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EFFECTS OF REINFORCEMENT LOADING ON PHYSICAL AND MECHANICAL PROPERTIES OF DEVELOPED RECYCLED LOW DENSITY POLYETHYLENE/MAIZE COB ASH PARTICULATE COMPOSITE.

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ABSTRACT

Recycling of empty water sachet (commonly called pure water nylon) and maize cob, which are all waste released into the environment in Nigeria into useful materials of good physical and mechanical properties has been reported. Efforts have now been made to analyze the effects of reinforcement loading on the physical and mechanical properties of the developed composite material. The empty water sachet was used as a matrix, which was reinforced by maize cob ash particulate. The composites were compounded and compressively moulded. The analysis revealed that the results obtained at 20-25wt%MCSp indicate that some mechanical properties such as hardness values, density, young's modulus, flexural strength, impact energy and thermal properties are similar to LFRT. The developed composites had the better properties at the ranges of 20-25wt%MCSp additions, and for optimum service condition, maize cob particle addition should not exceed 20% to enhance better properties.

Key Words: *Composite, Maize cob ash, Properties, Automobile, Bumper*.

1.0 INTRODUCTION

Polymer composite materials are being used in a wide range of structural applications in the aerospace, construction and automotive industries due to their lightweight and high specific stiffness and strength (1). A variety of materials are being used ranging from lower performance glass fibre/polyester, used in small sail boats and domestic products, to high performance carbon fibre epoxy systems used in military aircraft and spacecraft. One sector where the use of composite materials is still evolving is the automotive industry. The use of polymers in US automotive applications has risen dramatically from an average of 18 pounds per vehicle in 1960 to well above 300 pounds per vehicle in 2004 (8% of vehicle weight).(2) Notably, most of the plastic applications in vehicles are lower-performance commodity polymers and short-fiber composites. The use of advanced composites in structural vehicle body applications has been far less extensive, but there have been some notable recent applications (3). Composite part production success relies on the correct selection of a manufacturing technique as well as judicious selection of processing parameters (4).

One key technical design strategy for improving vehicle efficiency is the reduction of vehicle mass, or light-weighting. Vehicle light-weighting not only enhances fuel efficiency, but also lowers vehicle emissions and improves driving performance (5).The requirement for energy saving in the automotive industry has risen dramatically over the years. One of the options to reduce energy consumption is weight reduction. A new invention in material technology was introduced with polymeric based composite materials, which offer high specific stiffness, low weight, freedom from corrosion, ability to produce complex shapes, high specific strength, and high impact energy absorption.

Despite the amount of research work carried out on composite bumper, there is very limited information on the conceptual design of polymer-based composite bumper system using recycled low density polyethylene (RLDPE) reinforced with maize cob particles (MCA).

A lot of research has been carried out in the area of composite development and study of effects of reinforcement loading on the properties of the developed composite material [6-10]. Some of these are on development of composite for automobile application [11,12] and many on suitability of some natural filler reinforced composite material [13-17].

This current research is aimed at studying the effects of the introduction of maize cob ash on the properties of a composite material, which is environmentally friendly, recyclable, and made from renewable natural sources.

The specific objectives of this research are as follows:

i. Evaluation of the variation in the physical properties of the developed composite material with increase in MCA loading and,
ii. Evaluation of the variation in the mechanical properties of the developed composite material with increase in MCA loading.

Finally, the major contributions of this research work include the following:

i. It has given insight into the effects of MCA loading on the selected properties of the developed composite Material.
ii. It has determined clearly, the optimum loading of MCA in the composite for applications of known functional requirement.
iii. It will guide users on the correct loading of MCA in the composite to suit for certain application.

2.0 MATERIALS AND METHODS

Materials and Equipment that were used in this research are-,Maize cob, pure water sachet, Metal mould, hydraulic press, Avery Denison impact tester, Rockwell hardness, Instron machine, grinding and polishing machine, Scanning electron microscope(SEM) and TA Instrument TGA Q50 thermogravimetric analyzer.

