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SOME MECHANICAL AND END-USE PROPERTIES OF BAMBOO POWDER FILLED LOW DENSITY POLYETHYLENE COMPOSITES

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ABSTRACT

Plastic and bamboo powder can be used to produce composites for the construction industry. This would reduce the pressure on conventional materials such as wood from forest resources. In this research, the effects of bamboo powder filler on some mechanical properties of low density polyethylene (LDPE) composites were studied. Composites of LDPE and bamboo powder (BP) were prepared by melt extrusion using 0, 1, 3, 5 and, 7 % of bamboo powder filler. The results showed that the tensile strength and the elongation at break decreased with increasing filler loading for LDPE composites while the stiffness (modulus) of the composites increased with increasing filler loading. The percentage of water sorption by BP/LDPE composites is so small making these materials still suitable for use in damp environments. Specific gravity determination showed that BP/LDPE composites are very light materials since its specific gravity did not increase too much with respect to LDPE. Bamboo powder incorporation into the LDPE enhanced the flame retardant property of the LDPE.

Keywords: Low Density Polyethylene (LDPE), Bamboo Powder (BP), Composites, Matrix, Organic Filler

INTRODUCTION

Natural fibre reinforced thermoplastic composites (NFRTC) represent an opportunity to partially enhance the environmental impacts by integrating biodegradable filler material, such as flax, hemp, wood flour and bamboo, as an alternative for synthetic fillers, such as glass, carbon, or steel and perhaps more critically, the cost of some biodegradable filler materials is better than an order of magnitude less than synthetic reinforcing fibres.

(http://dspace.unimap.edu.my/bitstream/1,2,3,4,5,6,7,8,9/3362/6/introduction.pdf)

The use of the natural fibres, which is a type of organic filler, in polymeric materials especially in the thermoplastic polymer to form composite had been widely developed in order to reduce wastage of the natural fibres (Sapuan and Maleque, 2005; Singh et al, 1996; Saxena et al, 2008).

Natural fibre composites have considerable potential to replace conventional materials like metal, plastics and wood in structural and non-structural applications, especially in furniture industry (Sapuan and Maleque, 2005). Such composites impart strength and stiffness to the product, besides having advantages such as low cost, environment friendliness, low density, abundant availability, renewable nature and allow reducing the use of non-biodegradable plastic materials (Baron and Scmidth, 2005; Perez-Rigueiro et al, 2000).

Thermoplastic resins such as polypropylene, polyethylene, polystyrene and poly (vinyl chloride) soften when heated and harden when cooled. These characteristics allow other

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materials such as wood to be blended or mixed with the plastic to form a composite product (Adrian et al 2002).

Currently, bamboo utilization is confined to domestic use due to lack of modern skills, inappropriate processing skills and technology. This has resulted in wasteful processing and utilization (Bhatnagar, 2004).

Wood fibres are one of the natural fillers that were used as fillers in thermoplastics composites. The commercial market for wood fibre filled thermoplastic composites (WFTPC) has grown four-folds between the year of 1997 and 2000(Jamal et al, 2007). Twenty to thirty pounds of wood-based composites are used in cars behind the vinyl and carpeting on the doors, consoles, headlines, trunk liners, and seat backs. Other uses of wood fibre based composites are deck surface boards, picnic tables, industrial flooring, etc (Jamal et al, 2007).

There is need for a shift from wood based composites in order to reduce pressure on forest resources. Forest area in Nigeria is fast diminishing due to excisions for human settlement and less reforestation to match harvesting. According to the United Nations (UN) standards, forest cover should be at least 10% of a Country's total area.

EXPERIMENTAL

Materials

In this research, Low Density Polyethylene (LDPE) and Bamboo (Dendrocalamus strictus) Powder were used. The LDPE has a density of 0.923g/cm^3, and melt flow index of 2.25g/min and was obtained from Eleme Petrochemical Company, EPCL (now known as INDORAMA), Port Harcourt, Rivers State, Nigeria. The density of the Bamboo is 0.649g/cm^3.

The processing equipments used includes Mesh sieve (0.3mm), Cutlass, Laboratory Size single screw extruder, Instron machine (Universal Testing Machine),Electronic weighing balance, Shredding machine, Permanent marker (Ink), Grinding Machine, Personal Protective Equipment (PPE).

Preparation of Low Density Polyethylene Composites

The bamboo stem was shredded and the dust from the shredded bamboo stem was collected, sun-dried for three days to remove moisture from it. Then a home-made grinder was used to manually grind the bamboo dust to powder. The bamboo powder was later sieved at the Erosion Control Laboratory, FUTO.

