

Effect of Particle Size and Filler Content on Some Properties of Recycled Low Density Polyethylene/Periwinkle Shell Composite

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Abstract:- The effect of periwinkle shell addition on some physical and mechanical properties of recycled low density polyethylene (RLDPE) reinforced periwinkle shell particulate composite was evaluated to assess the possibility of using it as a new material for engineering applications. The composites were produced by compounding and compressive moulding technique by varying the periwinkle shell particle fractions from 5 - 25 wt % with particles sizes of 53, 75 and 106 μm . The mechanical and the physical properties of the composites were investigated. The hardness of the composite increases with increase in periwinkle shell content and the tensile strength of the composite increased to optimum of 10 wt %. The composites produced with 75 μm particle size have the best properties of the entire grade. Hence this grade can be used for interior automobile applications such as assist grip, luggage trim, and other interior parts of automobile where high strength is not considered a critical requirement.

Key words: Composite, Filler content, Periwinkle, Polyethylene, Recycled

1.0 INTRODUCTION

The indiscriminate litter of polymeric waste products and also agricultural wastes in the environment calls for serious attention by researchers to provide temporary but preferably permanent, solutions to this environmental problem.

Over the last three decades, composite materials, plastics and ceramics have been the dominant emerging materials [1]. Natural fibres/particulate reinforcements have recently attracted the attention of researchers because of their advantages over other established materials. They are environmentally friendly, biodegradable, abundantly available, renewable, cheap and have low density. A number of automotive components previously made with glass fibres are now being manufactured using environmentally friendly composites [2].

Generally, the mechanical properties of filled polymer composites depend strongly on size, shape and distribution of filler particulates in the polymer matrix and good adhesion at the interface.

Periwinkle shell contains calcium carbonate as one of its major constituents. It is a domestic waste and found littered in lots of areas in big cities, farm yards and markets in coastal communities. Waste low density polyethylene bags otherwise known in Nigeria as "pure water sachets" are seen littered in most communities in Nigeria. Hence, in an attempt to address the environmental problem of waste disposal, this study presents an alternative to indiscriminate

discharge of these wastes to the environment by producing a composite material from completely waste materials, hence converting waste to wealth.

2.0 MATERIALS AND METHODS

2.1 Periwinkle shells

Periwinkles (*Turritella communis*) are small edible species of medium-sized sea snails of the marine gastropod molluscs [3]. It is an external exoskeleton which protects the winkles from their predators and mechanical damage. Structurally, the wrinkle shell has several layers and is typically made of an organic matrix (conchiolin) which is bonded with calcium carbonate precipitates. These calcium carbonate-filled organic matrix shells are impervious to water and this property makes it possible for periwinkle shells and their derivatives to have very wide applications [4].

2.2 Low density polyethylene

LDPE is defined by a density range of 0.910–0.940 g/cm^3 . LDPE has a high degree of short and long chain branching, which means that the chains do not pack into the crystal structure as well. It has, therefore, less strong intermolecular forces as the instantaneous-dipole induced-dipole attraction is less. This results in a lower tensile strength and increased ductility. LDPE is created by free radical polymerization. The high degree of branching with long chains gives molten LDPE unique and desirable flow properties.

Some physical properties of low density polyethylene are good toughness, low temperature resistance, creep and large thermal expansion.

Low density polyethylene is also easy to process by moulding, can be extruded, injection moulded, it is chemically unreactive at room temperature although it is slowly attacked by strong oxidizing agents etc.

3.0 EXPERIMENTAL DETAILS

3.1 Materials

The low density polyethylene used in this study was obtained by hand picking waste water sachets (pure water sachets) from Samaru community in Zaria, Kaduna state, Nigeria, and recycling these wastes to produce the matrix in the Nigerian Institute for Leather and Science Technology, Zaria in Kaduna State, while the periwinkle shells were locally sourced from Ikot- Abasi in Akwa –

Ibom state, Nigeria. The distilled water and particle sieves were obtained from the National Geological Survey Agency, Kaduna State, Nigeria.

