EFFECT OF MAHOGANY FILLER ON MECHANICAL PROPERTIES OF REINFORCED POLYETHYLENE MATRIX

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ABSTRACT

The effect of mahogany filler as an agricultural waste material used in thermoplastic polymer composite was investigated. Polyethylene (PE), as the matrix, and mahogany sawdust, as the filler, were prepared in five levels of filler loading (10, 20, 25, 30, and 35 wt %) to form thermoplastic composites. Two forms of composite samples were prepared with a recycled polyethylene and mahogany wood filler called recycled polyethylene (RPE) composite and 20 percent of virgin polyethylene with recycled polyethylene wood filler called virgin polyethylene recycled polyethylene (VRPE) composite and their mechanical properties were studied. Test results show that the tensile strengths, tensile modulus, flexural strengths, flexural modulus and hardness properties increased while impact strength, decreased with increase in filler loading for the mixed polyethylene composites but tensile strength of the recycled polyethylene composite decreased with increased filler loading. The appreciable improvement on the tensile strength indicates that mahogany can be used as a reinforced material of the mixed polyethylene composite. Again the presence of 20 percent of virgin PE has significant effects ($p < 0.05$) on mechanical properties of the mahogany filler – recycled polyethylene composite.

Keywords: Mahogany sawdust filler, Mixed Polyethylene (VRPE), Recycled Polyethylene (RPE), Mechanical properties

INTRODUCTION

The carcinogenic effect of mahogany wood dust on exposure to human beings due to increased risk of cancer of nasal cavities has been a major concerned in the world today (IARC, 1995). Though, it has been reported that wood primarily consists of ash, pectin, cellulose, hemicelluloses and lignin, hence called lignocelluloses materials such as hemp and sisal, fibers (Horvath, 2006; Pukansky, 2005; Nobre et al, 2009; Joseph et al, 1996; De – Paoli, 2002). The use of lignocelluloses material in thermoplastic composites has been employed so as to reduce the waste of biomass in the environment (Miguez-Suarez et al, 2005). Mahogany as a lignocellulose material has been used in construction and manufacturing industries through impregnation with phenol-formaldehyde resin, white glues and epoxy resins, and plastics like carvable putties, due to its attractive appearance, moisture content, and ecofriendly nature. Advantages of lignocelluloses fillers include renewability, unlimited availability, desirable properties (mechanical strength, chemical and biological stability, fire resistance, lightness, abrasion resistance and shear strength, among other properties), less abrasive than the artificial fillers, biodegradable in nature, less harmful to the environment and humans, low density and high deformability and economical in nature

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(Nechwatal et al, 2003; Balzer et al, 2007; Caraschi & Leao, 2001; Pukansky, 2005; Franco & Gonzalez, 2004; Osarenmwinda and Nwachukwu, 2011; 2010; 2007; TPMC, 2000; Nobre et al, 2009). Several additional techniques have been proposed to improve the properties of plastic modified with lignocelluloses fillers in which the surfaces of lignocelluloses materials contain polar hydroxyl groups due to cellulose and lignin, and these polar groups interact easily with polar polymeric matrices. The addition of processing aids such as calcium stearate and polyethylene waxes, and compatibilizers such as functionalized polymers improved the processability and/or introduces greater polarity in the polymeric composite, enhancing the dispersibility of lignocelluloses materials in composite applications (Aziz et al, 2005; Osarenmwinda and Nwachukwu, 2011; 2010; 2007). Chemical modification (with the use of silane, sodium alginate, sodium hydroxide, acetylation, etc.) have been employed to reduce fillers moisture sensitivity and improve mechanical and delamination of many natural fillers in thermosets and polypropylene composites through improved interfacial adhesion (Miguez-Suarez et al, 2005; Behzad, 2011; Raju et al, 2012; Imoisili et al, 2012). The objective of this research is to investigate the effect of mahogany filler loading on the mechanical properties of recycled low density polyethylene (LDPE) matrix blended with virgin (LDPE).

