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Studies on the Properties of Linear Low Density Polyethylene Filled Oyster Shell Powder

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ABSTRACT
Mechanical and end-use properties of linear low density polyethylene filled oyster shell powder (of varying particle sizes 75µm, 125µm and 175µm) as function of filler contents were investigated. The polymer composite was fabricated by mixing LLDPE with 0 to 30 wt % of oyster shell powder using injection moulding machine to obtain a material with enhanced and desired properties. The experimental test on mechanical properties such as tensile strength, tensile modulus, elongation at break, hardness, flexural test and end-use properties such as flame propagation rate, specific gravity and water absorption were carried out on the composite sample prepared. Experimental results confirmed that polymer composite produced from the combination of oyster shell powder and LLDPE matrix showed increment in tensile strength, tensile modulus, hardness and flexural strength with reduction in elongation at break. Flame propagation rate behaviour of the composite decreased with increase in filler content while the specific gravity and water absorption properties of the composite increased with increase in filler content.

KEYWORDS: *LLDPE, Oyster shell, Flame propagation rate, Water absorption, Mechanical properties.*

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I INTRODUCTION

The wide use of polymeric materials such as plastics in various applications like engineering, medicine, automobile, sports, domestics, packaging, etc is increasing rapidly nowadays as result of effective modification of the properties of plastics using additives. This enables polymeric materials to overcome its specific deficiencies during service and lowering the high rate dependency of petroleum-based plastics due to depletion of our natural resources, and new environmental regulations which demand the search for materials that are compatible with environment (Ewulonu and Igwe, 2012). Among all the additives being used in the modification of plastic properties, extending and reinforcing fillers (either in fibrous or particulate form) have played significant role. Recently, the sources of fillers for polymeric materials has been shifted to agricultural materials (Brydson, 1967) or natural products (as an alternative to expensive and toxic inorganic fillers) due to their availability, low cost, eco-friendly, biodegradability, etc.

The use of modern equipment capable of reducing the natural fillers to nano-particle sizes (Igwe and Onuegbu, 2011), chemical modifications and coupling agents (Onuegbu, Madufor and Ogbobe, 2012) for better matrix-filler adhesion has enlarged the scope of applications of the natural fillers in the plastic industries. Linear low density polyethylene is an important commercial polymer which is widely used for different applications in modern technology. It has higher tensile strength, impact and puncture resistance when compared to low density polyethylene, and is very flexible, elongates under stress, and can be used to make thinner films, with better environmental stress cracking resistance. It has good resistance to chemicals and good electrical properties. LLDPE has penetrated almost all traditional markets for polyethylene; it is used for plastic bags and sheets (where it allows using lower thickness than comparable LDPE), plastic wrap, stretch wrap, pouches, toys, covers, lids, pipes, buckets and containers, covering of cables, geomembranes, and mainly flexible tubing. LLDPE can be recycled though into other things like trash can liners, lumber, landscaping ties, floor tiles, compost bins, and shipping envelopes.

Oyster shell is a biomaterial containing 96% by weight of compound in the form of calcium carbonate ($CaCO_3$) and 4% by weight of organic materials such as SiO_2, MgO, Al_2O_3, SrO, P_2O_5, Na_2O, SO_3. It is clear that the oyster shell powder can change the properties of LLDPE matrix because of its nature, size, shape and distribution.In the scientific literature, different materials have been used to fill linear low density polyethylene. These materials include cassava starch (Madufor, 2007), potato starch (Mishra and Talele,2002), corn starch (Goheen and Wool 1991), sisal (Mokoena, Djoković and Luyt, 2004), rice husk (Khalf and Ward, 2010), starch (Raj, Sankar and Siddaramaiah, 2004), sepiolite (Rehmat, Tariq, Atif, Sadullah, 2011), sago starch (Nawang, Danjaji, Ismail, Mohd Ishak, 2001), Chitosan (Shahrzad, 2011), copper powder (Luyt, Molefi, and Krump,2006), Calcium Carbonate (Ji-Zhao, 2007), Calcite (Sangmin et al, 2002) and others. The use of oyster shell powder in filling linear low density polyethylene had not been reported in the scientific literature to the best of our knowledge. Oyster shell is a domestic waste. This study focused on the effect of oyster shell powder content and particle size on the properties of linear low density polyethylene to exploit the potential of the properties of the oyster shell for the development of a novel composite.

