Physical properties of some agro waste – polymer composites

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Natural fiber is a low cost and renewable material of great interest in composite fabrication. Presently, the automobile industry has found it very useful because of its unique properties. Three different agro wastes were incorporated into High Density Polyethylene (HDPE), respectively for composite fabrication to course modification on the properties of the Polymer, (High Density Polyethene). The mixing was done with the help of Two Roll Mill. The physical properties of the fabricated composites were determined using specified ASTM Standards specification for the various tests. Properties such as hardness, density, percentage water absorption, effect of UV and biodegradation were studied. The results obtained showed that EGR had better hardness at 100 g filler content, the densities of the three agro-wastes - HDPE composites obtained ranges from 0.8 to 0.9 g/cm³. In fact, the densities of the resultant composites were lower than some building materials like Zinc and Aluminum. Also, the composites fabricated with Coconut shell and Palm kernel nut shell with HDPE showed low percentage water absorption when compared to Groundnut shell – HDPE composites. ECO and EPK were stable to weather changes up to 12 months of exposure before visible degradation was observed. And for a period of the 18 months there was no evidence of microbial attack.

Key words: High density polyethylene (HDPE), groundnut shell – high density polyethylene composites (EGR), coconut shell – high density polyethylene composites (ECO), palm kernel nut shell – high density polyethylene composites (EPK), E - glass – high density polyethylene composites(EGP).

INTRODUCTION

The use of fibres derived from annually renewable resources provides positive environmental benefits with respect to ultimate disposability and raw material utilization. They serve as excellent reinforcing agent for plastics because of their moderate high specific strength and stiffness when used as reinforcing material. They are potential resources for making low cost composite materials. The fibrous type of agro - waste have attracted the interest of many researchers because, they give composites with improved overall properties compared to the non-fibrous fillers. Lignocellulose fibres like Jute, Coir and Pineapple have been reportedly used as reinforcements in Polymer matrices (Joseph et al., 2000).

The major setback to general acceptance of natural fibre – polymer composites is the relatively rapid water uptake which has the ability of causing dimensional instability and rotting of the material during service life. The fibre cell which is tubular in shape transports water into the composite system. Rouison et al. (2005) confirmed rapid uptake of water through material edges using magnetic resonance imaging. Also, research has shown that some fibres like coconut fibre, have bundles of fibre cells around its central cavity or lacuna (Brahmakumar et al., 2005). The existence of lacuna can enhance movement of water into the composite. At low fibre contents, the matrix restrains expansion of the fibres while at high fibre content there is insufficient matrix to maintain this restrain and the fibre can take up more
water than its weight in water (Hargital et al., 2006). Kevlar-reinforced composites reach equilibrium water absorption at less than 10% while glass – reinforced composites reach equilibrium moisture contents at less than 1% (Wan et al., 2005). Water uptake is associated with swelling, which has the tendencies of causing components to separate.

Kim and Sco (2006) compared composites made from woven sisal mat. After five wet-dry circles, the strengths of vinyl epoxy components had decreased to 80% and <20% of the original values, respectively. Loss of strength in the epoxy composite can be attributed to hydrolysis reaction. Series of attempts have been made to improve water resistance of natural fibres.

Bisanda and Anseel (1991) treated sisal with an organosilane to decrease the influence of water on the mechanical properties of sisal-epoxy composites. Stamboulis et al. (2000) showed that the water uptake of Flax polypropylene composites could be decreased by approximately 30% through heat treatment of the Flax prior to fabrication of the composite. Lee and Wang (2006) treated bamboo fibres with lysine diisocyanate to increase its water absorption property. Water absorption in natural fibre composite is highly reduced by fibre modification. Fibre modification helps to increase the interface adhesion between the fibre and the matrix by roughing the fibre surface. Research findings have shown that when the fibre surface is rough it help to increase bonding (Yuan et al., 2002; Babraukas, 1984).

When natural fibre plastic composites are exposed to sunlight – irradiation, various deteriorations including colour change occur (Robert et al., 2000). Most often the surface chemistry changes due to photodegradation (Falk et al., 2000; Matuana and Kamdem, 2002; Stark and Mantuana, 2002, 2003). It makes such articles to be aesthetically unappealing. Prolonged exposure to UV sometimes leads to fracture in the product and make it more vulnerable to other weathering elements in the surroundings such as water and wind. UV radiation sometimes is one of the major practical problems that natural fibre plastic composites products encounter in outdoor applications. Stark (2005) studies suggested that some processing techniques affect the degradation by UV exposure.

This work is designed to primarily investigate the behavior of the three chosen agro – waste – HDPE composite when exposed to water and other weather effect for some specified period of time. Fiber modification is not cost effective, therefore modified fibre polymer composites are expensive, hence the need to search for natural fibres that have relatively low percentage water absorption that could be used for low cost natural fiber composite manufacture.