The low density polyethylene composites of the bamboo powder filler of particle size 75um (0.3mm size) were prepared by thoroughly mixing 200g of low density polyethylene with appropriate filler quantities (0, 1, 3, 5 and 7 wt %) loadings. The prepared blend compositions were each extruded at the same temperature (145^{0}C).

Measurement of Mechanical Properties

Tensile properties of the composite were determined by an Instron Electromechanical Universal Testing Machine (UTM) - LR10K, model 3 type; using ASTM D5323 test method. 5 identical dumb bell samples for each composite were used to determine the tensile properties. Tensile Strength, Elongation at Break and Young's Modulus were recorded and calculated automatically by the instrument's software.

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Water Sorption Test

The extruded samples sheet was cut into identical average dimension of about 12mm * 15mm * 2mm.Then the cut samples were weighed with electronic weighing balance and it is recorded as the initial weight.

The test piece was loaded into a container (sample bottles) filled with water and they were immersed in water for 24 hours (one day) at 32^{o}C (room temperature).The test piece was then removed from their container, dried with filter paper to remove excess of water and weighed. The percentage of water sorption (24hours) was calculated using the expression:

Water Sorption (%) =[(W_f - W_i) / W_i] x 100 ……………………………….. (1)

Where W_i is the initial dry weight of the sample and

W_f is the final weight of the sample after 24hours of immersion in water.

Specific Gravity Test

An analytical weighing balance was used for specific gravity estimation. A beaker is used as an immersion vessel. A light thread was used in suspending the specimen in air, and water during weighing.

A test specimen (filled or unfilled low density polyethylene) was first weighed in air (n), and later in water (m).The specific gravity of filled or unfilled low density polyethylene was calculated using the expression:

Specific Gravity (S.G.) = n/m …………………………………………… (2)

Where n = weight of specimen in air

m = weight of specimen in water.

Flammability Test

A modification of ASTM D4804 method was used here. Since low density polyethylene filled or unfilled is a thermoplastic, flame spread is regarded as the rate of melt-burn, i.e. the rate at which the original length of the specimen decreases as flame/heat is applied or plays among the specimens.

A 6mm mark was made on each of the sample specimen. The specimen was then clamped horizontally in a retort stand with the mark 6mm distance protruding out of the clamp. The free end of the sample was ignited using a cigarette lighter, and the time taken for the sample to ignite was recorded as the ignition time (I_t). The sample was allowed to burn to the 6mm mark (D_p).

The relative rates of burning for the different samples were determined using the expression:

Rate of burning (mm/s) = D_p / (P_t – I_t) …………………………………… (3)

Where D_p = Propagation distance measured in millimeter

P_t = Flame propagation time measured in seconds

I_t = Ignition time measured in seconds

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RESULTS AND DISCUSSION

Mechanical properties

Table 1. Some mechanical properties of bamboo powder filled LDPE composites

Sample	*Wt. % of Filler*	*Tensile Strength (MPa)*	*Elongation at Break (%)*	*Young's Modulus (MPa)*
1	0	7.788	1169.372	5.304
2	1	5.007	1032.825	8.098
3	3	4.531	78.092	15.665
4	5	4.028	63.749	15.980
5	7	3.441	58.490	16.219

Tensile Strength

Table 1 shows the effect of filler loading on the tensile strength of BP-filled LDPE composites. It can be seen that the tensile strength for the composites decreases with increasing filler loading. This result, as shown in Figure 1, is similar to reports by Garg et al (2007). According to Salmah et al (2005), the decrease in tensile strength is due to the poor adhesion of the filler-matrix and the agglomeration of filler particles. Since the filler particles are very small, a high interfacial surface exists between the polar filler and the a polar matrix. As this area increases, the worsening bonding between them decreases the tensile strength (Katchy, 2000). On the other hand, poor interfacial bonding causes partially separated micro-spaces between the filler particles and the polymer matrix. The presence of voids obstructs stress propagation when tensile stress is loaded and induces increased brittleness (Yang et al, 2004). Bamboo powder filler is known for easy agglomeration. The presence of agglomerates can generate flaws and create additional voids between the filler and the polymer matrix thus diminishing tensile strength (Chand and Dwivedi, 2006).