3.2 Preparation of the composite samples

The thermoplastic composite of recycled low density polyethylene and periwinkle shell powder of nominal sizes 53µm, 75µm, and 106µm were prepared by proper and thorough mixing of 95 g of recycled low density polyethylene with 5 wt. % of periwinkle shell powder to make up 100% composition. The other samples were combined in similar fashion at filler contents of 5 wt %, 10 wt %, 15 wt % and 25 wt. % for all particle sizes considered. The resulting mixture of the composite constituents was melt blended and homogenized in a two way roll mill compression moulding machine at 150°C and at a curing time of 5 minutes, after which the resulting composites were produced as sheets.

3.3 Mechanical Properties Tests

The tensile test, 3-point bending test, and impact tests were carried out following the prescribed ASTM D-638, D-790, D-256 standards respectively, while the Durometer hardness ASTM D-2240 shore D was used for the hardness to ascertain the relevance of the composite material as an engineering material. All the mechanical tests were done at room temperature as discussed below.

- i. **Impact Test:** The impact strength test of the composite samples was determined using Charpy impact testing machine with model no 412-07-15269C. The procedure used was in accordance with that recommended by ASTM D-256. Samples were sectioned to 100mm×10mm×5mm dimensions, mounted on the machine and a swinging pendulum released, under gravity, to hit the sample(s). The energy at impact was read directly

from a dial indicator of the machine and the results obtained are given in Figure 1.

- ii. **Tensile Test:** The tests were performed in accordance with standard procedure specified in ASTM D638, using the Hounsfield Monsanto Tensometer in the department of Mechanical Engineering. Samples were sectioned to 100mm×15mm×5mm with gauge dimension 40mm×10mm×5mm. Each sample was then tested and maximum stress and strain values recorded for tensile strength computation. The Tensile values are given in Figure 2.

- iii. **Hardness Test:** The hardness tests were carried out using the Durometer hardness tester with model no DIN 53505 on shore D scale according to ASTM D- 2240.

The hardness test results are as presented in Figure 3.

- iv. **Flexural Test:** Flexural tests were carried out on a Hounsfield Tensometer. Samples were prepared to dimension of 100mm×40mm×5mm. The Samples were subjected to bending by supporting them at both ends and a midpoint load applied until failure as recommended in ASTM D790. The results obtained are presented in Figure 4.

3.4 PHYSICAL PROPERTIES

- i. **Water absorption test**

The specimens were prepared according to ASTM D 570.

- ii. **Determination of density**

The densities of the samples were determined using ASTM D-792.

4.0 RESULTS AND DISCUSSION

4.1 Results

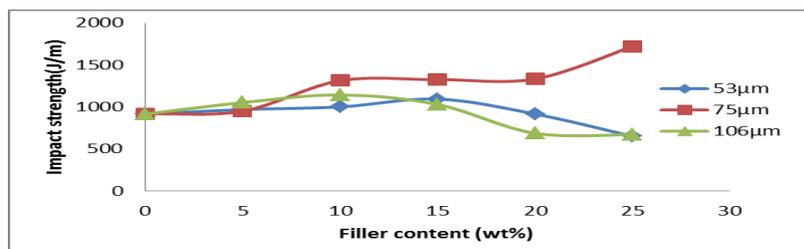


Fig.1: Impact strength profile for composite at varying filler content and particle sizes

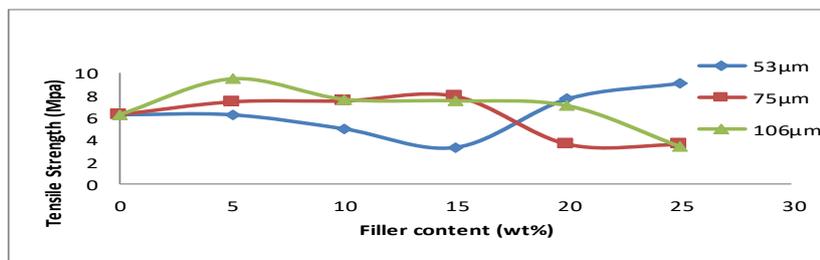


Fig. 2: Tensile strength profile for composite at varying filler content and particle sizes.