II MATERIALS AND METHODS

2.1. Materials

The linear low density polyethylene used in this study was a product of Indorama Petrochemical Company Limited, Eleme, Rivers State, Nigeria. It has a melt flow index of 2.5 g/min and density 0.926 g/cm^3. The oyster shell from which oyster shell powder was produced was obtained locally from Naze, Imo state, Nigeria. The oyster shell was properly treated to remove impurities before it was crushed and sieved to particle sizes of 75µm, 125µm and 175µm respectively

2.2. Preparation of Linear Low Density Polyethylene Filled Oyster Shell Powder

The linear low density polyethylene filled oyster shell powder (of varying particle sizes of 75µm, 125µm and 175µm) samples were prepared by proper and thorough mixing of 200g of linear low density polyethylene matrix with appropriate filler quantities (5, 10, 15, 20, 25 and 30 wt %). Then, the resulting constituent of each composite sample was melt-blended and homogenized in an injection moulding machine and the composite samples were produced and obtained as sheets.

2.3. Properties Testing

Tensile stress-strain measurements were evaluated using an Instron Universal Testing Machine (ASTM D638) from which tensile strength, elongation at break, and tensile modulus were determined. Rock well hardness (ASTM D 785), flexural strength (ASTM D 790), specific gravity (ASTM 792), water absorption (24hrs) behaviour (ASTM D570) and flame propagation rate (ASTM D 4804 with modifications) were determined by standard procedure.

III RESULTS AND DISCUSSIONS

3.1. Tensile Strength

The effect of oyster shell powdered filler content and particle size on the tensile strength of linear low density polyethylene is illustrated graphically in Figure 1. From Figure 1, the tensile strength of linear low density polyethylene/oyster shell powder composite was observed to increase as the oyster shell powdered filler content increases and decrease as the particle size increases. It is seen that the polymer composite with smaller particle size of oyster shell powder exhibited higher tensile strength than the polymer composite with high particle size. This behaviour could be attributed to better dispersion and filler-matrix interaction between the polymer matrix and finer oyster shell powder due to larger surface area associated with the finer particles. Bigg (1987) and Fuad et al (1995) have presented the similar observations in filling other polymer systems with particulate filler.

3.2. Elongation at Break

Data on Figure 2 shows the effect of oyster shell powdered filler on the elongation property of linear low density polyethylene. It can be seen from Figure 2 that the elongation at break of linear low density polyethylene/oyster shell powder composite decreased with increase in filler content at any given filler particle size considered. The increase of the filler content in the LLDPE matrix resulted in the stiffening and hardening of the composite which reduced its ductility, and led to lower elongation property. The reduction of the elongation at break with the increasing filler content indicates the incapability of the filler to support the stress transfer from filler to polymer matrix. Such a reduction in elongation at break of a polymer composite with increase in filler content, irrespective of filler particle size has been reported by Siti Shuhadah and Supri (2009).

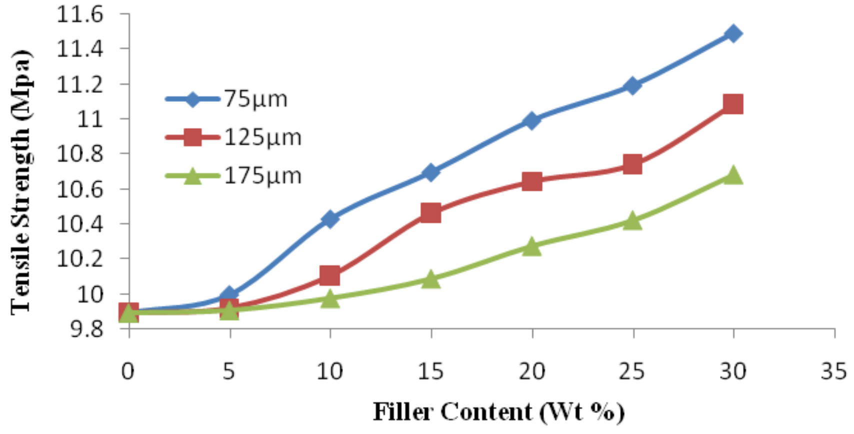

Fig 1: Plot of Tensile Strength (MPa) against Filler Content (Wt %)