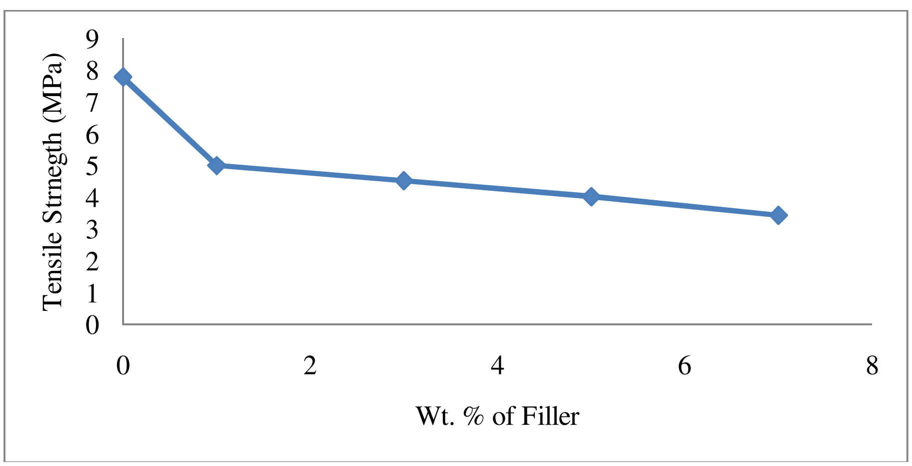

Figure 1. Effect of Filler Loading on the Tensile Strength of Bamboo Powder / LowDensity Polyethylene Composites

Elongation at Break

Table 2 shows the effect of filler loading on the elongation at break of BP-filled LDPE composites. From Figure 2, it can be seen that the elongation at break for the composites

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decreases with increasing filler loading. Increased filler loading in the LDPE matrix resulted in the stiffening and hardening of the composites. This reduced its resilience and toughness, and led to lower elongation at break (Jacob et al, 2004).The reduction of the elongation at break with increasing filler loading indicates the incapability of the filler to support the stress transfer from the filler to the matrix.

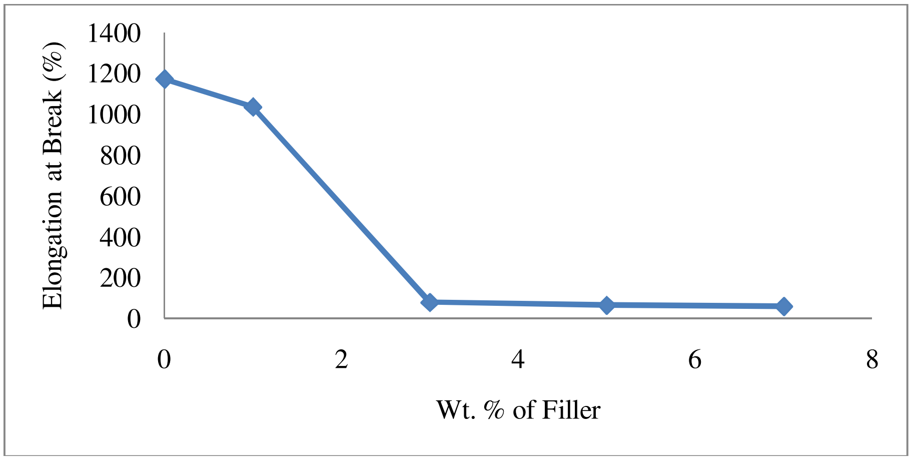

Figure 2. Effect of Filler Loading on the Elongation at Break of Bamboo Powder / Low Density Polyethylene Composites

Young's (Tensile) Modulus

Table 3 shows the effect of filler loading on the Young's modulus of BP-filled LDPE composites. Figure 3, shows that the Young's modulus for the composites increases with increasing filler loading. The increased modulus corresponds to more filler where its intrinsic properties as a rigid agent exhibit high stiffness (modulus) compared to polymeric material (Jacob et al, 2004).This is because at a high filler loading, the composites will be able to withstand greater loads. This behaviour is similar to a result reported by Ardhyananta et al, 2007). This is a common behaviour when rigid fillers are incorporated into softer polymer matrices (Yeh et al, 2003).

Natural lignocellulosic fillers have been found as having elastic modulus higher than PE, PP, and some other polymer materials (Wang et al, 2006). Because of this, the rigidity of its composites tends to strongly increase with addition of these fillers (Chui and Qing, 2008).

