Special Conference Edition, November, 2018

http://dx.doi.org/10.4314/bajopas.v11i1.23S

Bayero Journal of Pure and Applied Sciences, 11(1): 139 - 144
ISSN 2006 – 6996

EFFECT OF GROUNDNUT SHELL POWDER ON THE VISCOELASTIC PROPERTIES OF RECYCLED HIGH DENSITY POLYETHYLENE COMPOSITES

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ABSTRACT
In the quest to clean up the environment and produce economically viable materials from plastic wastes and readily available natural fibres, groundnut shell powder reinforced recycled high density polyethylene composite was prepared via two roll melt mixing and compression moulding technique. The dynamic mechanical properties of the composites such as storage modulus (E'), loss modulus (E''), and damping parameter (Tan ∂) were investigated using 242E dynamic mechanical analyzer in a temperature range from 30 ^{0}C-100^{0}C at a frequency of 1 Hz. It was found that the storage modulus of all the composites decrease with increase in temperature with composite containing 25%wt fibre having maximum E' value of 1158.47MPa compared to 1033.58MPa of the unreinforced recycled high density polyethylene. These results indicated that the thermal stability and load bearing capacity of the recycled high density polyethylene have been improved with the incorporation of groundnut shell powder. Scanning Electron micrographs showed better interfacial adhesion between treated groundnut shell powder in the polymer matrix; this explained the observed improvement in the viscoelastic properties of the composites.
Keywords: Mechanical Properties, Groundnut Shell Powder, Recycled polyethylene, Viscolastic, Composites.

INTRODUCTION

Polyethylene (PE) is one of the most widely used thermoplastic in the world because of its good properties such as toughness, near-zero moisture absorption, excellent chemical inertness, low coefficient of friction and ease of processing (Khanam and Al Maadeed, 2015).The precise degree of crystallinity and density are dependent on the molecular weight of PE (Usman *et al.*, 2016*)*. Generally, the most used PE grades are low density polyethylene (LDPE), medium density polyethylene (MDPE) and high density polyethylene (HDPE).

HDPE in particular exhibits excellent performances such as chemical stability barrier, mechanical strength, and dielectric properties (Musa *et al.*, 2017), and is the third-most frequently used plastic in the world (Kumar *et al.,* 2011). These properties makes HDPE a versatile material in agriculture, automotive, machine packaging and daily sundries (Dusunceli and Colak, 2008); in the manufacture of many other products such as milk jugs, detergent bottles, margarine tubs, garbage containers (Klyosov, 2007); water pipes (Vasile and Pascu, 2005) and bottle caps resulting in a large volume of wastes. Above all, HDPE has a strong plasticity and deformability (Pawlak and Galesky, 2005), being widely used in the preparation of polymer composites (Zhang *et al.*, 2017).

In recent years, there has been increased application of biodegradable materials in the form of fibres, particulates and laminates as reinforcement in polymer composites. Low cost, easy to use and environmentally friendliness are some of the properties that made natural fibres to have an edge over synthetic fibres in composites manufacture. In addition to traditional applications such as packaging and construction, the automotive and aerospace industries have demonstrated an interest in natural fibre reinforced composites to reduce vehicle weight and fuel consumption.

Lignified parts of agricultural wastes in the form of various types of shells such as groundnut shell powder (GSP) and husks have been valuable products in composite production processes due to their high availability and scarce interest in other industrial sectors. Several natural fibres have been investigated in this regard including but not limited to banana fibre (Naidu *et al.*, 2013), rice husk (Tong *et al.*, 2014), pineapple peel (Danladi and Shui'ab, 2014), bagasse (Naguib *et al.*, 2015), kenaf core powder (Majid *et al.*, 2016) and jute fibre (Gupta, 2018).

The effect of groundnut shell powder on the mechanical properties of recycled polyethylene and its biodegradability has also been reported by (Usman *et al.*, 2016). The current trend of research in the field of natural fibre based composites is the application of dynamic mechanical analysis technique.

Dynamic mechanical analysis (DMA) is one of the most widely used techniques to characterize the thermal properties of natural fibres which are important in selecting processing conditions and applications field.