2.1 Characterization of Maize Cob

The maize cob was subjected to the following processes before use:-

i. Chemical treatment of the maize cob was done by soaking it in sodium hydroxide solution.
ii. ***The processing of the maize cob into maize cob Particles-*** These involve collection, drying and grinding of the waste to form powder.
iii. ***Carbonization of the maize cob-*** the powder was packed in a graphite crucible and fired in electric resistance furnace at a temperature of 1200^{o}C to form maize cob ash.
iv. ***The sieve analysis of the particles-*** The particle size analysis of the maize cob particles was carried out in accordance with BS1377:1990 .About 100g of the particles was placed unto a set of sieves arranged in descending order of fineness and shaken for 15minutes which is the recommended time to achieve complete classification. The particles that were retained in the BS. 300µm (MCLp) and 100µm (MCSp) were used.

2.2 Sample preparation

The fabrication of the various composite materials was carried out through the compressive technique. Maize cob ash particles (MCS and MCL) are reinforced with RLDPE. After drying in an oven at 105^{o}C, the maize cob ash particles and the RLDPE were compounded in a two roll mill at a temperature of 130^{o}C, into a homogenous mixture. The composite production was carried out in an electrically heated hydraulic press. The mixtures were placed in a rectangular mould with a size of 350mm by 350mm. The composites were pressed to a thickness of 4mm. At the end of each press cycle, the composite was removed from the press for cooling. 5-30wt% of maize cob ash particles were used with interval of 5wt%. Five different types of composites were fabricated with two different maize cob particle sizes (MCS and MCL).

2.3 Microstructural Analysis

The scanning electron microscope (SEM) JEOLJSM-6480LV was used to identify the surface morphology of the maize cob ash and composite samples. The surfaces of the specimens were examined directly by scanning electron microscope microscopeJEOLJSM-6480LV. The samples were washed, cleaned thoroughly, air- dried and coated with 100Å thick platinum JEOL sputter ion coater and observed by the SEM at 20kV. The digitized images were recorded.

2.4 Test Procedure

Test samples were cut from the composites for the mechanical test according to the recommended Standard for each test.

2.4.1 *Determination of Density*

The basic method of determining the density of composite samples is by measuring the mass and volume of the sample used. A clean sample is weighed accurately in air using a laboratory balance and then suspended in water. The weight of the sample when suspended in water was determined, the volume of the sample was determined from the effect of displacement by water (Archimedean principle). The density of the sample was estimated from the equation [19]

$$Density = \frac{Mass}{Volume} \quad (1)$$

2.4.2 *Water Absorption Determination*

Specimens with dimensions of 50 mm x 50 mm were prepared for evaluation of the water absorption. The masses of the test specimens were measured with a digital balance. Then the test specimens were placed in water and soaked for 24 h before further measurement of the weight of the soaked samples. The values of the water absorption as percentages were calculated as follows. [20]

$$WA_{(t)} = \frac{W_{(t)} - W_0}{W_0} x\ 100 \quad (2)$$

Where $WA_{(t)}$ is the water absorption (%) at time t,
W_0 is the initial weight, and
$W_{(t)}$ is the weight of the sample at a given immersion time t.

2.4.3 *Tensile test*

The tensile test of the composite sample was conducted on Instron machine, using a strain rate of $2x10^{-3}S^{-1}$ as specified by the American Society for Testing and Materials (1990).

2.4.4 *Static Bending Test*

A static bending test (dry) was conducted according to the American Society for Testing Materials standard D1037, on a specimen of size 150x50x4mm, bending speed of 10mm/min and at 67% relative humidity at 23°C. The bending strength was calculated from load deflection curves according to the following formula [20].

$$MOR = \frac{3P_b L}{2bh^2} \quad (3)$$

Where P_b is the maximum load (N), b is the width of the specimen (mm), h is the thickness of the specimen (mm), and L is the span (mm).

