# Selected Properties of Rattan Canes Fibre-High Density Polyethylene Composites

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**Abstract**

*The feasibility of using rattan canes as furnish for plastic composite production was investigated. Milled particles of Laccosperma secundiflorum and Eremospatha macrocarpa were used for the production of rattan plastic composites. Samples of the rattan plastic were tested for sorption, tensile and thermal properties. The rattan composites were dimensionally stable having low sorption rates and possessed adequate tensile properties and were thermally stable. Composites made from L. secundiflorum had higher strength and thermal properties but lower sorption values compared to those of E. macrocarpa and 50:50 mixtures of the two rattans. Differences in the anatomical structures of the rattans seemed to influence properties of the rattan plastic composites.*

**Keywords**: Eremospatha macrocarpa, laccosperma secundiflorum, plastic composites, rattans.

## Introduction

Traditional engineered wood products are susceptible to durability problems of enhanced water absorption and thickness swelling. Hence their use in exposed environments is limited. A means of curtailing these deleterious effects is the incorporation of thermoplastic matrix which would provide moisture barriers to the wood elements and thus integrate the production of composites adaptable for exterior uses (Fabiyi and McDonald, 2010). While wood serves as a low cost filler and reinforcement in plastic composites production, it is becoming scare in developing countries like Nigeria because of economic pressures resulting from the over exploitation of the available timber resources. In this regard, alternative furnish that are accessible without problems of collection and haulage are now resorted to. A candidate furnish material for the production of plastic composite is rattan, a versatile climbing palm available in abundance in the forests of western Nigeria (Adefisan, 2010).

Several advantages accrue when rattan is incorporated as furnish in the production of plastic composites. This is because rattans have short rotation and can be harvested in less than seven years after planting. They can be processed with simple and inexpensive technology (Olorunnisola, 2005). Different rattan species such as *Laccosperma*, *Eremospatha* and *Calamus* exhibit different strength and anatomical properties (Dahunsi, 2000; Lucas and Dahunsi, 2004; Adefisan, 2010) which

may influence the properties of the composite products. Currently, literature is scarce on the properties of rattan plastic composites. A study of this kind will provide information on the suitability of rattan canes as alternative furnish for plastic composite production. This information may invariably help in alleviating the existing pressure on the demand for wood and help integrate the use of these lignocellulosics as furnish for plastic composite production. However, in the production of plastic composites certain additives such as zinc stearate, maleated polyethylene, etc. need to be incorporated to enhance composites properties and improve the adhesion between the lignocellulosics and thermoplastic components (Fabiyi and McDonald, 2010). This paper report findings of a study which examined the production and evaluation of the tensile strength, sorption and thermal properties of plastic composites made from two rattan species, *Eremospatha macrocarpa* and *Laccosperma secundiflorum* canes and their mixtures.

## Materials and Methods

### Production of fibre reinforced plastic composites

High density polyethylene (60% by weight) (Equistar petrothene®, LB 0100-00, Melt Flow Index (MFI) = 0.3 g/10 min, and density = 0.950 g/cm$^3$), rattan cane species (38% by weight) (*Eremospatha macrocarpa, Laccosperma secundiflorum* and their mixtures (50:50 by weight) and maleated polyethylene, a coupling agent (Polybond 3029, Crompton) (2% by weight) were used for fibre reinforced plastic composites production. Materials were compounded and extruded on a 18 mm counter rotating conical twin-screw extruder (Leistritz®, LD ratio 40, 200 rpm) and extruded into 1.5mm x 50 mm sheets using a 3-roll calendaring unit (Leistritz®). The barrel and die temperature were between 140 and 160$^o$C.

### Properties Characterization of Fibre Reinforced Plastic Composites

### Sorption and mechanical properties

Water absorption (WA) and thickness swell (TS) tests were conducted following a modified ASTM D570-95 procedure. Three 5 mm × 20 mm × 50 mm replicate specimens from each High Density Polyethylene (HDPE) rattan species combination were immersed in water at 23°C for 2, 24, 48, 72, 96 and 120 hours. Weight gain and thickness swell were measured on a total composite basis for determination of WA and TS respectively.