DMA gives information about the mechanical responses of materials by monitoring property changes as a function of frequency, temperature and time. Storage modulus (E'), loss modulus (E"), damping (tan ∂), effectiveness of reinforcement and glass transition temperature are some of the thermal properties that can easily and accurately be obtained by DMA.

Many researchers have reported studies on the dynamic mechanical properties of natural fibre reinforced polymer composites, and highlighted that these composites have acceptable mechanical properties for many industrial applications (Dan asabe, 2016; Zhang *et al.*, 2017; Palanivel *et al.,* 2017and Gupta, 2018). Therefore, this work seeks to evaluate the influence of GSP addition on the dynamic mechanical properties of recycled HDPE with a view in determining its suitability for different applications.

MATERIALS AND METHODS

Waste bottle caps with resin identification code “2” made from commercially high density polyethylene was collected from refuse dumps and plastic waste collection centre in Samaru and Sabon Gari, Zaria, Kaduna State, Nigeria. These have been thoroughly washed with water, dried and shredded into particles of smaller sizes which constitute the polymer matrix.

Ground nut shell was locally sourced from Kala’a, Hong L.G.A Adamawa State. Appropriate mill grinder was used to convert the shells into powder and was then sieved to a particle size of 150µm.

Chemical Treatment of GSP

In order to reduce potential surface hindrances and bring about better adhesion between hydrophilic GSP and the hydrophobic polymer matrix, the GSP was immersed in 10% NaOH for 5 hours, stirred and filtered. It was then rinsed with distilled water until the solution becomes neutral. The resulting residue was finally being dried at 80^{o}C for five hours.

Composite Production

The GSP-RHDPE composites were compounded on a two roll mill (Model number 5183, USA) at the Polymer recycling Laboratory, Nigeria Institute of Leather and Science Technology, Zaria. The composite samples were produced by compounding process achieved by the addition of the shredded recycled HDPE while the rolls were in counter clockwise motion for a period of 10 minutes at a temperature of 170^{0}C. Upon achieving a paste like matrix, the filler material (GSP) was introduced by gently applying manually as the rolls rotate at a rate of 500 rpm. The percentage fibre loading was varied from 0-25% (0, 5, 10, 15, 20 and 25%) respectively. The 0% in this case serves as the control sample.

Dynamic Mechanical Analysis (DMA)

DMA was carried out using DMA 242E machine in strength of materials laboratory, Mechanical Engineering Department, ABU Zaria according to (ASTM D7028, 2015). The test parameters: E', E" and tangent of delta (Tan ∂) were first configured via the proteus software using personal computer. Instrument set up included the sample holder (3-point bending), furnace temperature range of 30-110 ^{0} C, dynamic load of 4N, frequency range of 1-10 Hz and heating rate of 3K/min were configured. Sample dimension of 60 x 12 x 5 mm were produced for each test. The test specimens were loaded into the machine using a three- point bending and locked into the furnace.

Scanning Electron Microscope

Micro structural analysis of the composite material properties caused by GSP incorporation was complemented by Pro X: Phenonm World 800-07334 Model Scanning Electron Microscope. Samples imaging was done at accelerating voltage of 15kV at various magnifications.

RESULTS AND DISCUSSION

Dynamic mechanical properties of GSP reinforced composites at 1 Hz frequency

3.1.1 Storage Modulus

Storage modulus (E') of polymeric materials represents how the materials are stiffer (Gupta, 2018). In other words, it describes the energy stored in the system which depicts the elastic portion. Figure 1 below shows the storage modulus of unreinforced and reinforced composites. It was observed that the storage modulus increased with weight percentages of GSP fibres up to 25% due to proper adhesion between fibres and matrix.

With the higher content of GSP, the RHDPE dispersion in the composites was more homogeneous and the energy of the storage modulus is increased. Similar observation has been reported by other authors (Zhang *et al.*, 2017 and Palavinel *et al.*, 2017).
Similarly, in the glassy region, the highest value of E' was shown by composite A25 while its lowest value was shown by A0, this implies that the incorporation of GSP into RHDPE matrix increases its thermal stability. Therefore, the storage modulus was found to decrease with increase in temperature due to loss in stiffness of the fibres at higher temperature.

