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THE EFFECT OF PARTICLE SIZE DISTRIBUTION ON THE MECHANICAL PROPERTIES OF DPF AND GNSF-RECYCLED LOW DENSITY POLYETHYLENE COMPOSITES

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Abstract: The particle sizes analysis on the properties of date palm–wood-flour (DPF) and groundnut shell–flour (GNSF) in recycled low density Polyethylene (r-LDPE) were studied. The study was performed at 150, 212, 250 and 300 µm sizes. The impact energy of Date palm-wood-flour-recycled-low-density-Polyethylene (DPF-r-LDPE) and groundnut shell–flour-recycled-low-density-Polyethylene (GNSF-r-LDPE) composite improved with sizes range, respectively. The other properties of the composite reduced at above 250 µm of fiber injection in the r-LDPE matrix. Scanning electron microscopy (SEM) differentiated the bond between DPF and GNSF in the r-LDPE. Based on the result obtained, DPF indicated good mechanical properties than DPF when reinforced in the r-LDPE plastics.

Keywords: DPF, GNSF, properties, size distribution, DPF-r-LDPE and GNSF-r-LDPE composites

Introduction

In recent years, the use of raw material from agro-wastes as alternative additive in polymer composite is rapidly increasing (Abdulkhalili and Razman, 2000; Yang *et al.*, 2006; Thygesen *et al.*, 2007; Dungani *et al.*, 2014; Obasi *et al.*, 2015; Government *et al.*, 2019). Plant fiber is a major additive in the composite preparation. Nevertheless, it is an abundant and cheap resources, low weight, biologically degradable, etc. This is the main reason why mineral/inorganic filler is limited in composite application (Berger and Stark, 1997). Agro-wastes have the ability to induce stiffness and enhance specific strength in the polymer composite (Bledzki and Gassan, 1999). They also give support to corrosion resistance, enhancement of dimension stability and electro-mechanical features. The agro-fibers as wastes viz: groundnut shell-flour, wood-flour, oil palm-wood flour, date palm wood, coconut palm-wood flour, etc.

For agro-wastes to perform as filler, it must certify some factors. These are sizes interval of the wastes, age of the plant, polymer characteristic, plant species, treatment, coupling agents, etc. (Myers, 1991; Bogoeva- Gaceva *et al*., 2007).

The largest constituent of composite is the matrix, which acts as bonding agent between fiber and the other components. It carries the bulk of the other materials which aids the adhesion of other constituent (Mueller and Krobjilowski, 2003). It may be polymer, metal or ceramic.

In the society, there is a lot of waste generated from polymer as plastic. This waste has cause much havoc in the environment leading to reduction of oxygen intake for mankind, large deposits of non-biodegrade substance in the soil and economic loss, etc invariably potential candidate for environmental pollution (Government, 2013; Atuanya *et al.*, 2014). In order to minimize this stigma, there is need to make use of this waste in form of recycled plastic to polymer-fiber composite for components of engineering materials in solution to societal problems.

However, much works have not been executed in the application of recycled plastic wastes in the composite making. The limited researches on applying cellulosic substance from wood in utilizing recycled polymeric material for composite production are Iroko (Atuanya and Nwigbo, 2011) and radiata pine wood (Adhikary *et al.*, 2010).

The research was carried to compare DPF-r-LDPE and GNSF-r-LDPE composites at different size effect to determine the maximum size of filler for composite application in domestic use. Also, the micro-structure arrangement of the fibers in the polymer matrix was displayed by SEM analysis.

Materials and Methods

GNSF processing

The GNSF was obtained at Oba in Udenu Local Government Area of Enugu State. The GNSF was rinsed with water to remove dirt. The GNSF was initially dried by sun rays, crushed and ground. The crushing and grinding processes took place in Timber market, Kenyettta Enugu were accomplished with the help of wood log crusher (model no. FSJ I Anyang GEMCO Energy Machinery Company Limited, China production (output size of 3-5 cm) and ball mill (model no.MQG, a fabrication of Shangai Tian Jin Machinery Company Ltd, China at sizes range of 75-890 µm), respectively. The sieving of GNSF was carried out at 150, 212, 250 and 300 µm.

DPF preparation

The DPF was obtained from Nnamdi Azikiwe University Awka, permanent site Anambra State. The DPF was sun-dried, crushed and grind. The DPF was sieved for 150, 212, 250 and 300 µm mesh size.

r-LDPE extraction and processing

The r-LDPE plastic was sourced in Enugu metropolis. The r-LDPE was washed and sun- dried to eliminate dirt. The r-LDPE was slash to tiny sizes before inputted in the grinding machine.