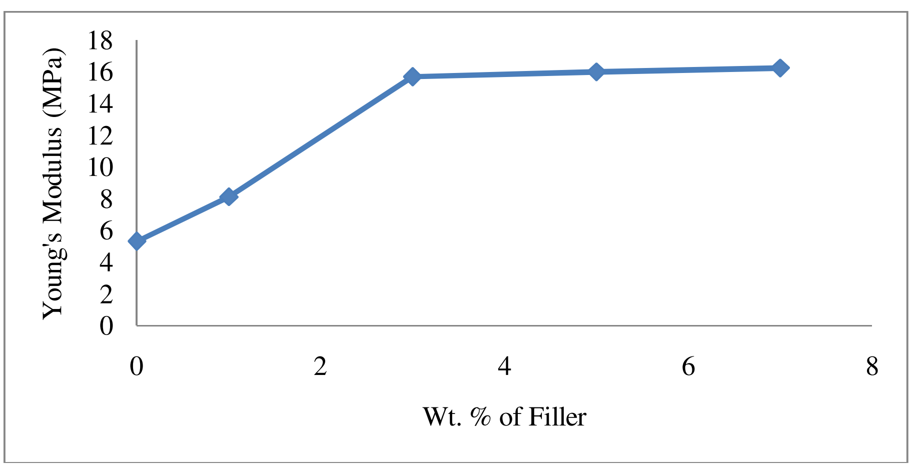

Figure 3. Effect of Filler Loading on the Young's Modulus of Bamboo Powder/Low Density Polyethylene Composites

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Table 2. Some end-use properties of bamboo powder filled LDPE composites

Sample	*Wt. % of Filler*	*Water sorption (24hrs) (%)*	*Specific Gravity*	*Flame propagation rate (mm/s)*
1	0	0.75	0.938	0.35
2	1	1.99	1.020	0.30
3	3	2.34	1.220	0.27
4	5	2.48	1.267	0.23
5	7	2.67	1.311	0.18

Water Sorption

Table 2 shows the percentages of water sorption (for 24 hours) for the BP/LDPE composites with different filler loading. Composites with higher BP loading show more water sorption as shown by Figure 4. This is due to the higher contents of filler loading in the composites that can absorb more water. As the filler loading increases, the formation of agglomerations increases due to the difficulties of achieving a homogeneous dispersion of filler at higher filler loading (Wang et al, 2006).

The agglomeration of the filler in composites increases the water sorption of the composites. The composite containing 7 wt % of BP showed the expected behaviour of highest level of water sorption attained by the composite with the highest concentration of the hydrophilic filler (Vera et al, 2007). This suggests that water penetration into the filler voids can be the more important mechanism of water uptaking as the BP level increases in the composites (Qunfang et al, 2002).

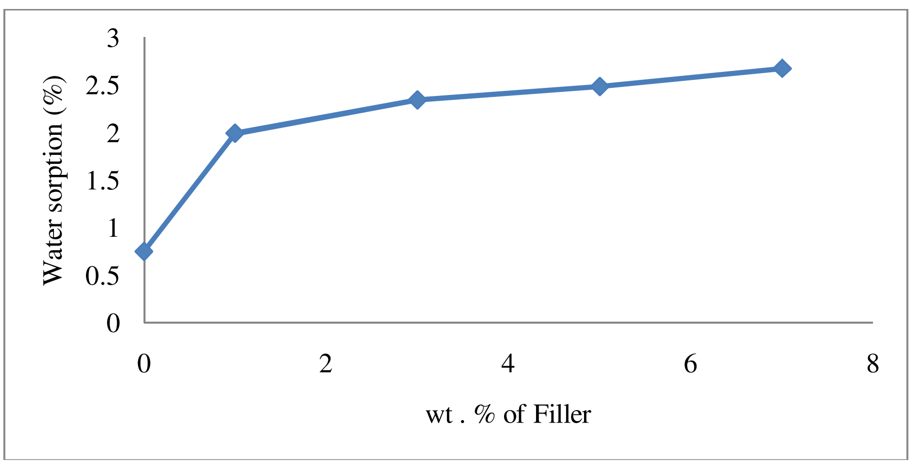

Figure 4. Effect of Filler Loading on the Water Sorption of Bamboo Powder/Low Density Polyethylene Composites

Specific Gravity

In solid-like composites, the specific gravity of natural fibres is a key for determining the specific gravity of the composites (Shibata et al, 2005). Table 2 shows that there was a continuous increase in the specific gravity for all the composites in comparison to that of LDPE.

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From Figure 5 it seems that a slight tendency of increasing specific gravity with increasing bamboo powder concentration occurred.