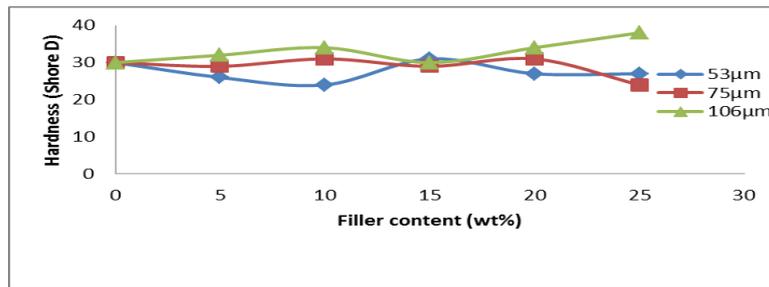


Fig. 3: Hardness profile for composite at varying filler quantity and particle size

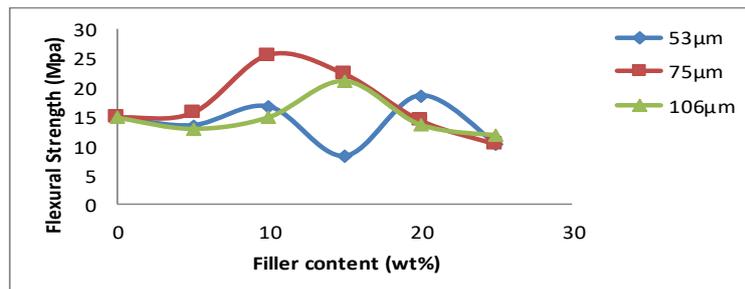


Fig. 4: Flexural strength profile for composite at varying particle sizes and filler content

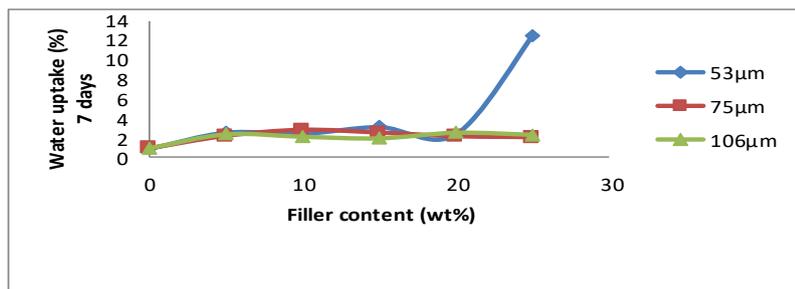


Fig. 5: Percentage water absorption profile for composite at varying filler quantity and particle sizes after 7 days

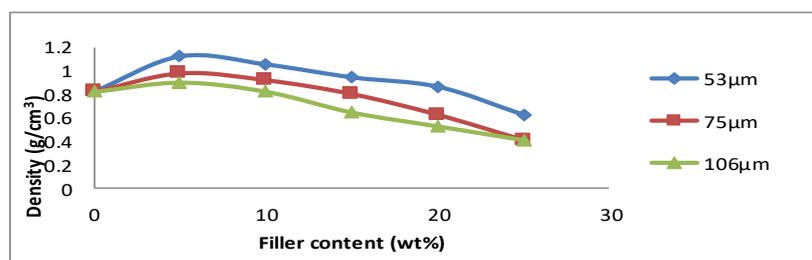


Fig 6: Density profile for RLDPE/PWS composite at differing particle sizes and filler contents

5.0 DISCUSSION

Impact strength

Figure 1 shows the impact strength profile for the produced RLDPE/PWS composite. From figure 1, it can be deduced that there was a progressive increase in impact strength for the 75µm particle size as the filler content increased from 5 wt. % to 25 wt. % with 950 J/m and 1720 J/m respectively while that of the recycled low density polyethylene was 915.63 J/m showing an 87.9% increase in impact strength. On the other hand, a slight increase in impact strength was observed with increase in filler content from 5 wt. % to 10

wt. % for 106µm sieve grade, and later falls from 15 wt. % filler content to 1028.57J/m and a subsequent decrease to 25 wt. %. Furthermore, for the 53µm particle size, a gradual increase in impact strength was observed from 968.75 J/m at 5 wt. % to 1093.75 J/m at 15 wt. % after which a decrease to 915.63 J/m was observed.

