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THE EFFECTS OF BAMBOO POWDER ON SOME MECHANICAL PROPERTIES OF RECYCLED LOW DENSITY POLYETHYLENE (RLDPE) COMPOSITES

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ABSTRACT

Despite the advantages that plastics have over the conventional materials, there are also some problems and challenges they pose to the industrial world. Many parts of the world including Nigeria face serious problems of managing the generation and disposal of plastic wastes. To reduce the volume of plastic wastes that go to landfills or litters the environment, there are three alternatives: recycling, incineration and biodegradation. In this research work, the effects of bamboo powder filler on some mechanical properties of recycled low density polyethylene (RLDPE) composites were studied. Pure water sachets and Bamboo stems were sourced. Recycling of Plastics (Low Density Polyethylene, LDPE) and the preparation of RLDPE/BP composites were carried out using locally made Laboratory-size Agglomerating Machine (agglomerator) and Single-Screw Extrusion Machine. The results of the mechanical tests carried out showed that the tensile strength and elongation at break decreased with increasing filler loading for RLDPE composites while the stiffness (Young's Modulus) of the composites increased with increasing filler loading. These results produced materials with lower void content that decreased the water sorption level with slight increase in the specific gravity of the composites. Bamboo powder incorporation to the RLDPE, also, enhanced the flame retardant property of the composites.

Keywords: Recycled Low Density Polyethylene (RLDPE), Bamboo Powder (BP), Agglomerator, Extruder, Recycling, Filler.

INTRODUCTION

Polyethylene or polythene (IUPAC name polyethene or poly (ethylene)) is a thermoplastic commodity heavily used in packaging and having the repeating mer molecule structural unit of $(C_2H_4)_n$. Over 60 million tons of the materials are produced worldwide every year. The recommended scientific name polyethylene is systematically derived from the scientific name of the monomer (Piringer & Baner, 2008; Carraher, 2010; Allcock et al., 2003).

Being one of the classes of polyethylene, Low Density Polyethylene (LDPE) was originally prepared some fifty years ago by the high pressure polymerization of ethylene. Its comparatively low density arises from the presence of a small amount of branching in the chain (on about 2% of the carbon atoms). This gives a more open structure. Low Density Polyethylene (LDPE) is defined by a density range of 0.910-0.940g/cm^3 and a specific gravity of 0.92. It has a high degree of short and long chain branching, which means that the chains do not pack into the crystal structure as well (http://en.wikipedia.org/wiki/polyethylene; Crawford, 1998; Berins, 1991; Ward, 1983; Cardarelli, 2008).

Materials systems which can be conveniently made to flow or deform into a desired shape or form, usually under heat and / or pressure, are commonly known as plastics. The binding material in a given plastic product is invariably a polymer or resin. A resin is defined as a material, organic in nature and of either synthetic or natural origin, which has the capacity to produce a thin coherent film either from its melt or from its solution. If we go to the ancient era, we find that development starts from Stone Age, Metal Age and now Plastic Age. Most of the items which are used for domestic and industrial purposes are made of plastics. The conventional materials such as metals, aluminium etc are fast being replaced by plastic materials. Plastics offer advantages such as resistance to corrosion, transparency, lightness, cheapness, easy processibility, etc.

Despite the advantages that plastics have over the conventional materials, there are also some problems and challenges they pose to the industrial world. Many parts of the world including Nigeria face serious problems of managing the generation and disposal of plastic wastes (Katchy, 2000; Charrier, 1990; Bhatnagar, 2004; Gruenwald, 1992; Hensen, 1997; Allcock, 2008; Piringer & Baner, 2008).

At present, plastics account for roughly a quarter of all solid waste by volume in U.S.A., Nigeria and many countries of the world. At the present rate, landfill capacity could be exhausted in few decades mostly in the urban settlements.

To reduce the volume of plastic wastes that go to landfills or litters the environment, there are three alternatives: recycling, incineration and biodegradation (Jimenez, 2008).

