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POTENTIAL OF AGRICULTURAL WASTE PRODUCTS FOR USE IN REINFORCING POLYMERIC MATERIALS

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Abstract
This work provides variation in flexural properties of Kenaf and Pineapple leaf fibre (PALF) reinforced high-density polyethylene (HDPE) composite. Natural fibre reinforced HDPE composite has been successfully formulated at both low and high percentage of the fibre in the matrix. Interestingly, reinforcement of the matrix had taken place with properties obtained exceeding that of the neat matrix. Both flexural strength and modulus of PALF is superior to kenaf because flexural strength and young's modulus of plant fibres increases with increase in cellulose content of the fiber. Introduction of natural fibre into the matrix has shown to enhance the flexural properties of the synthetic matrix, in additional to reducing environmental problem that normally arise in the afterlife of products made from such polymeric materials. This is because the percentage of natural fibre build into polymeric materials is directly proportional to the biodegradability of products made from it. There are far greater potentials of most agricultural waste products serving as raw materials for both structural and non-structural application.

Keywords: Natural fibre, Modulus, Percentage Fibre Weight, Properties, Raw Material

1.0 Introduction
Interest has been placed on biodegradable materials because it offers great advantage during usage, processing and its ability to safeguard our environment because of its ability to degrade after use. Many scholars have used various agricultural bye products to reinforce polymeric materials for use in both structural and non-structural products. For many years, synthetic fibres such as carbon fiber, glass fibre, aramid and the likes have been in use for reinforcing polymeric materials. Though this tend to improve the mechanical properties of polymeric materials, it offers disadvantage in cost, increase weight of product, difficulty in processing and the inability to introduce higher percentage of these fibres into the polymeric material. It is therefore of interest to replace these synthetic fibres with natural ones to counter the disadvantage of the former. Several factors have aided the use of this natural fibres, i.e. light weight, environmental friendliness, ease of formulation, availability in most countries, its relative non abrasiveness to processing equipments(Li et al. 2008; Aji et al. 2009; George

et al. 2001), to mention a few. Some marketable reasons in replacing synthetic fibres with natural ones include low cost (~1/3 of glass fibres), lower density (~1/2 of glass), acceptable specific strength properties and enhance energy recovery, CO_2 sequesterization and its natural tendency to degrade(Kim et al. 2007). This is in addition to their hollow cellular structure that can provide excellent insulation against heat and noise(Jacob et al. 2006). Cautiously however, natural fibre's hydrophilic tendencies has slowed its potentials in outdoor application, however, this problem can be countered through various chemical treatments and hybridization. Various agricultural waste/bye-products, has been in use; these include sugarcane baggase in Polyvinyl chloride (PVC)(Wirawan et al. 2010; Wirawan et al. 2011), Banana fibre in polyeste(Pothan et al. 2003), Banana Psudo-stem in PVC(Zainudin et al. 2009) Flax fibre in Polypropylene(Arbelaiz & others 2005), hybridized kenaf and PALF in HDPE(I.S. Aji et al. 2011), hybridized Oil palm empty fruit bunch (OPEFB) and jute fibre in epoxy(Jawaid & Khalil 2011) and many others reviewed by Ray and co-workers(Sinha Ray & Bousmina 2005). Corresponding author's earlier work(Aji et al. 2009), reviewed some of the achievements so far recorded in enhancing the effectiveness of interface adhesion between cellulose-based fillers and thermoplastics and discovered that most of these studies have been carried out on wood fibres. Several techniques have been reported that ranges from grafting of short-chain molecules and polymers onto the surface to using coupling agents and radical induced adhesion promoters to improve interfacial bonding(Van de Weyenberg et al. 2003; Nishino et al. 2003; Ochi 2007). Brahmakumar et-al. and Abdelmouleh et-al.(Brahmakumar et al. 2005; Abdelmouleh et al. 2007) reported that, grafting improves wetting of the fibre with matrix by hydrophobizing the fibre surface, which then promotes interfacial bonding by diffusion of the chain segments of the grafted molecules into the matrix. Coupling agents and radical induced adhesion enhance interfacial bonding through producing covalent bonds between the fibre and the matrix.