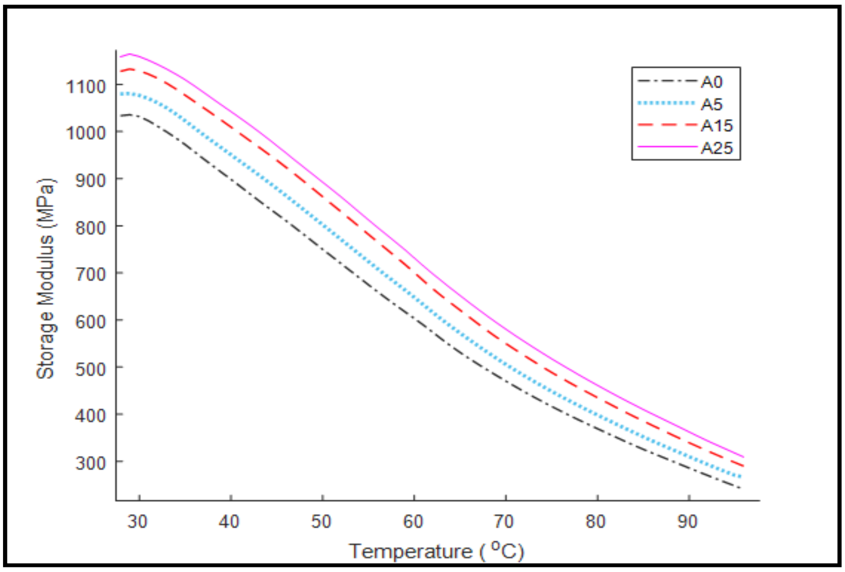


Figure 1: Variation of storage modulus with temperature of GSP composites at 1Hz

Loss Modulus
Loss modulus (E") is defined as the maximum energy dissipated by composite materials during deformation. It represents the viscous response of the materials which depends upon motion of polymeric molecules in the composites (Jawaid *et al.*, 2013; Gupta and Srivastava, 2016). The variation in loss modulus of GSP composites as a function of temperature at 1 Hz frequency is shown in figure 2. It was observed that the unreinforced composite (A0) has the highest loss modulus followed composite A5. Composite A25 has the least loss modulus. This implies that the incorporation of GSP into RHDPE increases its thermal stability. Similar observations have reported by other authors (Palanivel *et al.*, 2017; Gupta, 2018). However, the loss modulus was found to decrease with increase in temperature

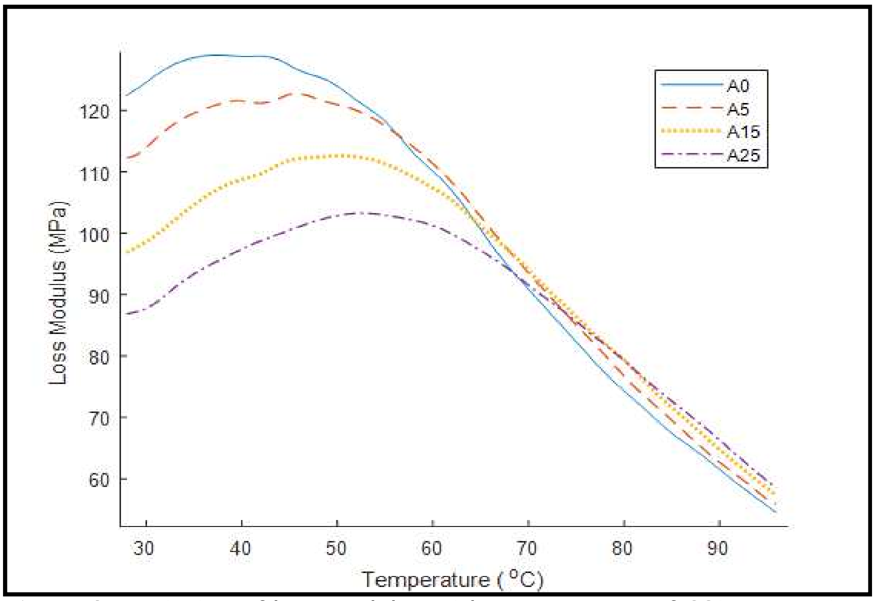


Figure 2: Variation of loss modulus with temperature of GSP composites at 1 Hz

Damping
Tan delta (Tan ∂) or damping is the ratio of loss modulus to storage modulus which is related to impact resistance of materials (Gupta, 2018). Figure 3 shows the temperature dependence of the tan ∂ of the unreinforced sample and the composites at 1 Hz frequency. From the curve of figure 3, the tan ∂ of the composites was lower than that of the unreinforced RHDPE. This indicates that the flexibility of the matrix is increased by molecular mobility of the polymer's molecular chain. Among the composites, the damping factor of sample A25 was the lowest. This could be due to better compatibility and reinforcing effect of GSP in the polymer matrix. Lower value of damping shows the good load bearing capacity of the composites.