Plastics recycling involve the use of some machines such as agglomerating machine, extruder, injection moulding machine, blow moulding machine, etc. The machines can be foreign or locally made. The use of locally-made machines is advisable in order to encourage indigenous technology (Ehrig, 1992; Chanda & Roy, 2008; Reyne, 2008).

In polymers used for recycling, contamination is omnipresent, resulting in reduction of the quality of recycled products. It can be in the form of dirt, printing inks, paper, metals, foils, additives, pesticides, partially oxidized polymers; contamination by foreign bodies can be noticed even in PET and HDPE bottles collected from road-sides. In very old scraps of building products, electrical and electronic system, vehicles, furniture etc, which now come for recycling may contain very high concentration of additives in particular, fire retardants, which are now banned. Contamination can be reduced if consumers can be organized to segregate polymer products before disposal. However, accidental or unintentional mixtures, multi-component products etc do pose problems (http://www.envis-icpe.com/recycling products.htm; Tran-Bruni & Deanin, 1987).

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 fibers (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 (Katchy, 2000).The most environmentally friendly alternative for plastic waste disposal – is the process by which we can re-utilize the energy content of the polymer in an ecologically acceptable way. The other two alternatives are land filling, and incineration, which have, amongst others, the following constraints, especially because of increasing rapid accumulation of plastic waste: Lack of adequate and suitable sites for landfilling and the feared toxic emissions from inadequate equipment and

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Vol. 4 No. 1 January 2013

inappropriate incineration conditions, and the resultant public resistance (http://www.envis-icpe.com/recycling projects.htm; Calister, 2000; Ghosh, 2002).

EXPERIMENTAL

Materials

In this research, some discarded pure water sachets (made from a commercially Low Density Polyethylene with density of 0.923g/cm^3 and melt flow index of 2.25g/min.) and Bamboo (Dendrocalamus strictus) Powder were used. The discarded pure water sachets were collected from a pure water production company, La Mimi Pure Water Company Limited, Nekede, Imo State, Nigeria. The density of the Bamboo used is 0.649g/cm^3. The processing equipments used includes Laboratory-size Agglomerating machine, Laboratory-Size single-screw extruder, Instron machine (Universal Testing Machine), cutlass, Shredding machine, Grinding machine, Electronic weighing balance, Beakers, Analytical weighing machine, Scissors, Stop watch, Sample bottles, Filter paper, Cigarette lighter, Permanent marker (ink), Personal Protective Equipment (PPE).

Preparation of Recycled Low Density Polyethylene Composites

The bamboo stems were shredded and the dust from the shredded bamboo stems 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 Pure water Sachets were torn open, washed in clean water to remove impurities and sun-dried. Then a laboratory-size agglomerating machine installed in the processing laboratory of the Department of Polymer and Textile Engineering in the Federal University of Technology, Owerri (FUTO) was used to shrewd the dried pure water sachets into pellets. The recycled low density polyethylene (RLDPE) composites of the bamboo powder (BP) 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. Then a laboratory-size single-screw extruder, also, installed in the Processing Laboratory of the Department of Polymer and Textile Engineering, FUTO was used for the extrusion of RLDPE/BP composites films (sheets) of 2mm in thickness. 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.

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:

$$\text{Water Sorption } (\%) = \frac{W_f - W_i}{W_i} \times 100 \quad \ldots\ldots (1)$$

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:

$$\text{Specific Gravity (S.G.)} = \frac{n}{m} \quad \ldots\ldots (2)$$

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 (RLDPE) 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:

$$\text{Rate of burning (mm/s)} = \frac{D_p\,(\text{mm})}{P_t - I_t\,(\text{s})} \quad \ldots\ldots (3)$$

Where D_p = Propagation distance measured in millimeter
P_t = Flame propagation time measured in seconds
I_t = Ignition time measured in seconds.

RESULTS AND DISCUSSION

Mechanical Properties

Table 1: Some mechanical properties of bamboo powder filled RLDPE composites.