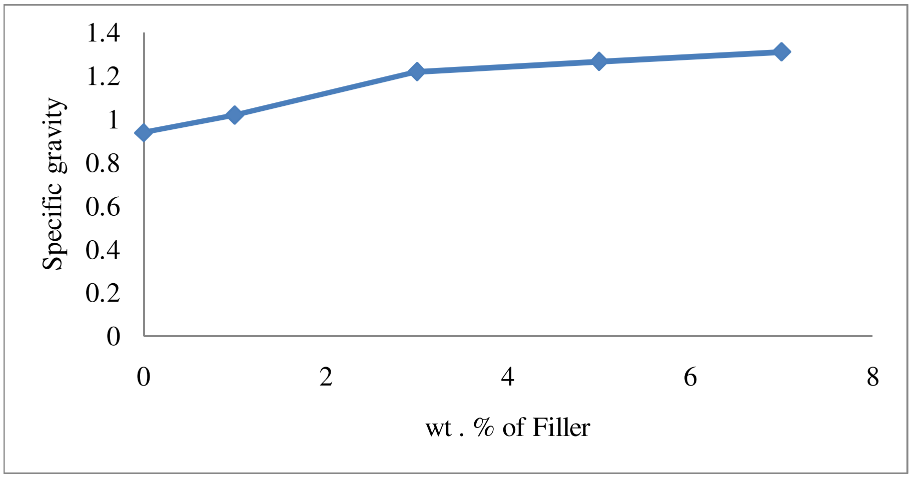

Figure 5. Effect of Filler Loading on the Specific Gravity of Bamboo Powder / Low Density Polyethylene Composites

Flame Propagation

From Table 2 it can be observed that the rate of flame spread of the composites decreases with increase in filler loading for all the composites. The results from Figure 6 indicate that the flame retardant property of LDPE is enhanced by bamboo powder filler. Thermo plasticity is observed as shrinkage and softening or melting when such materials are subjected to heat. Both melting and shrinkage have the effect of reducing apparent flammability (Morreale et al, 2007). On approaching the ignition source, a thermoplastic material will shrink and even drip away from the flame. This behaviour ensures energy removal, decrease in surface area exposed, and hence, reduction in flame accessibility. The present flame retardant property of the filler investigated could be attributed to the following factors: A good percentage of the filler contents might not be combustible, and so provide environments unfavourable to flaming. The BP in the LDPE is seen as impurities and it needs more heat for its constituents to break down before it begins to burn; hence enhancing the flame retardant property of the LDPE(Ismail et al, 2002; Hatta and Akmar, 2008).

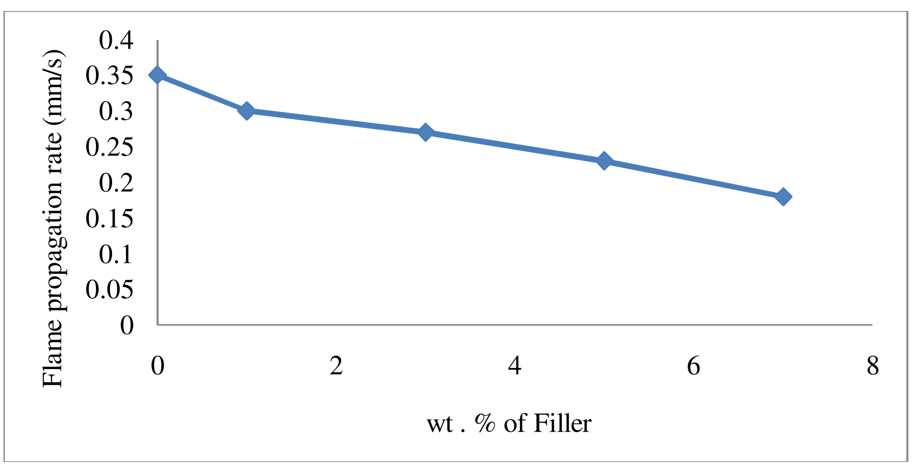

Figure 6. Effect of Filler Loading on the Flame Propagation Rate of Bamboo Powder/ Low Density Polyethylene Composites

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CONCLUSION

Bamboo stems were sourced, shredded, dried, ground to powder, sieved and used as filler in LDPE composites. The results obtained from this research showed that it is feasible to use bamboo powder as low cost filler, in view of the properties of the obtained products. For instance, the composites' stiffness (Young's Modulus) was seen to increase with increasing filler loading even though the tensile strength and elongation at break decreased slightly with increasing filler loading. The percentage of water sorption by BP/LDPE composites is so small making these materials still suitable for use in damp environments. Specific gravity determination showed that BP/LDPE and composites are very light materials since its specific gravity did not increase too much with respect to LDPE. The addition of Bamboo powder to the LDPE enhanced the flame retardant property of the LDPE.

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