MATERIALS AND METHOD

Materials

Both virgin and recycled polyethylenes were used in the study. The waste polyethylene (PE) was obtained from the industrial waste of IBETO Group of Companies and was pelletized using palletizing machine at National Engineering Design and Development institute (NEDDI) both in Nnewi, Anambra State, Nigeria. The virgin PE was obtained from chemicals line in Ugah market, Onitsha, Anambra state, Nigeria. The sawdust from Mahogany tree was obtained of local timber market at Head Bridge, Onitsha, Anambra State, Nigeria.

METHOD

Composite Preparation

Mahogany saw dust used was sun-dried and then oven-dried at 110^0C for 2 days to a moisture content of 3 percent and sieved to 18-mesh size. The composites were prepared in mixing-ratio of virgin polyethylene; recycled polyethylene and Mahogany filler as shown in the Table 1.

Table 1: Composition of the Prepared Composite

Sample	*% Virgin PE*	*% Regrind PE*	*% Mahogany Filler*
A	0	100	0
B	0	90	10
C	0	80	20
D	0	75	25
E	0	70	30
F	0	65	35
G	20	70	10
H	20	60	20
I	20	55	25
J	20	50	30
K	20	45	35

Composite Processing

Mahogany filler and polyethylene were fed into an injection moulding machine of the reciprocating screw type to produce the composite samples. The operating pressure and temperature of the injection moulding machine was 150MPa and 160^0C respectively, and the process time for each sample was between 30 – 60 seconds averagely.

The following mechanical tests were carried out after conditioning to room temperature and relative humidity of 65% to assess the influences of the Mahogany sawdust filler on the mechanical properties of polyethylene. Samples of the Mahogany filler - polyethylene composites were cut into specified dimensions and tested at room temperature in accordance with ASTM standards.

Tensile Testing

Tensile properties were carried out on the specimens using a KAOH TIEH Instron Testing Machine, in accordance with ASTM 638-90, at a cross-head speed of 200rev/min. The dimension of each sample was 150mm (length) x 30mm (width) x 5mm (thickness). Held by the gripping heads, the specimens were pulled till failure occurred, and the respective loads and extensions noted. The values thus obtained were used to evaluate the strain, tensile strengths, and modulus of the specimens A to L using the equation (1) and (2) as reported by Raju et al (2012).

$$T_s = \frac{P}{bt} \tag{1}$$

T_s is the tensile strength of the sample, P is the pulling force, b is the sample width and t is the sample thickness.

$$T_m = \frac{\sigma}{\varepsilon} \tag{2}$$

T_m *is the tensile modulus*, σ is the stress and ε is the strain.

Flexural Testing

Flexural properties were carried out by 3-point bending tests on composite samples with dimensions 60mm (span) x 20mm (width) x 5mm (thickness) using a WP 300.4 bending device in accordance with ASTM 790 – 90. Equation 3 and 4 were used to obtain the flexural strengths and modulus respectively of the samples.

$$R_f = \frac{3FL}{2bt^3} \tag{3}$$

R_f is the applied flexural strength, F is the flexural load, L is length of the support span (mm), b is the width of the sample and t is the thickness of the composite sample.

$$R_m = \frac{mL^3}{4bt^3} \tag{4}$$

R_m is the flexural modulus, m is the slope of the tangent to the initial line portion of the load deflection curve.

Impact Testing

The unnotched impact properties were conducted on all samples in accordance with ASTM D 256-90. Prepared specimens were subjected to fracture by a pendulum – Type Impact Testing Machine and the unnotched toughness values of the composites obtained by reading off the energy expended to rupture of each sample.

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Hardness Testing

Brinell Hardness Test was conducted on flat samples of both RPE and MPE composites using a manually-operated Universal Testing Machine. A hardened steel ball with a diameter of 10mm was used in performing the test. The indentations on the specimens were measured (diameter-wise) and appropriate mathematical methods used for conversion to obtain the Brinell Hardness Values reference made to figs 3.6, and 3.7. The equation for the Brinell Hardness Number (*HB*) is given as:

$$HB = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})}$$

P is the applied Load measured in kg, *D* is diameter of steel ball (10mm) and *d* is the diameter of indentation (mm)

Statistical Analysis

The statistical analysis was conducted using SPSS Version 17.0 in conjunction with bivariate correlations. The Pearson's correlation coefficient test was performed for the test of significance with two tail of p-value inferior than 0.05 was considered statistically significant between RPE and VRPE composites.