Sample	*Wt. % of Filler*	*Tensile Strength (MPa)*	*Elongation at Break (%)*	*Young's Modulus (MPa)*
1	0	5.764	1172.305	7.152
2	1	3.438	1081.541	7.843
3	3	3.314	124.415	8.006
4	5	2.291	84.978	8.927
5	7	1.098	63.768	9.796

ISSN-L: 2223-9553, ISSN: 2223-9944
Vol. 4 No. 1 January 2013

Tensile Strength

The effects of filler loading on the tensile strength of bamboo powder (BP) filled recycled low density polyethylene (RLDPE) composites are shown in Table 1. From Figure 1 it can be seen that the tensile strength decreased with increasing filler loading for RLDPE. 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 apolar matrix. As this area increases, the worsening bonding between them decreases the tensile strength. It has been shown that for irregularly-shaped fillers, the strength of the composites can decrease due to the inability of the filler to support stresses transferred from polymer matrix (Ismail et al., 2002). On the other hand, poor interfacial bonding causes partially separated micro-spaces between the filler particles and the polymer matrix. 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 (Yang et al., 2004). Recycling of LDPE is known to cause decrease in its tensile strength, due to the loss of some energy content (decrease in the intermolecular bond strength) of the LDPE through:

i. Thermal, chemical, stress and ultraviolet degradation during indoor and outdoor service and

ii. Contaminants or impurities that might be present in the LDPE which may occur during its processing, outdoor and indoor service or during recycling.

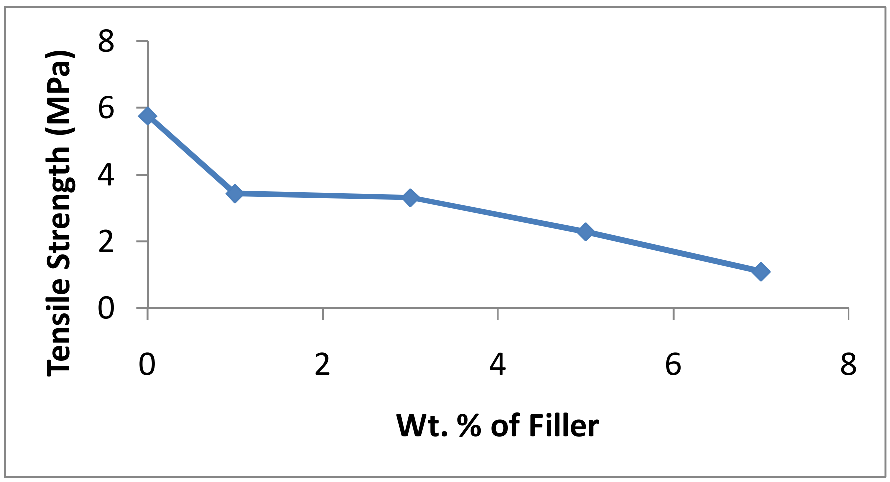

Fig. 1: Effect of Filler Loading on the Tensile Strength of Bamboo Powder/Recycled Low Density Polyethylene (RLDPE) Composites.

Elongation at Break

From Figure 2, it can be seen that the elongation at break for BP filled RLDPE composites decreases with increasing filler loading. This can also be seen from Table 1. Increased filler loading in the RLDPE 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.