Procedures

The GNSF and DPF were infused in r-LDPE matrix, respectively. The GNSF and DPF were filled at 30% weight of the filler content for the sizes studied, respectively. The pulverized flour and r-LDPE were compounded with injection molding machine at Ekenedilichukwu workshop, Onitsha.

Tensile and flexural examination

This tensile and flexural test was carried out by universal tensile machine assembled by Richard parker Ltd, Sheffield, England (Model TUC-100) in Standard Organization of Nigeria, Enugu State according to ASTM D638 and ASTM D790, respectively (ASTM D638-03; ASTM D790-03, 2003). A cross-head speed of 5mm/min was used. The composite sample was sized at 3 x 12.5 x 60 mm and 3 x 40 x 140 mm, for these investigations, respectively. The sample was affixed in the equipment at a period till the occurrence of failure. The maximum tensile and flexural strength, elongation and modulus were recorded.

Izod notch impact testing

The impact machine analyzer produced by Samuel Devison Ltd, Leeds, England (Model LS102 DE) executed in Standard Organization of Nigeria, Emene in Eastern part of Nigeria. The standard employed was ASTM D256 with specification of 3 × 10 ×55 mm (ASTM, 1990). A striking hammer banged the sample after fixing in the equipment and impact values were measured.

SEM analysis

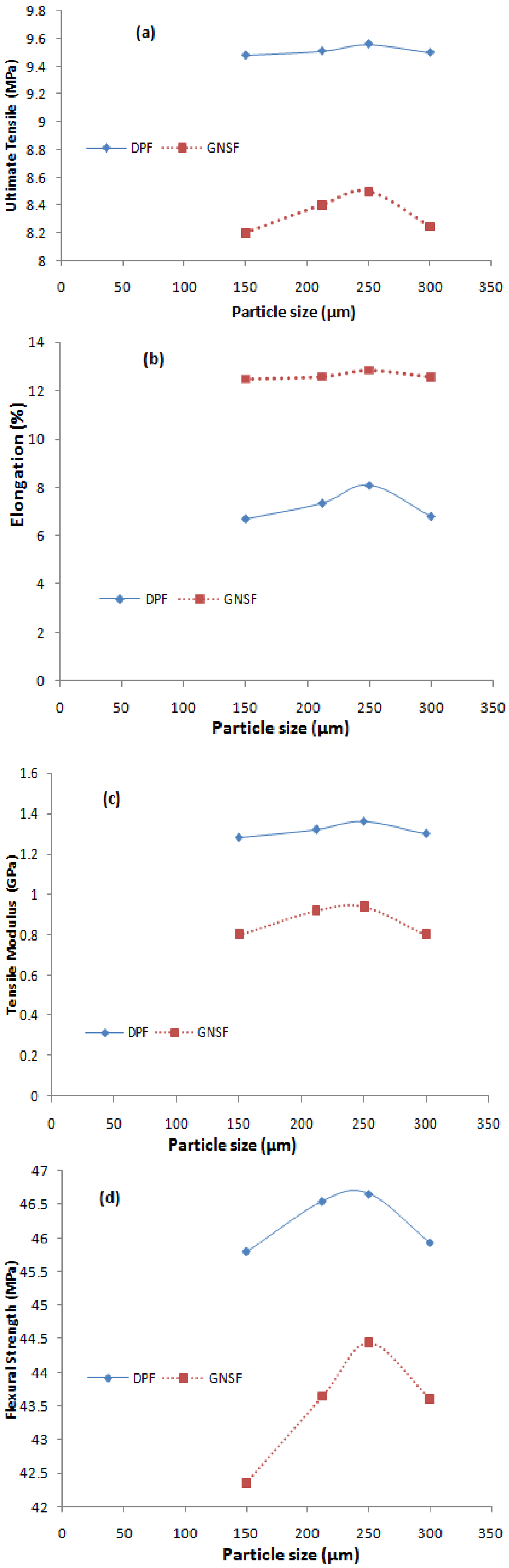
The composite sample material was pulverized and placed in machine. The SEM (Model PHENOM Pro X) is specifically used for this examination. After the injection of the sample in the equipment, the SEM micro-graph displayed on the computer was attached to the device after 5 seconds.