RESULTS AND DISCUSSION

Tensile strength and modulus of the mahogany filler - polyethylene composites

It can be observed in Figure 1 that tensile strength of the recycled polyethylene composite decreases with increased Mahogany filler loading from 30.33 MPa to 17.12 MPa. Contrarily, the tensile strength of the virgin recycled polyethylene (VRPE) composites increases from 30.33MPa to 38MPa which amount to 25.29 percent. This is in agreement with the report of (Imoisili et al, 2012; Raju et al, 2012). There is statistical significant effect of 0.031 ($p < 0.05$) in mahogany filler loading between polyethylene and mixed polyethylene composites. The tensile modulus of the composites increases with increased filler loading as shown in the Figure 2 with a significant effect 0.000 ($p < 0.05$) at high correlation (0.998) of mahogany filler loading on tensile modulus between recycled polyethylene and mixed polyethylene composites.

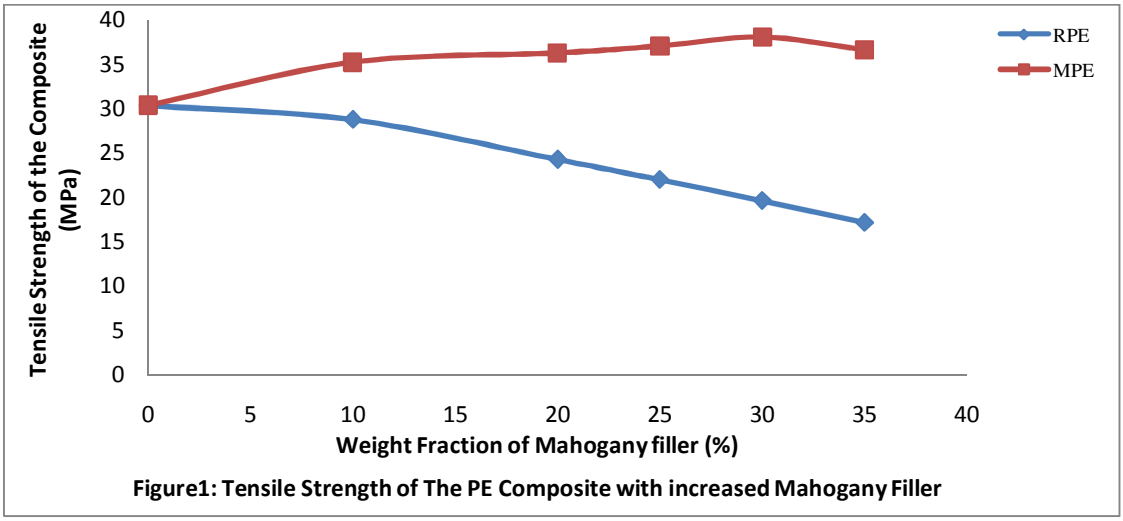

Figure1: Tensile Strength of The PE Composite with increased Mahogany Filler

The tensile strength of the recycled polyethylene composites as shown in the Figure 1 decreases with increased filler loading due to the inability of the filler to support stresses transferred from the polymer matrix while in the tensile strength increases in mixed

polyethylene composite is as a result of stress transferred and distributed by polyethylene. This resulted in increase in the strength and stiffness of the composite. Effective transfer of stress from polymer matrix to filler depends on the strength of the links in an imaginary chain of polymer-filler. Mechanical interlocking is probably the primary mechanism by which polyethylene adheres to porous structures of mahogany wood and deeper penetration into the fine microstructure which increases the surface area of contact between polyethylene and mahogany filler (Charles, 1999).