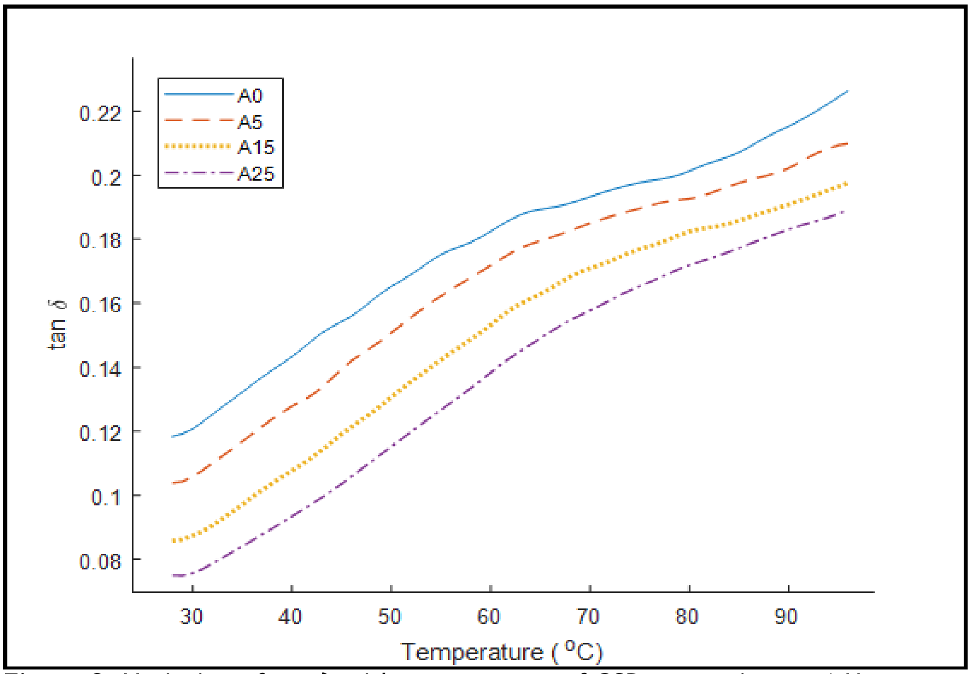
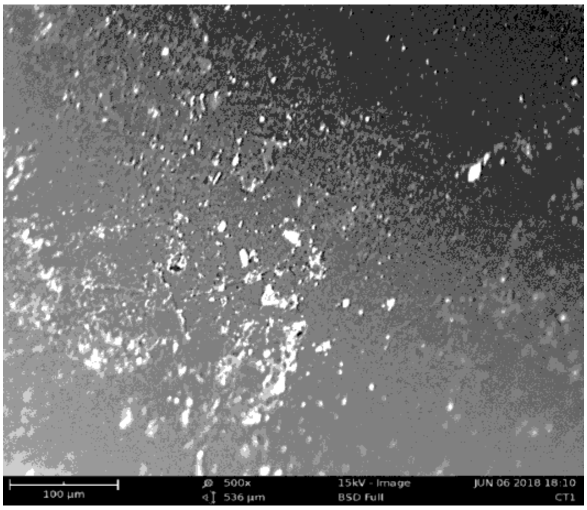


Figure 3: Variation of tan ∂ with temperature of GSP composites at 1 Hz.