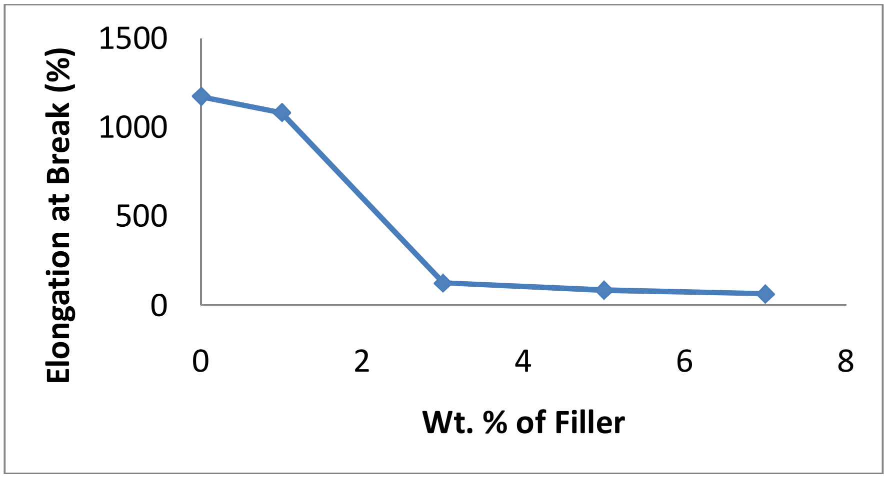

Fig. 2: Effect of Filler Loading on the Elongation at Break of Bamboo Powder / Recycled Low Density Polyethylene (RLDPE) Composites.

Young's (Tensile) Modulus

Figure 3 shows that the Young's modulus for BP filled RLDPE composites increases with increasing filler loading as can also be seen from Table 1. 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 a common behaviour when rigid fillers are incorporated into softer polymer matrices. Natural lignocellulosic fillers have been found as having elastic modulus higher than PE, PP, and some other polymer materials (Wang et al., 2006). Some other authors have also related the increase in composites' rigidity with the reduction of polymer chains mobility in the presence of the filler (Rana et al., 1998). The stiffness of the composites increased gradually with associated decrease in the elongation at break.

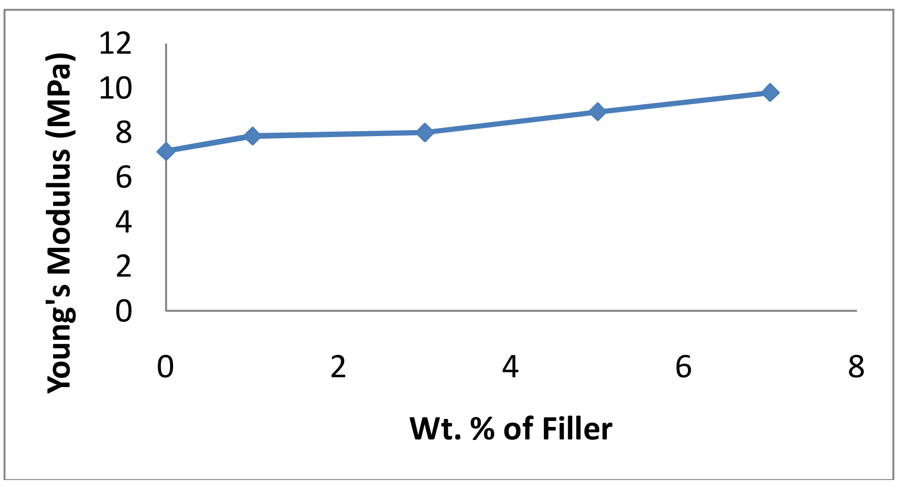

Fig.3: Effect of Filler Loading on the Young's Modulus of Bamboo Powder / Recycled Low Density Polyethylene Composites.

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Vol. 4 No. 1 January 2013

Table 2: Some end-use properties of bamboo powder filled RLDPE composites

Sample	*Wt. % of Filler*	*Water sorption (24hrs) (%)*	*Specific gravity*	*Flame propagation rate (mm/s)*
1	0	0.77	0.941	0.33
2	1	2.26	1.023	0.28
3	3	2.73	1.287	0.26
4	5	2.92	1.299	0.21
5	7	3.21	1.320	0.17

Water Sorption

Table 2 shows the percentages of water sorption (for 24 hours) for the BP/RLDPE 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). This result may also be attributed to the distortions in the molecular chains of the RLDPE due to degradation, impurities or contaminants present in the RLDPE.