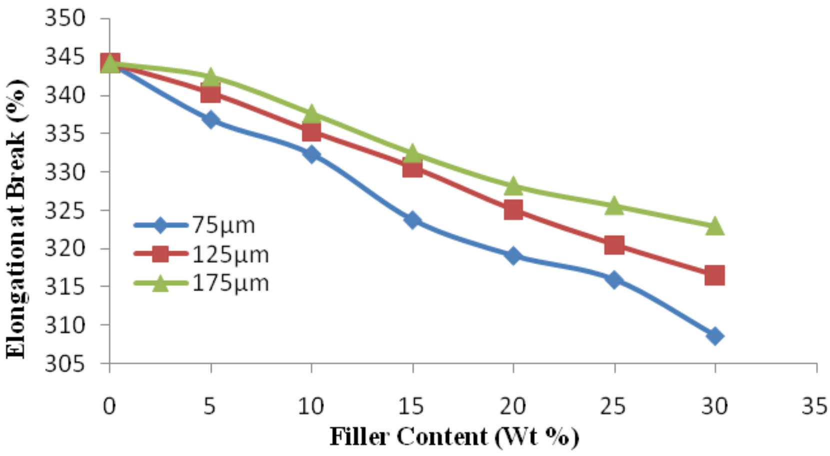

Fig 2: Plot of Elongation at Break (%) against Filler Content (wt %)

3.3. Tensile Modulus

The effect of oyster shell powdered filler on the tensile modulus of LLDPE matrix is shown in Figure 3. Figure 3, shows that the modulus of oyster shell powder filled linear low density polyethylene is higher than the modulus of unfilled linear low density polyethylene, and increased with increase in filler content. This observation is a clear indication that the addition of powdered filler into linear low density polyethylene matrix improves the stiffness of the polymer composite. In addition, Figure 3 exhibits that as the particle size increased tensile modulus decreases. This behaviour could be envisaged from the fact that particulate filler with smaller particle size are embedded more within the polymer structure than particulate filler with greater particle size.

3.4. Flexural Strength

Data on the impact of flexural strength of oyster shell powder filled linear low density polyethylene is illustrated graphically in Figure 4. It is observed that at any particle size of the oyster shell powder considered, the flexural strength of the composites increased with increase in oyster shell powdered filler contents. Furthermore, there is a general decrease in the flexural strength of the composites as the particle size of the fillers increased from 75µm to 175µm. The increase in flexural strength with corresponding increase in filler content may relate the fact that when oyster shell powdered filer is added to the polymer system it acts like a binder which stiffens the elasticity of the polymer matrix and increase the ability of the composite absorb and dissipate energy.

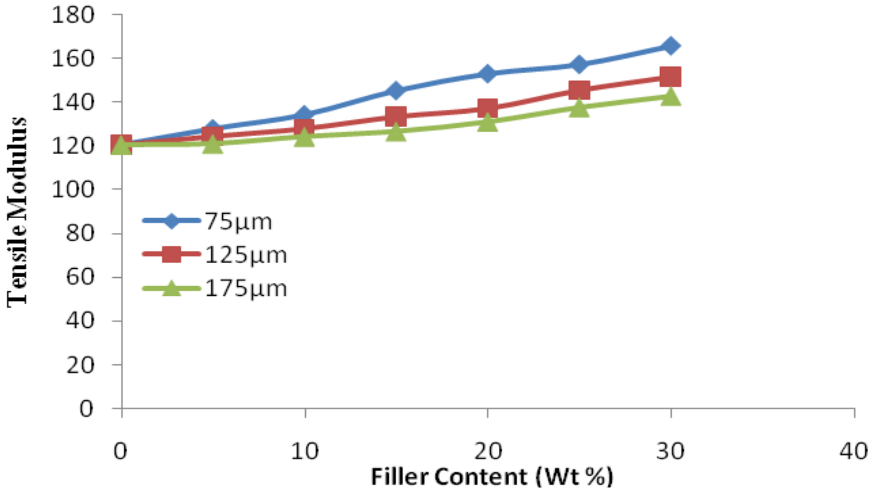

Fig 3: Plot of Tensile Modulus (MPa) against Filler Content (Wt %)