Scanning Electron Microscopy (SEM)
SEM micrographs (Plates 1- 4) reveal the morphological features of GSP-recycled high density polyethylene composites. Presence of voids was observed in the RHDPE (plate 1) and was found to increase with the incorporation of GSP (plate 2). However, there is better distribution of GSP with composites A15 (plate 3) and A25 (plate 4) leading to the voids being considerably reduced. Therefore, SEM results indicate that there is better interaction between treated GSP fibres and RHDPE matrix. This confirms that increase in the viscoelastic properties of GSP- recycled high density polyethylene was as a result of better interfacial adhesion between the fibres and the polymer matrix.



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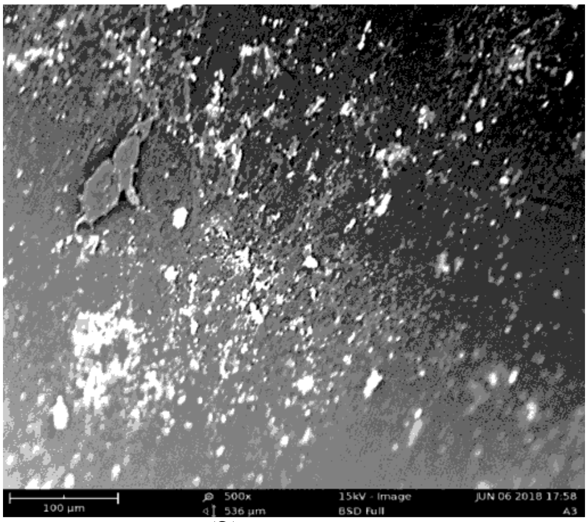

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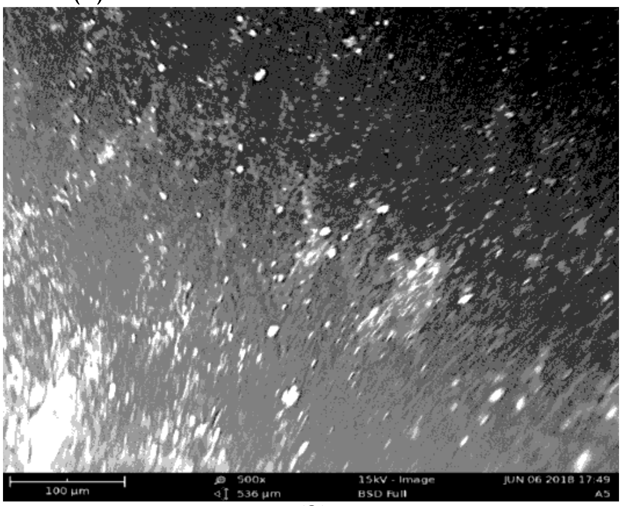

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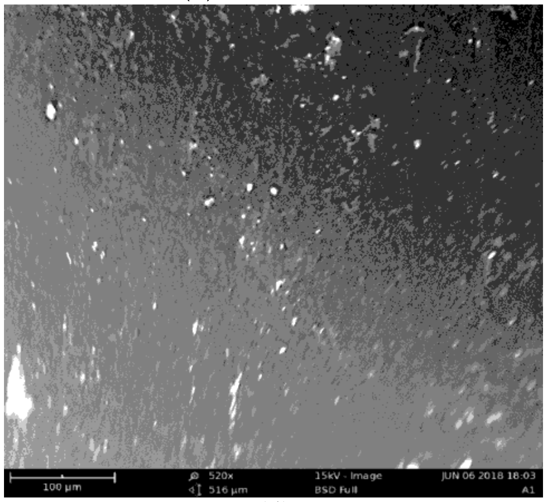

(4)

Plate 1- 4: SEM micrographs with (1) recycled HDPE at x500; (2) 5% GSP (A5) at x500; (3) 15% GSP (A15) at x500; (4) 25% GSP (A25) at x520, at accelerating voltage of 15kV.

CONCLUSION

Dynamic mechanical characterizations of GSP reinforced composites were successfully investigated and the following conclusions are made:

- Incorporation of GSP fibres improved the thermal stability of RHDPE matrix.
- Storage modulus and load bearing capacity were found to be maximum for GSP composite having 25% wt. fibres content.
- Loss modulus was found to decrease with increase in fibre loading and temperature.
- The acceptable dynamic mechanical properties of the GSP composites indicate that it can be used for structural and non-structural applications.
- The SEM result further affirms why composite higher percentage loading shows better dynamic mechanical properties.

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