Results and Discussion

Figure 1(a) presents the variation of DPF and GNSF size on the tensile strength of r-LDPE at 30wt % content, respectively. It was observed that during the injection of DPF and GNSF in the r-LDPE plastic, the particle size increased to 250 µm, the tensile strength of the composite improved from 9.48 to 9.56 MPa and 8.2 to 8.5 MPa, respectively. This observation could be due to addition of bigger particle size enriches the adhesion of DPF, GNSF and r-LDPE matrix inter-phase, respectively. Furthermore, adding more DPF and GNSF particles above 250 µm in the r-LDPE resulting to diminishing of the strength to 9.50 and 8.25 MPa, respectively. This phenomenon was exhibited by previous scholars (Myers, 1991; Stark and Berger, 1997; Zaini *et al.*, 1996; Stark and Rowland, 2003; Boutif *et al.*, 2008; Boutif *et al.*, 2009).

Figure 1(b) shows the effect of particle size of DPF and GNSF on the elongation of DPF-r-LDPE and GNSF-r-LDPE composite at 30 wt % filler content, respectively. The elongation of DPF and GNSF-r-LDPE composites improved to 250 µm from 12.5 to 12.58 and 6.7 to 8.1, respectively. This is due to the ductility of the composites increases at the size range of the increment. But, above 250 µm, the ductile ability of the r-LDPE reduces for inclusion of high particle of DPF and GNSF content which in turn minimizes the elongation of DPF and GNSF-r-LDPE composites, respectively. These were agreed by later workers (Stark and Berger, 1997; Zaini *et al.*, 1996: Stark and Rowland, 2003; Government, 2013).

Figure 1(c) describes particle size influence of DPF and GNSF on the tensile modulus of the DPF and GNSF-r-LDPE composites. From Fig. 1(c), it can be deduced that the tensile modulus of DPF-r-LDPE and GNSF-r-LDPE composites increases from 1.28 to 1.36 GPa and 0.8 to 0.94 GPa, when DPF and GNSF particle increased to 250 µm is added to r-LDPE, respectively. This is as result of more sizes of the GNSF has higher dispersion in the r-LDPE matrix which stiffens and amplifies the modulus of composites, respectively. However, beyond 250 µm the elastic modulus of both composites of DPF and GNSF also noticed a fall to 1.3 and 0.8 GPa, respectively. The rate of dispersion for the DPF and GNSF in the r-LDPE matrix reduces, respectively. This occurrence is due to higher size of the fiber increases micro-void in the r-LDPE leading to the decline in the ductility of the DPF-r-LDPE and GNSF-r-LDPE composites, respectively. Similar results were previously explained by other researchers (Myers, 1991: Stark and Berger, 1997; Zaini *et al.*, 1996; Boutif *et al.*, 2008; Boutif *et al.*, 2009).