2.4.5 *Impact Energy Test*

The impact test of the composites sample was conducted in accordance with (ASTM D256-93, 1990) using a fully instrumented Avery Denison test machine. Charpy impact tests were conducted on notched samples. Standard square impact test sample measuring 75 x 10 x 10 mm with notch depth of 2 mm and a notch tip radius of 0. 02 mm at angle of 45° was used. Before the test sample was mounted on the machine, the pendulum was released to calibrate the machine. The test samples were then gripped horizontally in a vice and the force required to break the bar was released from the freely swinging pendulum. The value of the angle through which the pendulum has swung before and after the test sample was broken were used to determine the energy absorbed in breaking the sample and this was read from the calibrated scale on the machine.

2.4.6 *Hardness Test*

The hardness test of composites is the relative resistance of the surface to indentation by an indentor of specified dimension under a specified load. Hardness of the composites was determined by Rockwell hardness machine (BS903 part A 26)(ASTM, 1990) using 1.56mm steel ball indenter, minor load of 10kg, major load of 100kg. Before the test, the mating surface of the indenter, plunger rod and test samples was thoroughly cleaned by removing dirt, scratches and oil, and calibration of the testing machine was carried out using the standard block. The samples were placed on anvils, which act as a support for the test samples. A minor load of 10kg was then applied; to the sample in a controlled manner without inducing impact or vibration and zero datum position was established, and then the major load of 100kg was applied; the reading was taken when the large pointer came to rest or had slowed appreciably and dwelled for up to 2 seconds. The load was removed by returning the crank handle to the latched position and the hardness value read directly from the semi automatic digital scale.

3.0 RESULTS AND DISCUSSION

The results and discussion are summarized below.

3.1 Surface Morphology of the Maize Cob Ash

Morphology of the maize cob ash by SEM with EDS is shown in Plate 1. The structure reveals that the maize ash particles were solid in nature (precipitators), but irregular in size. Some spherical shaped particles can also be seen in the microstructure. The EDS reveals the presence of C, Si, O, Al, Ca, (see Plate 1). From the EDS, chemical analysis shows that SiO_2, carbon, CaO and Al_2O_3 were the major constituents. Silicon dioxide, carbon, alumina are known to be among the hardest substances. Some other oxides viz. MgO, K_2O, Na_2O were also found to be present in traces. The presence of hard oxides like SiO_2, Al_2O_3 suggested that the maize cob ash may be used as particulate reinforcement in rLDPE.

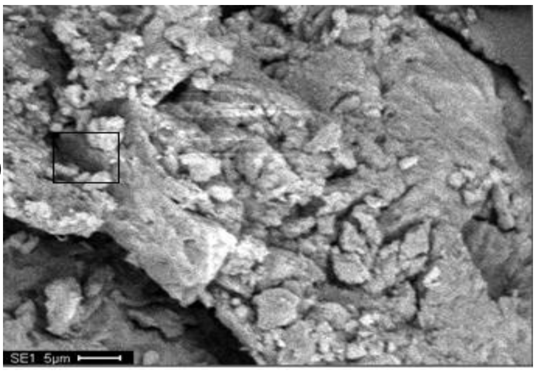
(a)


Plate 1(a): SEM of the maize ash particles

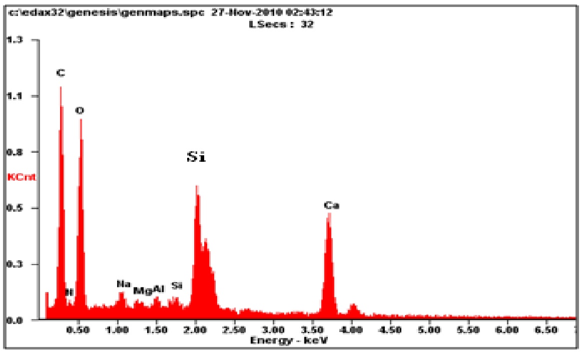
(b)