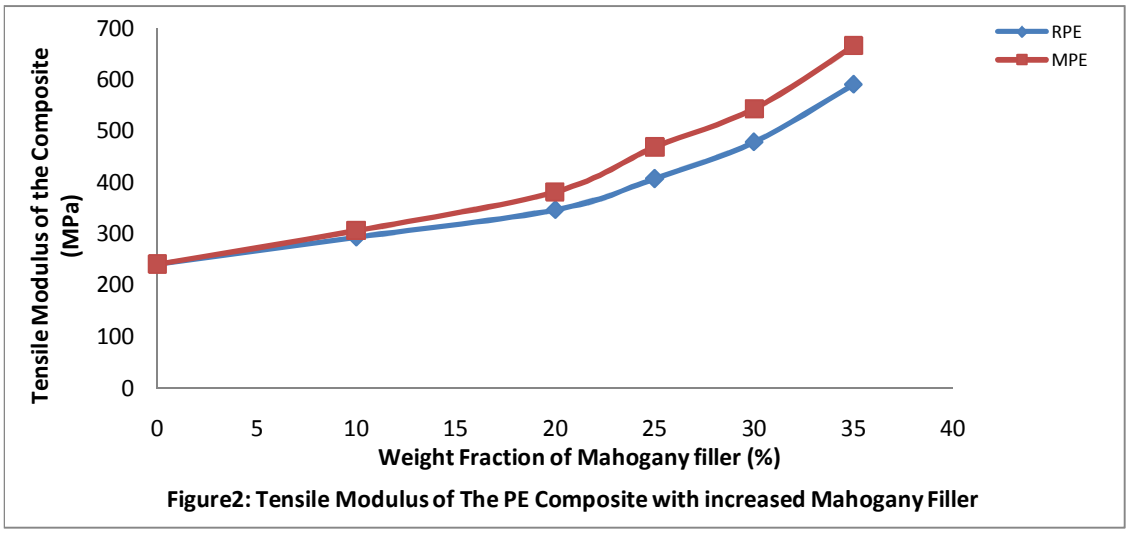

Figure2: Tensile Modulus of The PE Composite with increased Mahogany Filler

Flexural strength and modulus of the mahogany filler - polyethylene composites

The flexural strength of RPE and MPE composite increases from 240.7 MPa to MPa and 664.9 MPa which is about 47.63 percent and 78.16 percent respectively with increased mahogany filler loading up to 35 percent loading as shown in the Figure 3. This is in agreement with many natural fibers as reported by Bledzki and Gasan (1999). The flexural modulus of RPE and MPE composite increases to 117.07 and 147.97 percent respectively at increased mahogany filler loading up to 35 percent loading as shown in the Figure 4 with statistical significant of 0.003 ($p<0.05$) and correlation of 0.958.