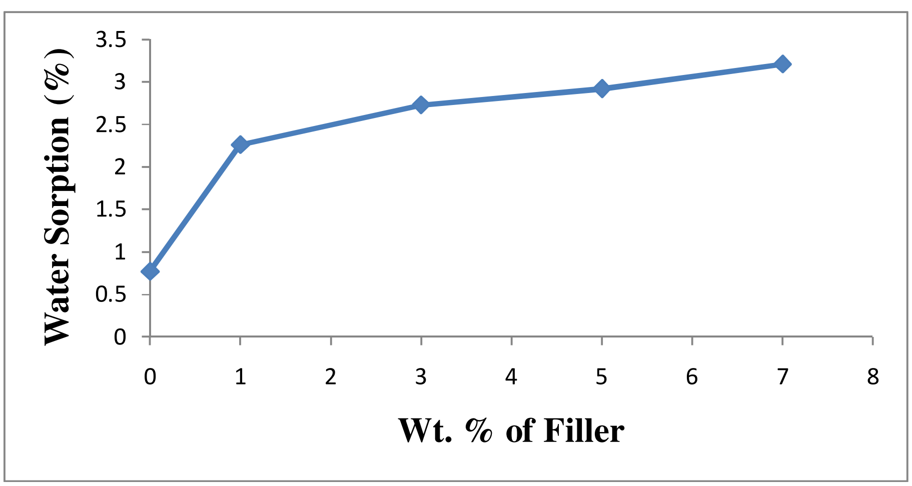

Fig. 4: Effect of Filler Loading on the Water Sorption of Bamboo Powder/Recycled Low Density Polyethylene Composites.

Specific Gravity

Table 2 shows that there was a continuous increase in the specific gravity for all the composites as the filler loading increases. In solid-like composites, the specific gravity of natural fibres is a key for determining the specific gravity of the composites (Shibata et al., 2006).

From Figure 5 it can be seen that there is a slight tendency of increasing specific gravity with increasing bamboo powder concentration. The presence of some impurities and contaminants in the RLDPE may also contribute to the slight increases in the specific gravity of the composites. The important conclusion is that these (RLDPE) composites are very light materials that can be useful in applications that require low weight.

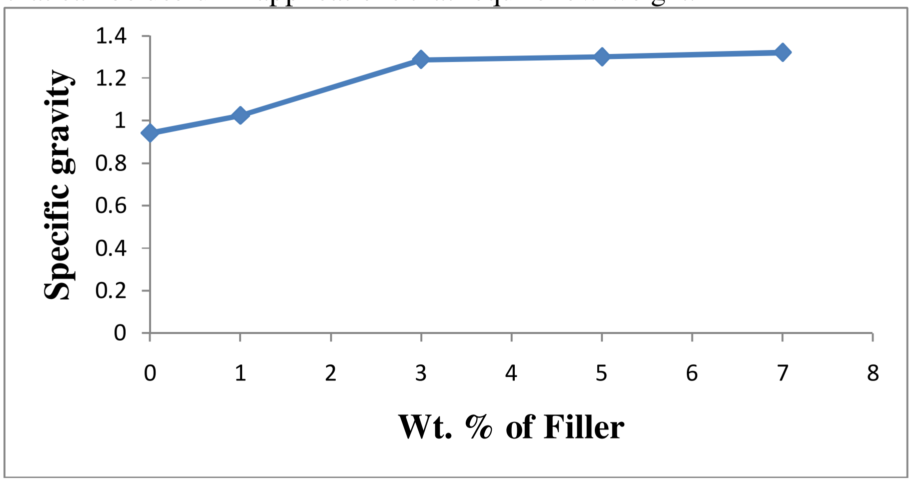

Fig. 5: Effect of Filler Loading on the Specific Gravity of Bamboo Powder / Recycled Low Density Polyethylene Composites.

Flame Propagation

Figure 6 shows that the flame retardant property of RLDPE is enhanced by bamboo powder filler 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.