Plate 1(b): EDS of the maize ash particles

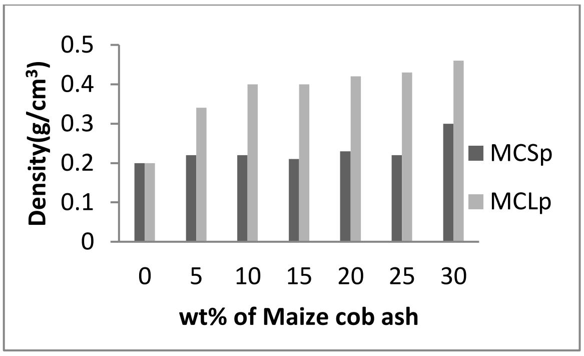


Figure 2: Plot of Density versus wt.% Maize cob ash

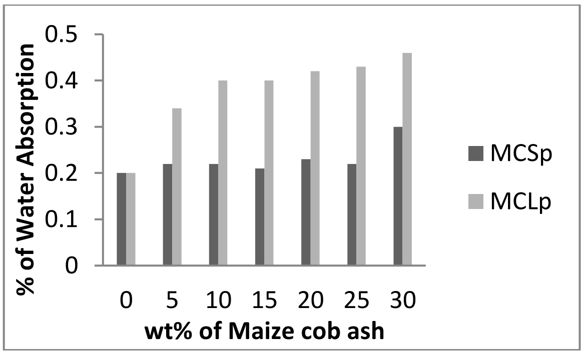


Figure 3: Plot of Water Absorption versus wt.% Maize cob ash

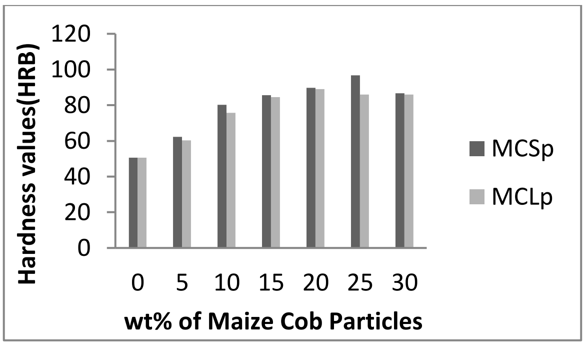


Figure 4: Plot of Hardness values against wt.% Maize cob ash

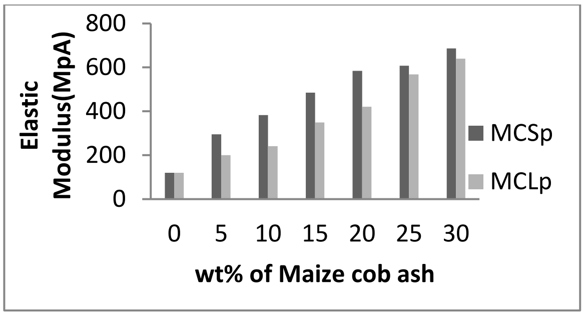


Figure 5: Plot of Elastic Modulus against wt.% Maize cob ash

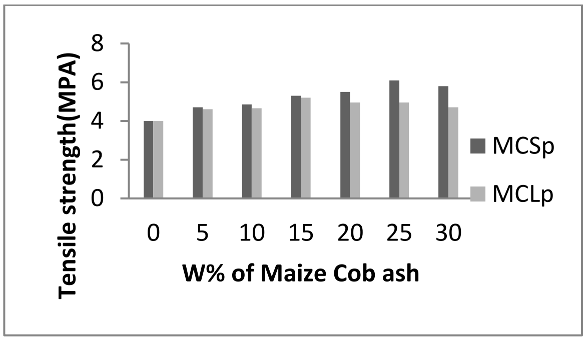


Figure 6: Plot of Tensile strength versus wt.% Maize cob ash

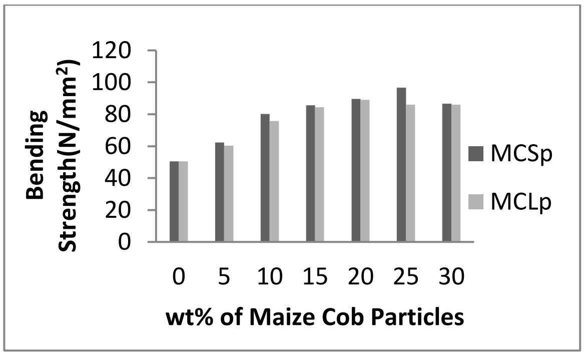


Figure 7: Plot of Bending Strength versus wt.% Maize cob ash

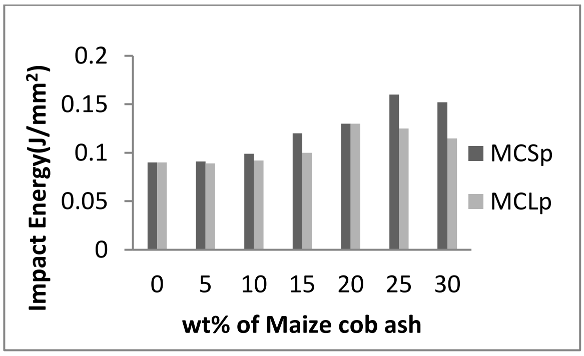


Figure 8: Plot of Impact Energy versus wt.% Maize cob ash

The results reveal that the presence of maize cob ash particulates slightly increased the density of the PMCs. The density of the reinforced PMCs increased from 0.75 g/ cm^3 at 0wt% of maize cob ash addition to 1.18g/ cm^3 and 1.22g/ cm^3 at 30wt% of maize cob ash addition for MCSp and MCLp respectively. This implies that increase in the loading of the MCA particles increases the density of the developed composite irrespective of the particle size (see Fig. 2).

There is increase in the rate of water absorption with increase in the loading of the MCA though the highest is less that 5ppt. The low level of water absorption recorded may be due to the surface treatment of the maize cob ash with NaOH solution and better interfacial bonding between the RLDPE and the maize cob particles which resulted in lower porosity (see Fig. 3).

Also, mechanical properties like hardness, tensile strength, modulus, bending strength of the developed composite as well as Impact energy absorbed by them increase with increase in percentage loading of the reinforcement up to a certain composition, mostly 25% loading, after which the properties begin to decline (see Fig. 4-8).