Tensile tests were performed on moulded samples (5 replicates) in accordance with ASTM Standard D638 with a constant strain rate of 5 mm/min applied on an Instron® 5500R-1132 universal test machine and strain measured using an extensometer (model 3542, Epsilon Technology Corp.). Data was collected and processed using Bluehill® v2 software

### Thermal characterization

#### *Thermal stability*

Thermogravimetric analysis (TGA) was conducted using a Perkin Elmer® TGA 7 Thermogravimetric analyzer. Samples of 4-5mg were randomly obtained from the thoroughly mixed ground sample. Specimens were analyzed at a heating rate of 20°C/min from 50 to 600°C in a nitrogen atmosphere (flow rate 60

mL/min) and analyzed using Pyris® v8 software.

***Thermal analysis***

Differential Scanning Calorimetry (DSC) was performed on 4-6 mg samples (in triplicates) using a Thermal Analyzer (TA) Instruments model Q200 DSC with refrigerated cooling. The samples were initially equilibrated at 70$^{o}$C (3 min) then ramped to 180$^{o}$C at 10$^{o}$C/min, held isothermally for 3 min, then cooled to 70$^{o}$C at 10 $^{o}$C/min and later held isothermally for 3 min. These cycles were repeated for all treatments. Data were analyzed using TA Universal Analysis v4.4A software. The degree of crystallization of HDPE was calculated from the ratio of the melting enthalpy ($\Delta H^{o}f$, 105-145 $^{o}$C) of the samples to $\Delta H^{o}f$ of 100% crystalline HDPE293 J/g).

**Results**

Sorption properties *E. marcocarpa,* and *L. secundiflorum* increased with soaking period (Table 1). Water absorbtion of both species was highest at 120 hrs of soaking and at this time, *E. marcocarpa* had higher percentage water absorption compared to *L. secundiflorum,* or a the mixture of both materials. Percentage thickness swelling however, was not significantly different between the species while the 50:50 mixture swelled the least after 120 hrs of soaking.

Significantly higher tensile strength was recorded for *L. secundiflorum* compared to *E. marcocarpa* and the mixture which had the lowest (P>0.05) tensile strength (Table 2). Similar trend was observed for Moduli of elasticity and energy break, although, the 50:50 mixture and *E. marcocarpa* were not significantly different.

**Table 1: Sorption Properties of Rattan Plastic Composites over a soaking period from 2 to 120 hours**

| Species | 2 | 24 | 48 | 72 | 96 | 120 |
|---|---|---|---|---|---|---|
| | | | Water Absorption (%) | | | |
| *E. marcocarpa* | 2.9±0.91$^{gh}$ | 5.4±0.55$^{e}$ | 8.1±1.1$^{d}$ | 9. ±1.7$^{bc}$ | 10.8±1.22$^{ab}$ | 11.4±1.54$^{a}$ |
| *L. secundiflorum* | 0.7±0.16$^{j}$ | 2.1±0.58$^{hi}$ | 2.4±0.44$^{ghi}$ | 2.8±0.19$^{gh}$ | 3.3±0.15$^{fgh}$ | 4.2±0.07$^{f}$ |
| 50:50 Mixtures | 1.6±0.69$^{ij}$ | 3.4±0.64$^{fg}$ | 5.7±0.79) | 5.5±0.82$^{e}$ | 8.2±0.74$^{d}$ | 9.0±1.0$^{cd}$ |
| | | | Thickness Swelling (%) | | | |
| *E. marcocarpa* | 0.9±0.62$^{fgh}$ | 1.3±0.92$^{efg}$ | 2.4±0.73$^{bcd}$ | 2.7±0.66$^{abc}$ | 3.1±0.7$^{ab}$ | 3.5±1.4$^{a}$ |
| *L. secundiflorum* | 0.2±0.13$^{h}$ | 0.9±0.23$^{fgh}$ | 2.1±0.38$^{cde}$ | 2.8±0.25$^{abc}$ | 2.9±0.34$^{abc}$ | 3.0±0.26$^{ab}$ |
| 50:50 Mixtures | 0.84±0.57$^{gh}$ | 1.1±0.67$^{fg}$ | 1.2±0.48$^{fg}$ | 1.7±0.43$^{def}$ | 2.1±0.25$^{cde}$ | 2.1±0.27$^{cde}$ |

* Means ± Standard Deviation with the same superscripts in the same column are not statistically different (p >0.05).