The highest impact strength was observed at 25 wt. % filler content with 1720 J/m and at 75µm particle size, while the least impact strength was observed at 25 wt. % filler quantity for the 53µm particle size. An increase in filler was observed to have improved impact strength

beyond 915.63 J/m reported for the control sample (RLDPE). The increase in impact energy of the composite upon increase in filler content may be attributed to the presence of the filler material in the matrix, thus, increasing the restriction to deformation processes and hence improving ability to absorb and dissipate energy, while a decrease may have been as a result of particle to particle interaction, hence giving rise to zones of weakness which may induce failure at lower stress values. This is in agreement with the work of [5], [6], and [7]; who studied the mechanical properties of particle filled polymer systems and reported an increase in impact strength with increase in filler loading, and is also in line with the work of [8], who investigated carbonate/polypropylene systems and found that an increase in filler content gave rise to an increase in the ability to absorb and dissipate energy and hence improved impact strength, but decreased with further filler content addition.

Tensile strength

Figure 2 shows the tensile strength of the composite material produced, the profile shows a progressive decrease as filler quantity increased from 5 wt. % to 25 wt. % for 106 μ m, with 9.50 MPa and 3.33 MPa respectively. For the 75 μ m particle size, there was an increase in tensile strength as the filler quantity increased from 5wt% to 15wt% with values of 7.40 MPa at 5 wt. % and 7.89 MPa at 15 wt. %, beyond which there was decrease in tensile strength, followed by a decrease to 3.57 MPa at 20 wt. % filler content, and 3.55 MPa at 25 wt. % filler content. When we compare this with the control sample with a value of 6.25 MPa, we can deduce that at finer particle sizes, tensile strength decreases upon addition of filler, but increases at a point where there is enough volume to provide better stress transfer between filler and matrix, and hence improved tensile strength.

At 53 μ m particle size, there was also a decrease in tensile strength from 6.24 MPa at 5 wt. % to 3.56 MPa at 15 wt. % filler quantity, but at 20 wt. % filler, a sudden increase to 7.70 MPa was observed, with the highest value of 9.12 MPa for 53 μ m particle size at 25 wt. % filler content. This sudden increase in tensile strength may be due to increased surface area, which enhanced load transfer between RLDPE matrix and PWS filler. This is in agreement with the work of [9], who carried out a research on the effect of alkali treatment on coir reinforced cashew nut shell liquid, and reported an increase in tensile strength with a subsequent decrease in tensile strength.

The highest tensile strength of 9.50 MPa was observed with 5 wt. % filler content at 106 μ m, while the least value for the tensile strength was 3.26 MPa at 15 wt. % filler and 53 μ m size.

The increase in tensile strength of the composite at 75 μ m could be attributed to an improvement in stress transfer between matrix and filler material, caused by improved interfacial adhesion. Furthermore, an increase in surface area and bonding surface has been known to improve tensile strength as reported by [10] and [7], but a decrease could be attributed to a decrease in wettability, which could be as a result of the increase in filler-filler interaction. On

the other hand, the progressive decrease in tensile strength of the composite at 106 μ m may be attributed to improper distribution of the filler in the matrix, and a decrease in interfacial adhesion between filler/matrix of the composite, thereby decreasing its tensile strength.

Hardness Property

Figure 3 shows the hardness profile for the RLDPE/PWS composite at different filler content and particle size.

The figure shows a gradual increase in hardness for the 106 μ m and 75 μ m particle sizes at 5 wt. % (32 shores) and 10 wt. % (34 shores) filler quantity, but there was a decline in hardness at 15 wt. % (30 shores) filler quantity followed by an increase. The increase can be attributed to the increase in the hard and brittle phases of the periwinkle shells in the polymer matrix, but at the point of decline, an uneven distribution of phases may have been responsible for the decrease in hardness. Furthermore, the presence of the filler may have improved the matrix surface resistance to indentation. This is in agreement with the work of [8], who studied the effect of palm kernel shell on the microstructure and mechanical properties of recycled polyethylene/palm kernel shell particulate composite.