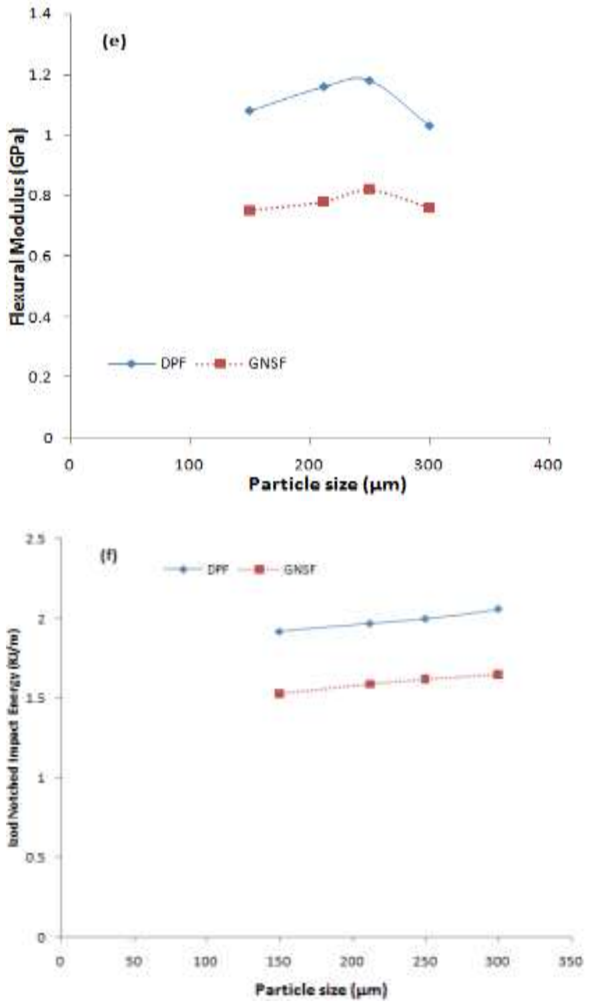
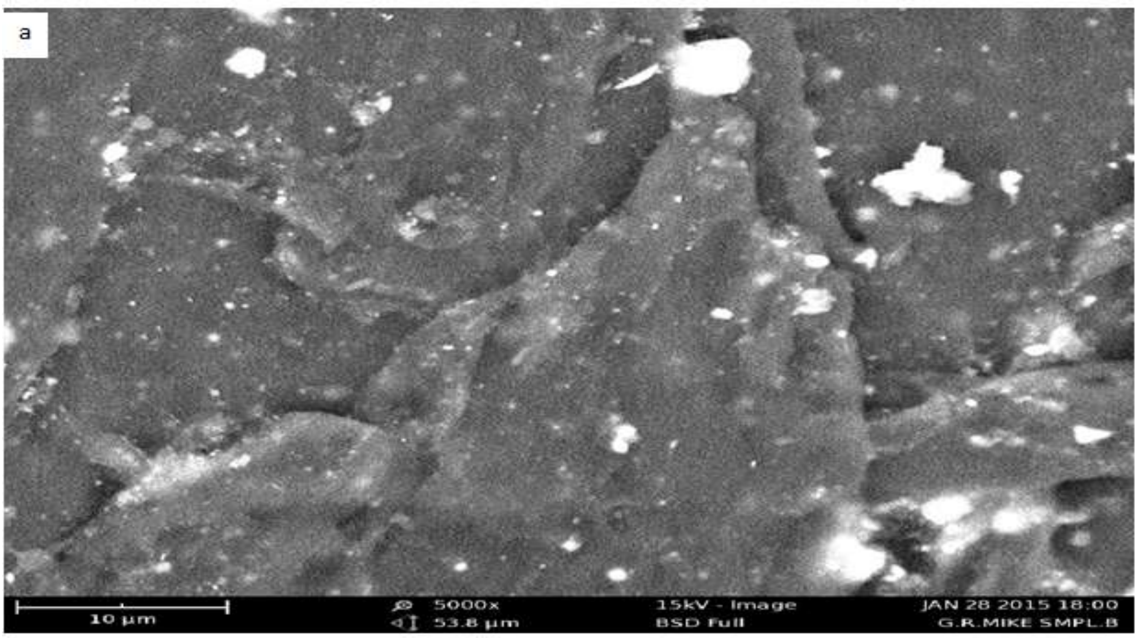


Fig. 1: The variation of particle size of the DPF and GNSF on the (a) tensile strength (b) elongation (c) tensile modulus (d) flexural strength (e) flexural modulus (f) Izod impact energy of r-LDPE composite

Figure 1(d) demonstrates the potential of sizes for DPF and GNSF on the flexural strength of DPF and GNSF-r-LDPE composites, respectively. The flexural strength of DPF-r-LDPE and GNSF-r-LDPE composites rises from 45.8 to 46.66 MPa and 42.35 to 43.6 MPa as the filler sizes of DPF and GNSF content marginally advanced from 150 to 250 µm, respectively. This phenomenon ascribes to those fiber sizes interval enable the r-LDPE to resist bending which enhances the flexural strength of DPF and GNSF composites of r-LDPE. Although, slightly higher fiber sizes than 250 µm dwindled the bending strength of DPF-r-LDPE and GNSF-r-LDPE composites to 45.93 and 43.6 MPa, respectively. The trend can be due to greater fiber sizes deteriorate the strength of the r-LDPE which falls the bending strength of the composites. These had been scholarly reported (Myers, 1991; Stark and Berger, 1997; Zaini *et al.*, 1996; Boutif *et al.*, 2008; Boutif *et al.*, 2009).

The impact of the flexural modulus of DPF and GNSF-r-LDPE composites on the particle size of DPF and GNSF is shown in Fig. 1(e). The flexural modulus of DPF and GNSF-r-LDPE composites increases to the utmost of 250 µm from 1.08 to 1.18 GPa and 0.75 to 0.82 GPa when adding the DPF and GNSF in the r-LDPE matrix, respectively. This is due to larger particles of DPF and GNSF were scattered in the molten r-LDPE improves the stiffness to bending. At ahead of 250 µm particle, the bending modulus of DPF and GNSF-r-LDPE composites lessened to 1.03 and 0.76 GPa, respectively. This means that any size interval greater than this diminishes bending modulus of the composites. The following reporters had close outcomes (Myers, 1991: Stark and Berger, 1997; Zaini *et al.* 1996; Boutif *et al.*, 2008; Boutif *et al*., 2009).