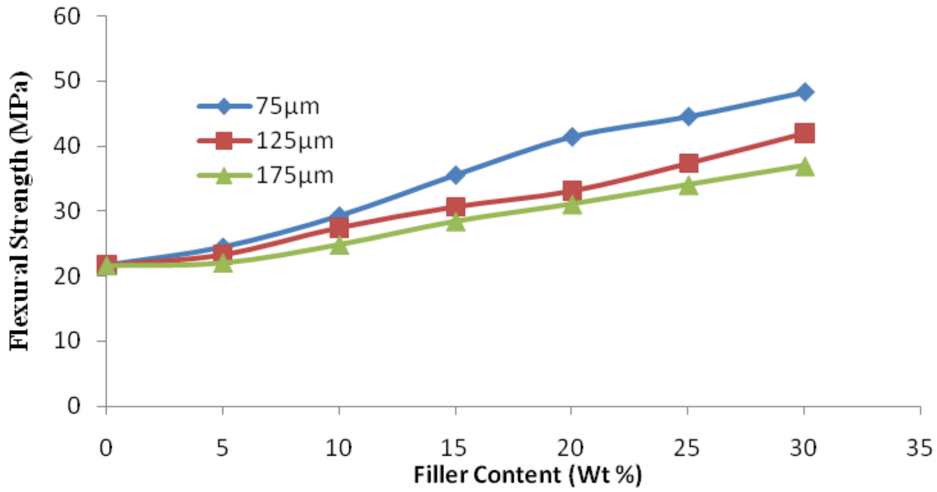

Fig 4: Plot of Flexural Strength (MPa) against Filler Content (Wt %)

3.5. Hardness

Figure 5 shows the effect of oyster shell powdered filler on the hardness of filler linear low density polyethylene. It is observed that incorporation of the oyster shell powdered filler into polymer matrix increased the hardness of the composites for all the particle size investigated. This is attributed to the fact that hardness is generally considered to be a surface effect or property, therefore the addition of the oyster shell powder leads to a decrease in the elasticity and increase in the matrix surface resistance to indentation.

3.6. Specific Gravity

The specific gravity or density of polymer composites is a very important property that determines specific load application of the composite. This is because specific gravity or density has a direct relationship with the load bearing capacity of the composite as well as the cost. Figure 6, shows that there is a general increase in the specific gravity of the composites with increase in filler content of all the oyster shell powdered filler particle size considered. The figure also shows that there is a general decrease in the specific gravity of the composites as the particle size of the oyster shell powder increases. This behaviour is envisaged from the fact that there is more or greater uniform dispersion between the smaller particle size of the filler and the matrix.

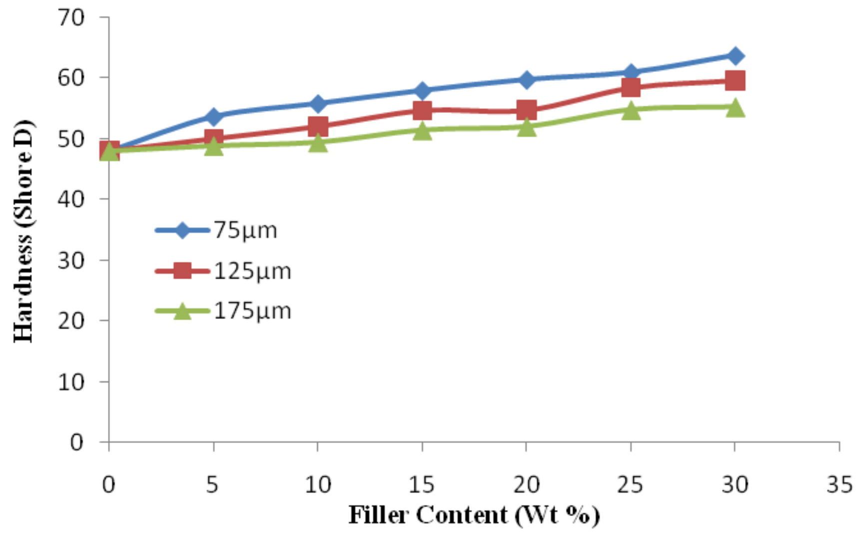

Fig 5: Plot of Hardness (Shore D) against Filler Content (Wt %)