**Table 2: Strength Properties of Rattan Plastic Composites**

| Species | Tensile Strength ($N/mm^2$) | Moduli of Elasticity ($GN/mm^2$) | Energy at Break (J) |
|---|---|---|---|
| *E. marcocarpa* | $13.7\pm0.92^b$ | $1.15\pm0.17^b$ | $0.225\pm0.07^b$ |
| *L. secundiflorum* | $21.7\pm2.93^a$ | $1.66\pm0.29^a$ | $0.423\pm0.2^a$ |
| 50: 50 Mixtures | $7.3\pm4.33^c$ | $0.77\pm0.43^b$ | $0.123\pm0.06^b$ |

* Means ± Standard Deviation with the same superscripts in the same column are not statistically different (P>0.05)

Weight loss with increasing temperatures were similar for both species and their mixture (Fig. 1). The canes went through four stages of thermal decomposition with increasing temperatures (Table 3). Final decomposition of *L. secundiflorum* was at a temperature of 490 $^oC$ followed by *E. marcocarpa* and the mixture with 487$^oC$ and 486$^oC$, respectively. The crystallization temperatures and percentage crystallinity were similar for both rattan cane materials and their mixture (Table 4).

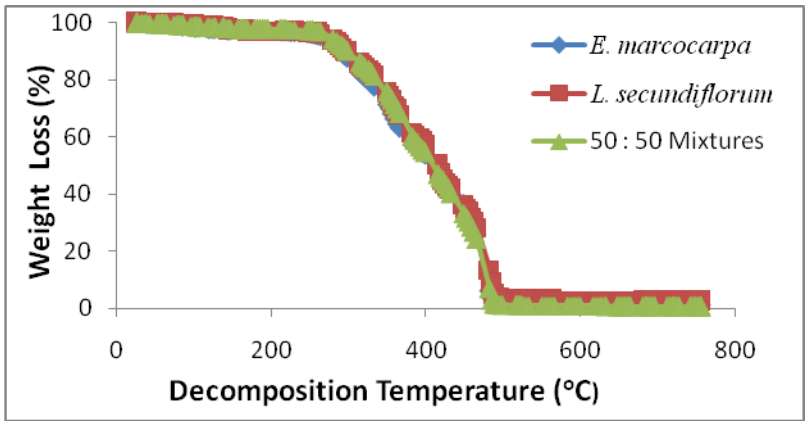


Figure 1: Thermograms of Rattan Plastic Composites

**Table 3: Thermal Decomposition Temperatures of Rattan Plastic Composites**

| Samples | First stage | | Second stage | | Third stage | | Fourth stage | |
|---|---|---|---|---|---|---|---|---|
| | $\alpha_1$ | $\alpha_2$ | $\beta_1$ | $\beta_2$ | $\gamma_1$ | $\gamma_2$ | $\omega_1$ | $\omega_2$ |
| *E. marcocarpa* | 271 | 324 | 324 | 381 | 404 | 443 | 443 | 487 |
| *L. secundiflorum* | 272 | 334 | 334 | 377 | 408 | 446 | 446 | 490 |
| 50:50 Mixtures | 270 | 327 | 327 | 389 | 404 | 438 | 438 | 486 |

* Numerical subscripts (1 and 2) on the Greek letters refer to the temperatures at the first onset and final decomposition