Figure 1(f) indicates the presence of particle size for DPF and GSF on the Izod impact energy of DPF-r-LDPE and GNSF-r-LDPE composites, respectively. The Izod impact energy of DPF-r-LDPE and GNSF-r-LDPE improves from 1.92 KJ/m to 2.06 and 1.53 to 1.65 KJ/m for all the particle sizes examined, respectively. This characteristic is as result of addition of heavier particles of DPF and GNSF in the melting-blended r-LDPE resists high capacity of energy to initialize cracking. Usually, properties of both composites were at the peaks of 60 mesh (250 µm) with exception of the impact energy. Previous scholars also established much related results (Myers, 1991: Stark and Berger, 1997; Zaini *et al*., 1996: Stark and Rowland, 2003).



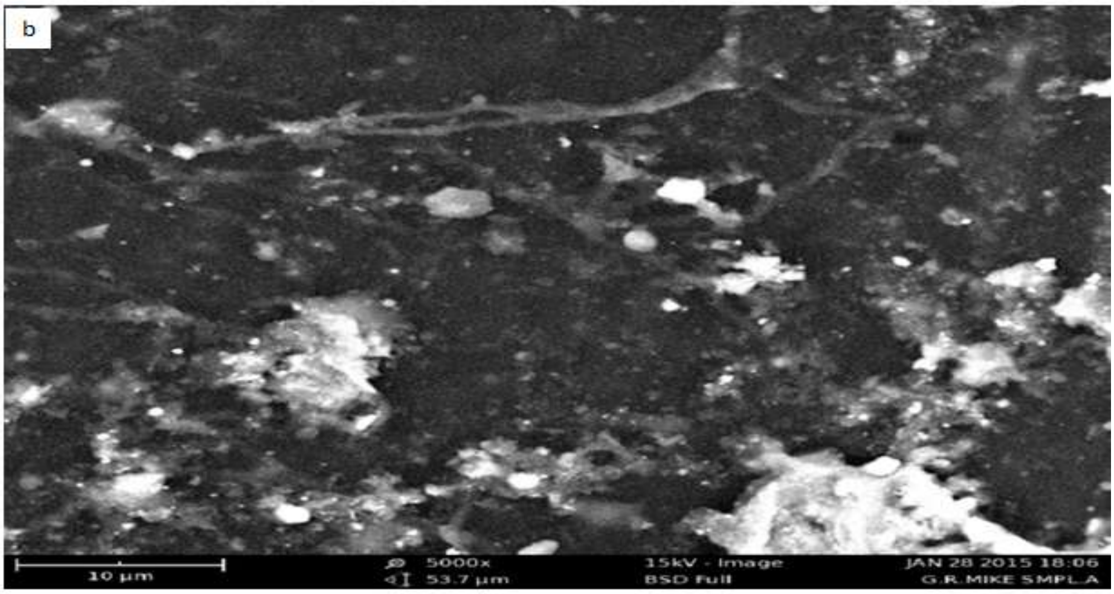


Fig. 2: SEM Photograph of (a) DPF-r-LDPE (b) GNSF-r-LDPE composite at 250 µm, at 30 wt% filler content

Figure 2(a) indicates the micro-picture of SEM of DPF-r-LDPE composites. The presence limited adhesion of DPF and r-LDPE was recorded on the SEM portrait in Fig 2(a). Also, slight few particles of unreinforced DPF were found on the photograph. Fig. 2(b) captures the SEM snap of GNSF-r-LDPE composite. The concentration of high GNSF particles was found on the SEM portrayal with lower union between GNSF and r-LDPE matrix in Fig 2(b). This distinction between Figs. 2(a) and 2(b) is a substantial reason while the characteristics of DPF is higher than GNSF in r-LDPE composites, respectively.

Conclusion

The comparative analysis for effectiveness of the size distribution of DPF and GNSF on the r-LDPE was successfully studied. The optimum particle size for the DPF and GNSF were found to be important factor on the properties of reinforced r-LDPE. Therefore, the best fiber-r-LDPE composite at maximum particle size of the fiber can be recommended for domestic application.

Conflict of Interest

Authors declare that there is no conflict of interest.

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