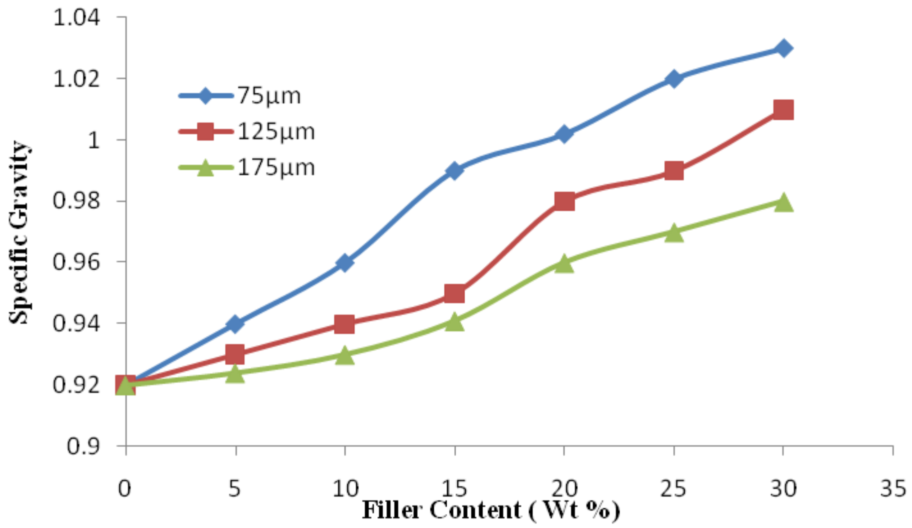

Fig 6: Plot of Specific Gravity against Filler Content (Wt %)

3.7. Water Absorption

Water absorption (cold water-24hrs) behaviour is a very important characteristic to be considered in selecting the possible applications of the polymer composites. This is because it provides clear information on the suitable and limited applications of the filler in the different applications. Data on the variations of water absorption behaviour as a function of filler contents and particle sizes (75µm, 125µm and 175µm) is illustrated graphically in Figure 7. It is observed that all the linear low density polyethylene/oyster shell powder composites investigated generally showed increase in water absorption with increase in oyster shell content. Furthermore, it is also observed that the amount of water absorbed at any given filler content decreased with reduction in the particle size of filler. This could be attributed to proper distribution of the filler with smaller particle size within the matrix and increase in the surface area of the filler with smaller particle size.

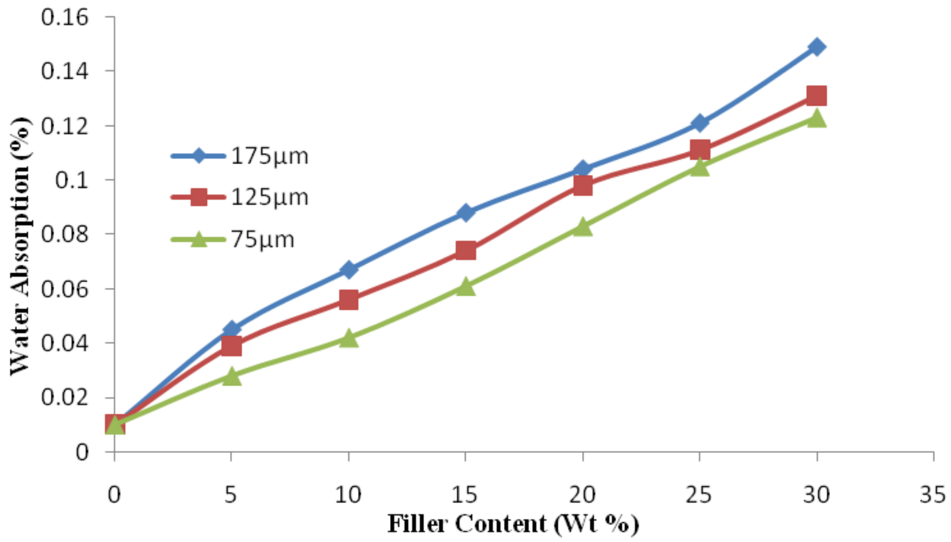

Figure 7: Water Absorption (%) Versus Filler Content (Wt %)