However, research effort have shown that E-glass composites has approximately zero percent water absorption, therefore, for the purpose of this study, E-glass was made the reference sample; the properties obtained from the agro-waste composites were compared to that of the E-glass.

**EXPERIMENTAL**

**Preparation of composites**

Different amounts of shell particulates; Groundnut, Coconut, Palm kernel nut and E-glass were compounded into 100 g of High Density Polyethene (HDPE) ranging from 5 to 100 g. This was achieved using Carvers Two Roll Mill model No. 5183 at a processing temperature of 150°C and speed of 1.0 and 2.5 rpm for rear and front roll, respectively for 7 min. The resulting materials were compression molded at a pressure of 10 tons on a Carver Laboratory Hydraulic Hot Press at a temperature of 150°C (Plate 1). The specimens for the different properties tested were prepared according to ASTM standard specifications using an appropriate mold (Plate 2).

**Comparative studies of the densities of the various composites**

Specimens of equal dimension (50 × 30 × 2.5) mm were cut from all the composites and two other conventional roofing materials; Zinc and Aluminum. The densities of these samples were determined using flotation method and were compared with the density of each of the conventional roofing materials and the results obtained are presented in Figure 2.

**Water absorption of composites**

For this study, rectangular specimens were cut from each sample with dimension 150 mm × 70 mm × 2 mm. The samples were conditioned and weighed to the nearest 0.001 g in accordance with ASTM standard specification. The samples were immersed in water for 48 h at room temperature according to ASTM procedure D96 – 06 and excess water on sample surface was removed before reweighing (Plate 3). The percentage increase in mass during immersion was calculated to the nearest 0.01% using the following equation:

\[
\text{%Increase in mass} = \frac{\text{Weight after 48h} - \text{Initial weight}}{\text{Initial weight}} \times 100
\]

**Environmental effect**

Different composites of various shell compositions and dimensions were weighed and exposed on a bench to the weather for a period of 18 months as shown in Plate 4. In the beginning data were collected and observation made on weekly basis. But when there was no measurable change, the interval of measurement was increased.
Plate 1. Wooden pattern for a prototype roofing sheet mould.

Plate 2. Agro - waste – high density polyethylene (HDPE) composite samples for various tests.

Plate 3. Water absorption test of the various fabricated composites.
Plate 4. Agro waste – high density polyethene (HDPE) composites of various formulations before exposure to the weather.

Plate 5. Agro waste – high density polyethene (HDPE) composites of various formulations after exposure to the Weather for 18 months.

Plate 6. Agro waste – high density polyethene (HDPE) composites of various Formulations buried for 18 months.

Biodegradation

A rectangular sample of various composite formulations of dimensions 70 mm × 20 mm × 2 mm were buried for a period of 18 months (Plate 6). At first, samples were observed on weekly basis, when no significant change was observed; the period was later extended to monthly basis.
RESULTS AND DISCUSSION

Shore-A Durometer hardness test proved the fabricated material to be a hard material with an optimum value of 93 Shore for EGR as shown in Figure 1. From the curves obtained, it is evident that when each of the agro waste was incorporated into the matrix, the hardness of the material was improved upon.

The fabricated composites showed a clear density advantage over the conventional roofing materials considered in this work. The densities of the composites are 0.8 g/cm³ for EPK, 0.9 g/cm³ for EGR and ECO, while Al and Zn have density values of 1.4 and 2.0 g/cm³, respectively as shown in Figure 2. The densities of the fabricated composite as obtained compared favourably with the densities of the regular roofing materials in the open market as all the agro – waste composites have densities lower than the two materials referenced to, zinc and aluminum. From the plot, the density obtained for zinc is approximately double of the value obtained for all the agro – wastes. Also, agro – waste – HDPE Composites had lower density when compared to the E-glass – HDPE composites which had a density of 1.1 g/cm³.

Organic filler are naturally hydrophilic because of the presence of the hydroxyl groups in its composition. This, in most times, makes its composites to absorb water. This is quite unsatisfactory for any engineering applications. From the results obtained in Figure 3, the % water absorption of the fabricated agro-waste - HDPE composites was zero up to 55 g filler content composition before water uptake occurred for EGR. ECO and EPK had zero % water uptakes at 80 g filler content which is quite encouraging because at that composition, the fabricated composite had a very good cost advantage.

At 60 g filler content, the quantity of water absorbed by EGR was less than 2%, while at 65 g filler content, the % water absorption went up to 10%. ECO and EPK at 85 g filler content had less than 5% water uptake. Their water uptake continued to increase with increase filler content until at 100 g filler content with less than 15% water uptake.