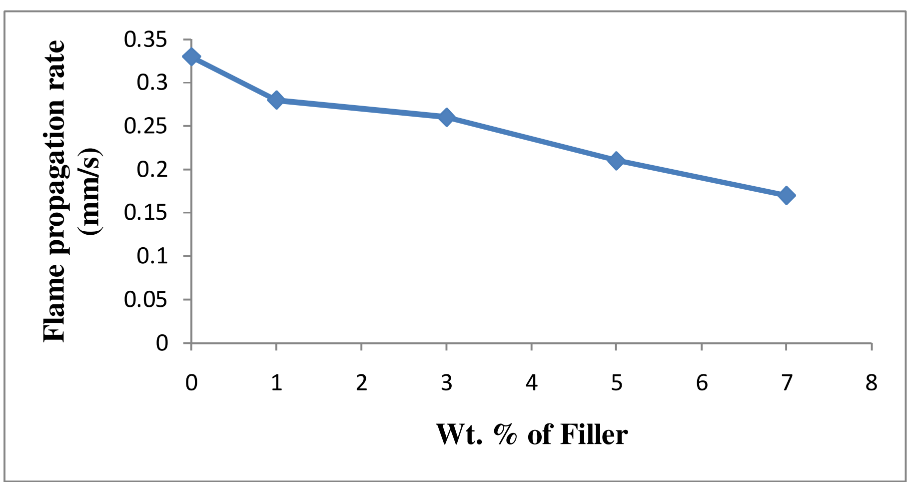

Fig.6: Effect of Filler Loading on the Flame Propagation Rate of Bamboo Powder/ Recycled Low Density Polyethylene Composites.

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Vol. 4 No. 1 January 2013

Thermo plasticity is observed as shrinkage and softening or melting when such materials are subjected to heat (Morreale et al., 2007). This behaviour ensures energy removal, decrease in surface area exposed, and hence, reduction in flame accessibility. The flame retardant property of the filler investigated could be attributed to the fact that a good percentage of the filler contents might not be combustible, and so provide environments unfavourable to flaming. The impurities, contaminants, and additives present in the RLDPE composites might not be combustible or needs more heat for its constituents to break down before it begins to burn; hence enhancing the flame retardant property of the RLDPE(Ismail et al., 2002).

CONCLUSION

In view of the properties of the obtained products, the results showed that it is feasible to use bamboo powder as low cost filler, reutilize the energy content of polymers (LDPE) in an ecologically acceptable way and helps to reduce the problems of plastic wastes disposal and management through recycling. The composites' stiffness was seen to increase with increasing filler loading while there is slight decrease in the tensile strengths and elongation at break with increasing filler loading. The percentage of water sorption by BP/RLDPE composites is so small making these materials suitable for use in damp environments. Specific gravity determination showed that BP/RLDPE and composites are very light materials since its specific gravity did not increase too much. The addition of BP to the RLDPE enhanced the flame retardant property of the composites. The results also showed that the locally-made machines (Agglomerator and extruder) performed excellently well compared with the foreign made machines. Therefore, locally-made machines can be used as good and viable substitutes for their foreign-made counterparts thereby encouraging the development of indigenous technology.

REFERENCES

Allcock, H. (2008).*Introduction to Material Chemistry*, Wiley, Hoboken, N.J., 209.

Allcock, H., Lampe, F. & Mark, J. E. (2003).*Contemporary Polymer Chemistry*, 3rd Ed., Prentice Hall, Upper River, N.J., 53, 71.

Berins, M. L. (1991).*Plastic Engineering Handbook of the Society of the Plastics Industry*, 5th Ed., van Nostrand Reinhold.

Bhatnagar, M. S. (2004). *A Textbook of Polymers:Chemistry and Technology of Polymers,* Vol. one, S. Chand and Company Ltd., 1-449.

Calister, W. D. (2000). *Materials Science and Engineering*, 5th Ed., Wiley, New York, 232.

Cardarelli, F. (2008). Materials Handbook: *A Concise Desktop Reference*, Springers, New York.

Carraher, C. (2010). *Introduction to Polymer Chemistry,* 2nd Ed., CRC Press, Boca Raton, 1-17.

Chanda, M. & Roy, S. (2008).*Plastic Fundamentals, Properties and Testing*, CRC Press, Boca Raton, FL, 57.

Charrier, J. M. (1990). *Polymeric Materials and Processing*, Hanser Publishers.