The 53 μ m particle size indicated the least increase in hardness of the three particle sizes considered at three different filler quantities of 5 wt. % (26 shores), 10 wt. % (24 shores) and 20 wt. % (27 shores), which may be due to the fact that the fine particles could not provide enough resistance to surface indentation. Furthermore, the indenter may rest on the surface of the filler material at some point and on the matrix surface at other points, thus giving such behaviour in hardness at certain compositions as shown on Figure 3

The highest hardness was observed at 25 wt. % filler with 38 shores for the 106 μ m particle size, while the least hardness was seen at 25 wt. % filler with 24 shores for 75 μ m particle size, and also at 10 wt. % filler (24 shores) for 53 μ m particle sizes, as opposed to the control sample with a value of 30 shores.

Flexural strength

Figure 4 shows the flexural strength of the RLDPE/PWS composite.

From the figure, it can be observed that there was an increase in flexural strength at 75 μ m particle size considered with an increase in filler up to 10 wt. % with 25.51 MPa which was the highest, but beyond 10 wt. % filler, a decrease was observed. A decrease at 5 wt. % was observed for the 106 μ m particle size, but a sudden increase followed up to 15 wt% with 21.14 MPa, beyond which a decrease was observed. On the other hand, initial increase and decrease, were observed with a sharp decline in flexural strength from 16.67 MPa at 10 wt. % filler to 8.19 MPa at 15 wt. % for the 53 μ m, this could be as a result of improper distribution of filler in the matrix. The control sample had a flexural strength of 14.79 MPa, which shows that the increase in filler produced an increase in flexural strength but decreased as the filler content increased to a point where there was extensive interaction between particles of filler material. The increase in flexural strength

upon addition of filler material may be due to the improved interfacial adhesion between matrix and filler material. This improves stress transfer between matrix and filler, while a decrease may be attributed to extensive interaction between filler materials in the matrix, thus, giving rise to inefficiency in bonding surface, and hence, reduced stress transfer between matrix and filler material. This is in agreement with the work of [11], who asserted that the presence of oil palm press particles, led to an increase in flexural properties, and subsequent decrease with increase in filler content. This behaviour is also supported by the work of [12], where they studied the influence of cow bone particle distribution on mechanical properties of cow bone reinforced polyester composite.

5.1 Water absorption

From Figure 5, it can be observed that the RLDPE/PWS composite has a generally low water absorption rate, for all particle sizes considered, the water absorption rate for all filler quantities was between 1.5% and 3.5% with the exception of 25 wt.% filler for 53 μ m particle sizes which had a water absorption rate of 12.50%. The high rate of water absorption at 53 μ m particle size and 25 wt. % filler may be attributed to the increased number of pores created by the increase in surface area of the periwinkle shell particulates, and also due to imperfect interfacial bonding between matrix and particulates since neither the matrix nor the reinforcements are hydrophilic in nature. This is in agreement with the work of [8], who studied the effect of palm kernel shell on the microstructure and mechanical properties of recycled polyethylene/Palm kernel shell composite and reported an increase in water absorption rate at finer particle sizes and higher filler content.

5.2 Density of the composite

From Figure 6, it can be deduced that the density of the composite generally decreased with an increase in filler quantity, while a decrease in particle size indicated an increase in density, with the highest density at 5 wt. % for the 53 μ m particle size with a value of 1.12 g/cm³, while the least value was obtained at 25 wt. % for the 106 μ m particle size with a value of 0.4 g/cm³.

Generally, at all particle sizes considered, there was a decrease in density as filler content increased, this may be attributed to the increased number of voids created by the periwinkle shell particulates thus reducing the composite's overall density. This is in agreement with the work of [13], who worked on the study of the mechanical properties of groundnut shell reinforced polymer composite, where they reported a decrease in density with increase in filler content.

6.0 CONCLUSION

The best impact and flexural properties of the entire composite produced were derived from the 75 μ m particle size, with an impact strength of 1720 J/m at 25 wt. % filler content and Flexural strength of 25.51MPa at 10 wt. % filler content, while the 53 μ m particle size presented weaker properties as compared with the other particle sizes considered, with the exception of tensile strength, where it presented a remarkable increase beyond 15 wt. % filler.

The properties of the composite hereof could be exploited to advantage for engineering applications such as interior automobile components. Furthermore, the recycling of the waste materials used in this research work would lead to a reduction in the huge volume of such waste in the environment and would provide a cheaper alternative to components which may have posed a challenge in terms of cost.

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