**Table 4: Crystallization Temperatures (Tc) and Crystallinity of Rattan Plastic Composites**

| Samples | $T_C$ ($^oC$) | Crystallinity (%) |
|---|---|---|
| *E. macrocarpa* | 116.6±1.0 | 42.2±1.1 |
| *L.secundiflorum* | 117.9±0.5 | 43.0±2.8 |
| 50: 50 Mixtures | 116.5±1.1 | 38.0±1.5 |

* Means ± Standard deviation

**Discussion**

The results of the sorption properties of the rattan composites compared favourably with those of Migneault *et al*., (2008); San *et al*., (2008); Shirp and Stender, (2010). The rattan plastic composites had low sorption properties indicating that they are suitable for indoor and outdoor applications. The sorption properties of the plastic composites varied significantly among the species tested. While the *L. secundiflorum* composites had the significantly lower WA and TS in comparison to *E. marcocarpa* composites, their mixtures recorded higher WA and TS than either the *L. secundiflorum* or *E. marcocarpa* composites. Dahunsi (2000) and Adefisan (2010) had reported differences in the anatomical structures of the *L. secundiflorum* and *E. marcocarpa* rattans. While preponderance of sclerenchyma cells (strengthening tissues) were observed in the *L. secundiflorum canes*, *E. marcocarpa* canes had prevalence of parenchyma cells (storage tissues). The observed differences in the sorption properties of the rattan plastic composites may be adduced to the differences in the anatomical structures.

The tensile strength, moduli of elasticity and energy at break of the *E. marcocarpa, L. secundiflorum* composites and their mixtures compared with those of Liqing *et al*., (2013). The tensile strength, moduli of elasticity and energy at break of the plastic composites varied significantly among the species tested (Table 2). While the *L. secundiflorum* composites had the significantly higher tensile strength, moduli of elasticity and energy in comparison to *E. marcocarpa* composites, their mixtures generally recorded lower

properties. Again, the differences in the anatomical structures of the rattans tested may be responsible for the observed variation.

The TGA curves of rattan/HDPE composites are shown in Figure1. All curves show a small weight loss before 100°C, which can be attributed to the evaporation of the insignificant amount of moisture that the rattan/HDPE composites samples contained. The weight loss due to thermal degradation of the rattan composites occurred in four distinctive stages (Table 3). The first and second degradation peaks can be attributed to the hemicellulose and lignin while the third degradation peak is attributed to the degradation of cellulose. The forth degradation is attributed to the C-C bonds of plastic matrix (HDPE) (Bledzki and Gassan, 1999; Fabiyi and McDonald, 2010). Kim et al., (2006) attributed the degradation at 150-350$^{o}$C to hemi-celluloses, 250-500$^{o}$C to lignin while the degradation of extractives and cellulose occurred at 275-350$^{o}$C.

Composites from *L. secundiflorum* had slightly higher decomposition temperature than either the *E. macrocarpa* or the mixtures of the two rattans (Table 3). Also, the decomposition temperatures of the hemicellulose, celluose and the C-C bonds of plastic matrix (HDPE) of the *L. secundiflorum* composites were higher than those of the *E. macrocarpa* and the mixtures of the two rattans. This implies that *L. secundiflorum* composites were more thermally stable than composites made from either the *E. macrocarpa* or the mixtures of the two rattans.

The degree of crystallinity in the rattan composites as determined by DSC is shown in Table 4. The extent of crystallinity and the crystallization temperature ($T_C$) of the *L. secundiflorum* composites were slightly higher than in composites made from *E. macrocarpa* and the mixtures of the two rattans. Liqing *et al*. (2013) observed that reduction in crystallinity of wood plastic composites oftentimes results in lower moduli of elasticity and tensile moduli. The higher crystallinity of the *L. secundiflorm* composites over those of the *E. macrocarpa* and the mixtures of two rattans may account for the higher tensile strength properties observed in this study.

Rattan canes are candidates furnish for plastic composites production. The integration of rattans in plastic composites production will cushion the increasing demand for wood, a dwindling natural resource and encourage its wider use as alternative furnish. Furthermore, since the fabricated rattan plastic composites possessed adequate tensile strength, thermal stability and low sorption rates.

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