Crawford, R. J. (1998). *Plastic Engineering*, 3rd Ed., Butterworth Heinemann, 1, 18 and 37.

Ehrig, R. J. (1992). *Plastic Recycling: Products and Processes,* Hanser Publishers, 83-91.

Ghosh, P. (2002). *Polymer Science and Technology*. 2nd Ed., 1-20, 228-229.

Gruenwald, G. (1992). *Plastics: How Structure Determines Properties*, Hanser Publisher, 1-57.

Hensen, F. (1997). *Plastic Extrusion Technology*, 2nd Ed., Hanser Publishers, 23-38.

http://dspace.unimap.edu.my/bitstream/123456789/3362/6/introduction.pdf; 07/05/2009.

http://en.wikipedia.org/wiki/polyethylene, 6/20/2009.

http://www. Envis-icpe. Com/ recycling projects htm, 7/16/2009.

Ismail, H., Edyham, M. R. & Wirosentono, B. (2002). Bamboo Fibre filled Natural Rubber Composites: the Effects of filler loading and Bonding Agent, *Polymer Testing,* 21(2), 139-144.

Jacob, M., Thomas, S., & Varughese, K. T. (2004). Mechanical properties of sisal oil palm hybrid fiber reinforced natural rubber composites. *Composite Science and Technology*," 64, 55-965.

Jimenez, A. & Zaikov, G. (2008). *Recent Advances in Research Biodegradable Polymers and Sustainable Composites,* Nova, Hauppauge, NY., 315.

Katchy, E.M. (2000). *Principles of polymer science,* 1st Ed., El'Demark Ltd, 1-28.

Morreale, M., Scaffaro, R., Maio, A. & La Mantia, F.P. (2007). Effect of adding Wood Llour to the Physical Properties of a Biodegradable Polymer Composite, 42, 214.

Piringer, O. & Baner, A. (2008). *Plastic Packaging Materials: for Food and Pharmaceuticals*, Wiley, Hoboken, NJ., 211.

ISSN-L: 2223-9553, ISSN: 2223-9944
Vol. 4 No. 1 January 2013

Qunfang, I., Xiaodong, E., & Gance, D. (2002). Effect of Hydrothernal Environment on Moisture Absorption and Mechanical Properties of Wood Flour filled Polypropylene Composites, *J. Appl. Polymer Science,* 85, 2824-2832.

Rana, A. K., Mandal, B. C., Mitra, R., Jacobson, R., Rowell, A. & Banerjee, N. (1998). Short Jute Fibre Reinforced Polypropylene Composites: Effect of Compatibilizer, *Journal of Applied Polymer Science*. 69(2), 329-338.

Reyne, M. (2008). *Plastic Forming Processes*,Wiley, Hoboken, Nj., 137.

Salmah, H., Ismail, A. & Baker, A. (2005). Dynamic vulcanization of sludge filled polypropylene (PP) ethylene propylene diene terpolymer (EPDM). *Malaysian Journal of microscopy,* 2, 15-22.

Shibata, S., Cao, Y. & Fukumoto, I. (2006). Light weight laminate composites made from Kenaf and Polypropylene fibres. *Polymer Testing*. 25(2), 142-148.

Tran-Bruni, C. V. & Deanin, R. D. (1987). *American Chemical Society, Polymer Materials Science and Engineering*, Vol. 56, 446.

Vera, S, Craig, M.C., & Heiko, T. (2007). Effects of Material Parameters on the Diffusion and Sorption Properties of Wood- Flour/Polypropylene Composites, *J. Appl Polymer Science,* 103, 725-763.

Wang, W., Sain, M. & Cooper, P.A. (2006). Study of moisture absorption in natural fiber plastic composites: *Composites Science and Technology*, 66(3-4), 379-386.

Ward, I. M. (1983). *Mechanical Properties of Solid Polymers*, 2^{nd} Ed., John Wiley and Sons Ltd.

Yang et al., (2004),"Rice-husk flour filled polypropylene composites; mechanical and morphological studies, *Composite Structures,* 63(3-4), 305-312.