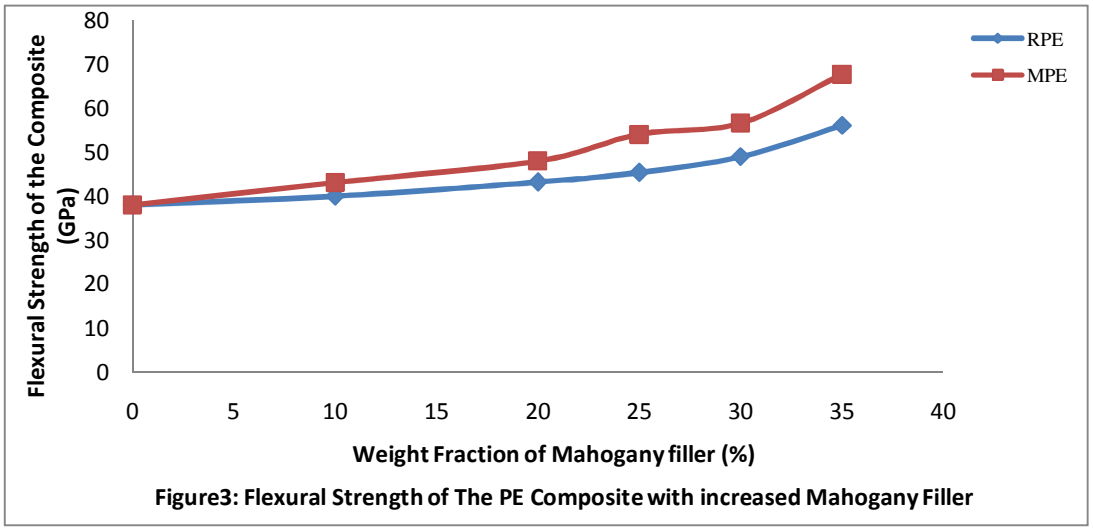

Figure3: Flexural Strength of The PE Composite with increased Mahogany Filler

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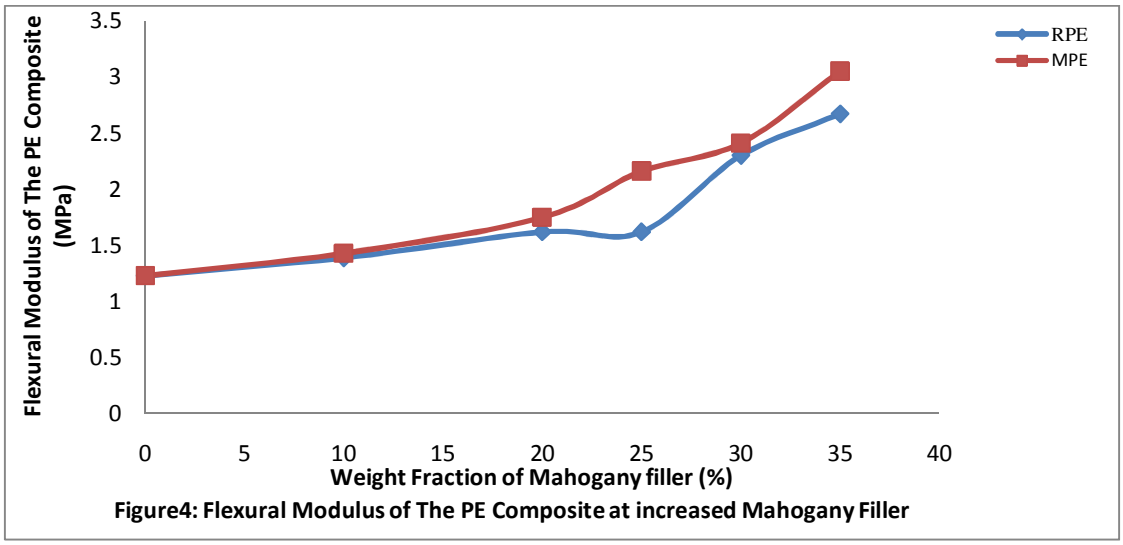

Figure4: Flexural Modulus of The PE Composite at increased Mahogany Filler

Impact strength of the mahogany filler - polyethylene composites

The decreases in the impact strength of both recycled and mixed polyethylene composites with increased mahogany filler loading up to 35 percent as shown in the Figure 5. This indicated that the increased Mahogany filler loading reduces the impact strength of the polyethylene (Haque et al, 2009; Joseph et al, 2002; Raju et al, 2012; Behzad, 2011). The decrease in impact strength with the increased mahogany filler loading is attributed to the poor interfacial adhesion between the hydrophobic (PE) matrix and hydrophilic mahogany filler with void formation in the composite thereby reducing the toughness of the composites as reported by Raju et al (2012). In addition to this, incorporation of fillers resulted in reduction in polymer chain mobility, thereby lowering the ability of the system to absorb energy during fracture propagation. There is statistical significant of 0.001 ($p < 0.05$) with a low correlation of 0.988 of increased mahogany filler loading on impact strength between RPE and VRPE composite.