However, it was also observed that E – glass – HDPE composite which is mineral filler did not absorb water, even at high filler load content. The water absorption measured after 48 h was zero. This could be as a result of the hydrophobic nature of the two materials used for the formulations.

The agro-waste had marginal impact on the melting temperature of most of the fabricated composites. There was significant increase in the melting temperature of EPK approx. 50°C at high filler content of 90 g. ECO maintained same melting temperature up to filler content of 90 g before it increased by less than 20°C (Figure 4).

The effect of the environment on the various composites was studied through weight loss. The composites fabricated were exposed to the sunlight as shown in Plate 4. The composites fabricated were susceptible to the UV portion of the sunlight. Solar irradiance on these materials caused deteriorations including color change and loss of gloss which reduced product life time. Under UV, the exposed surface chemistry of the composite changed probably due to the photodegradation which might have led to discoloration of the composite. Literature suggests that HDPE are susceptible to photo-oxidation under exposure to UV-radiation due to the presence of chromophores. Normally, the free radicals formed in the initiation stage attack the polymer in the propagation stage and form new radicals. In the termination stage, two free radicals combine together to seize the reaction. The exposed samples were analysed on weekly basis to determine the effect of the environment on the various composites. When there were no much observed changes, the measurement was extended to monthly interval for 18 months.

After 6 months of exposure, the various groundnut shell – HDPE composites became dimensional unstable and there was colour changes which is a typical indication of...
photo degradation of the composites. For the period of 6 months of exposure to the weather, there was no notable weight loss. At 12th month, there was still no weight loss except that very high filler content compositions failed and degraded as shown in Plate 4. At the 18th month all the exposed composites failed (became very brittle and could not be reweighed). This suggested that the EGR composites for outdoor application should be fabricated with antioxidant to protect it from weather effect. These could be traced to poor interaction of the groundnut shell and HDPE during material fabrication. So when exposed to UV - radiation, photo oxidation commenced with the vinylene and hydro peroxide concentration acting as initiator and the carbonyl groups acting as auto – accelerating photo activator as suggested by Jabarin and Lofgre (1994) and Kaci et al. (2000). And the free radicals formed probably attacked the composite.

Coconut shell - HDPE composite did not show any loss in weight after 18 months of exposure to the environment. The composites showed high stability to sunlight –
irradiation and other weather effects. There were no changes in the physical appearance of the composite during outdoor exposure to sunlight – irradiation. This is probably as a result of degradation by chain scissor. This result indicates that coconut shells composites can be better for outdoor applications when compared with the EGR composites.

The Palm kernel nut shell – HDPE composites were dimensionally stable all through the 18 months period of exposure to UV – radiation and other weather effects. There was no change in colour observed. It also retained the little initial gloss observed before exposure. The result showed that there was no interaction of the compound with external agents that induces degradation in a material.

E-glass - HDPE composite was stable for 6 months, thereafter, the entire E-glass composites fabricated ranging from 5 to 100 g failed before the end of 12 months as shown in Plate 5.

The various composites fabricated were buried for 18 months to investigate the effect of microbes on the fabricated composites. The investigation employed only weight loss as a measuring tool.

Groundnut shell - HDPE composite did not undergo any biological degradation/microbial attack for a period of 6 months after it was buried. It was on the 18th month that some of the composites with high filler content began to degrade which was evident in the change in the specimen's weight, but with less than 1% weight loss. Coconut shell – HDPE composites did not show any change in weight for the period it was buried. At the end of 18 months, there was no weight loss, which depicts no microbial attack on the composites.

There was also no loss in weight in Palm kernel nut shell – HDPE composite for the entire 18 months of exposure.

EGP was stable for a period of 6 months without any weight loss, thereafter; there was complete failure and material degradation, which also depicts microbial attack.

**Conclusion**

Shore-A Durometer hardness test proved the agro waste – HDPE composites fabricated to be a hard material with the optimum value of 93 Shore by EGR at 100 g filler content as shown in Figure 1.

The Palm kernel nut shell – HDPE composites showed density of 0.8 g/cm³, while ECO and EGR had densities of 0.9 g/cm³ each at high filler content. These values are lower than the density of the polymer matrix used for the composite fabrication. ECO and EPK showed low % water adsorption which made it a preferred composite to EGR, while EGP showed zero % water absorption. EPK composites showed increase in melting temperature. Environmental and biological analysis conducted confirmed that low filler content compositions of ECO and EPK are not affected by the two agents ( UV and Microbes) as the composites remained dimensionally stable without any significant loss in weight all through the period of analysis. Therefore, ECO may be a preferred agro waste composite for outdoor application. In summary, results obtained from the studies showed that low cost composites with minimal water absorption can be fabricated using coconut shell and palm kernel nut shell without going through the process of chemical modification of the filler before use.

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