The hardness values of the composite samples increase as the percentage maize cob ash particles (MCSp and MCLp) addition increases in the RLDPE matrix. The increase in modulus of elasticity with increasing maize cob particles addition is expected since the addition of maize cob particles to the RLDPE increases the stiffness of the composites. It is also interesting to note that bending strength increased with increase in maize cob particles in the RLDPE matrix. For example bending strength of 50.50N/mm^2 was recorded for the RLDPE matrix, 96.70N/mm^2 at 25wt% MCSp, and 89.00N/mm^2 at 20wt% MCLp. There is an improvement in bending strength of the composite as particle weight fraction increases.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion

From the results, the following conclusions can be made;

1) Increase in the loading of the MCA particles increases the density of the developed composite irrespective of the particle size.
2) There is increase in the rate of water absorption with increase in the loading of the MCA though it the highest is less than 5ppt
3) There is not much, difference between the density of unreinforced and reinforced RLDPE.
4) Mechanical properties like hardness, tensile strength, modulus, bending strength of the developed composites as well as Impact energy absorbed by them increase with increase in percentage loading of the reinforcement up to a certain composition, mostly 25% loading, and then the properties begin to decline.
5) The developed composites have the better properties at the ranges of 20-25wt% MCSp additions, and for optimum service condition, maize cob particle addition should not exceed 20% in order to have better properties.

4.2 Recommendation

In the course of the investigation, some recommendations and new areas of research have been identified.

1) It is recommended that the matrix-particle interface be investigated using high-resolution scanning electron microscopy (HRSEM) or high-resolution transmission electron microscopy (HRTEM) to reveal the presence of a reaction zone
2) Other mechanical property test such as fatigue and creep test should be carried out on this material

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