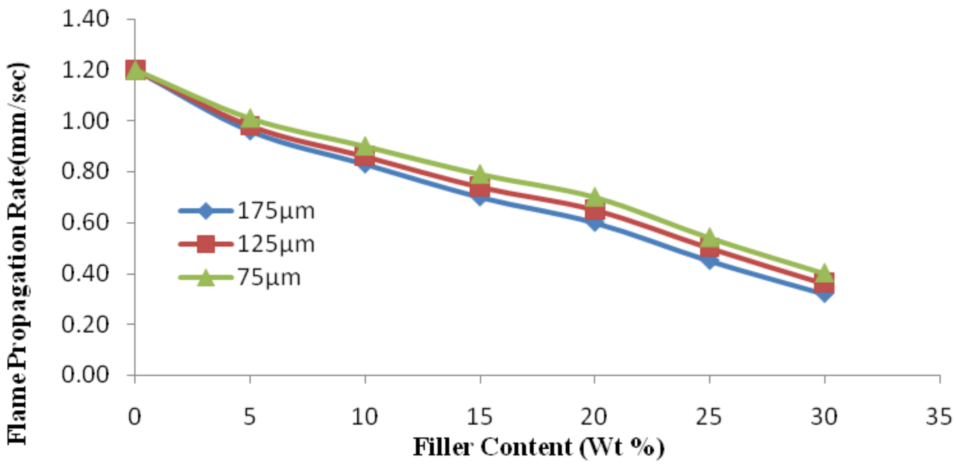

Figure 8: Flame Propagation Rate (mm/sec) Versus Filler Content (Wt %)

3.8. Flame Propagation Rate Behaviour

The flame propagation rate behaviour of the prepared composites at any given particle size of the oyster shell powdered filler considered was generally observed to decrease with increase in oyster shell powdered filler contents as shown in Fig 8. In addition, the effect of particle size of the oyster shell powdered filler on the flame retardant property does not show much variation because all the particle sizes investigated exhibited similar flame retardant property as seen from the curves in Fig 9. The resultant effect of the flame propagation rate behaviour of the prepared composites is a practical conformation that the flame retardant property of linear low density polyethylene is greatly improved by oyster shell powder. The calcium carbonate which is the major compound contained in the oyster shell could be attributed to the flame retardant property of the oyster shell. This is because on application of heat or flame calcium carbonate undergoes decomposition whereby calcium oxide is produced with the release of carbon dioxide which does not support combustion. Furthermore, the proper adhesion between the matrix and filler reduced flame spread characteristics of the polyethylene and improved the flame retardant behaviour of the composite. Finally, as the incorporation of oyster shell powdered filler into linear low density polyethylene matrix increases there is a reduction in the tendency of the composite to burn showing that calcium carbonate can be used to provide escape time in the case of fire outbreak.

IV. CONCLUSION

Oyster shell powder has been utilized efficiently in preparing linear low density polyethylene composites. The tensile strength, tensile modulus, flexural strength, hardness, and specific gravity of the linear low density polyethylene composites were found to increase with increase in filler contents, and decrease with increase in filler particle size. The elongation at break of the prepared composites decreased with increase in filler contents and particle sizes. The water absorption properties of the composites were increased on addition of oyster shell powder, while the incorporation of oyster shell powder into the polymer systems led to reductions in the rate of burning of the composites. However, the level of water absorbed by prepared composites is high compared to unfilled LLDPE. It is therefore highly recommended that the applications of the prepared polymer composites should be selected where water absorption by LLDPE composite is not limited factor. Generally these properties investigated were greatly enhanced and the trend of property improvement observed in the prepared composites is outstanding evidence that oyster shell powder can play significant role in the plastic industry.

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