at maximum load | 1.17ns | 3.35 |
| | Load at yield | 1.9E+04* | |
| | Extension at yield | 305.47* | |

$P < 0.05$ * significant, ns: not significant

**Table 3.** Fisher's Least Significant Difference of pair of means for tensile strength and other related properties for the oil-treated and untreated split-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 | $157.40^a$ | $3452.31^a$ | $0.15^a$ | $25019^a$ | $10.98^a$ |
| Samples soaked in oil at room temperature for 24 h | $153.83^b$ | $2125.22^b$ | $0.14^a$ | $23338^b$ | $10.92^a$ |
| Samples soaked in hot oil at60°C for 4h | $130.16^c$ | $2018.18^c$ | $0.13^b$ | $20637^c$ | $10.84^b$ |

Means with the same superscript in the same column are not significantly different ($P$<0.05)

## CONCLUSIONS

The results showed that treating split-bamboo culm samples with neem seed oil resulted in reduction in values for the selected tensile strength properties. It was also revealed that increased oil-treatment temperature also contributed to the reduction in the selected tensile strength properties as also documented in literature.

It is expected that more studies aimed at increasing the potential of using neem seed oil as preservative for wood and fibre and their products should be intensified to improve the efficacy of the oil in this regard.

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