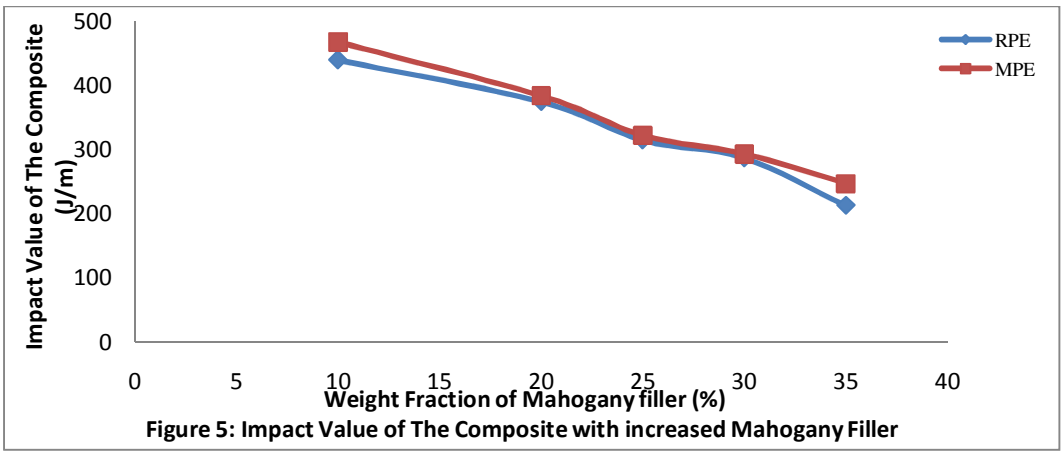

Figure 5: Impact Value of The Composite with increased Mahogany Filler

Hardness effect of the mahogany filler - polyethylene composites

The hardness of both recycled polyethylene (RPE) and mixed polyethylene (VRPE) composites increase with increased mahogany filler loading. The hardness of recycled polyethylene composite increased by 95.65 percent for 35 percent filler loading and hardness of virgin-recycled polyethylene (VRPE) composite increased by 417.39 percent for 30 percent filler loading and tremendously increased by 4830 percent for 35 percent filler loading as shown in the Figure 6. Though, there is insignificant difference of 0.161 ($p > 0.05$)

at increased mahogany filler loading between recycled and mixed polyethylene composites with a correlation of 0.492.

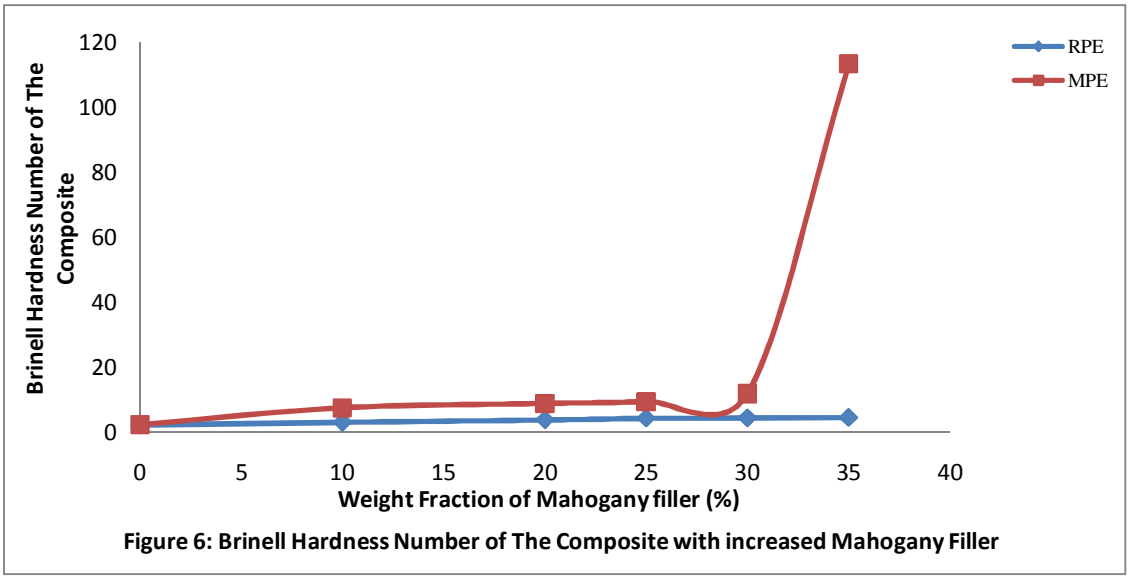

Figure 6: Brinell Hardness Number of The Composite with increased Mahogany Filler

CONCLUSION

An advantage of the developed technology is the possibility to utilize wastes of woodworking industry like mahogany sawdust to make high quality materials by modified synthetic polymer. Modified polymer materials may be used for model making and manufacturing products.

The tensile strength, tensile modulus, flexural strength, flexural modulus hardness and impact decrease impact strength of the mahogany filled - polyethylene composites results show increase value with increased up to 25 percent of mahogany filler loading reinforced mixed polyethylene composite compared with recycled polyethylene composite. Thus, the mechanical properties of the mahogany filler - recycled polyethylene composite have been significantly enhanced with combination of virgin polyethylene.

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