It has been reported that the structure, cell dimensions and defects, chemical composition and microfibrillar angle are the most important variables that determine the overall properties of fibres(Mukherjee & Satyanarayana 1984; Satyanarayana et al. 1986) and by extension its resulting composite properties. Similarly, Idicula et al.(Idicula et al. 2005) expressed that intrinsic properties such as high cellulose content and low microfibrillar angle gives fibres high tensile and flexural properties. In other words, tensile and flexural properties of plant fibres increase with increasing cellulose content and the orientation of the cellulose microfibrils with respect to fibre axis, determines the stiffness of the fibres in addition to its good ductility when the microfibrills have a spiral orientation to the fibre axis(Bismarck et al. 2005).

Polyolefin are widely used by industries for the production of bags, films, fibers etc; most common ones used are Polyethylene (PE) and Polypropylene (PP)(Harper 2002; Massey 2003; Goodship 2007). Polyethylene is a thermoplastic polymer consisting of long chains of the monomer ethylene created through polymerization of ethane. Its mechanical properties depend largely on variables such as extend and type of branching, the crystal structure and the molecular weight. Even though they are mostly synthetic in nature, HDPE and LDPE can be derived from sugarcane(Huang 2010; Anon n.d.; Al-Ostaz et al. 2008; Bensason et al. 1996) . PE has lower mechanical properties compared to PP, but application wise, they can compete favorably. They possess good resistance to chemical attack and can combine well with natural fibres in many applications; their hydrophobic nature also adds to its use in natural fiber composites.

2.0 Materials and Method

Materials.

Pineapple leaf (*Ananas Comosus*) was bought from Perniagaan Benang Serat Nanas M&Z, with source from Johor pineapple plantation, Malaysia. It was manually decorticated from the variety "*Josephine*". Kenaf (*Hibiscus cannabinus*) of variety V36, locally referred to as *rama* in northern Nigeria, was purchased from KEFI Malaysia Sdn. Bhd. were utilized in this research. These fibers were reinforced with high-density polyethylene also purchased from KEFI Malaysia. Flexural Properties of HDPE used as tested by us using ASTM-D790 condition are flexural strength and modulus of 16.87 MPa and 828.12 MPa respectively. Additional properties provided by supplier are shown in table 1. Table 2 presents some properties of the fibres used in this paper as obtained from literature.

Table 1 Properties of HDPE used

Density	**Melt Mass Flow rate**	**Dart Drop Impact**	**Tensile Elongation**	**Forms**	**Melt Temp. °C**	**Sec. Mod (MPa)**
	190°C/2.16kg	17µm, Blown film	TD : Break 17 µm, Blown film			1% Sec, TD 17 µm, Blown film
0.95g/cm³	0.10g/10 min	140g	700%	Pellets	180-240	1270

Table 2. Physical properties of kenaf and PALF(George et al. 1997; George et al. 1995; Tsoumis 1991; Mohanty et al. 2000)

	Density (g/cm³)	Microfibrilla angle(°)	Elongation at break(%)	Fibre Diameter (µm)	Cellulose (wt%)	Ten Str. (MPa)	E-Modulus (GPa)	Cell wall thickness (µm)
Kenaf	1.3	15	1.6	14-33	45-57	427	53	4.2
PALF	1.526	14	1.6	20-80	70-82	413-1627	34.5-82.5	8.3

2.1 Preparation of composite

Fibres of Kenaf and PALF at a fiber length of 0.25 mm were utilized for this experiment. The fibres were carefully and thoroughly mixed together in a Brabender Plasticod at a fibre loading of 10% and 40%. The Brabender was preheated and set at 190°C and 40 rpm processing speed. The HDPE was then charged at that temperature and allowed to stabilize (melt) before introducing the fibres. The total time used for the melt-mixing was 25 minutes(I. S. Aji et al. 2011). Sheets of composite for flexural specimen of 150 mm X 150 mm X 3 mm was produced in a compression-molding machine. The Compression molding machine was set at 170°C; 7min preheat, 5 min full press, 10 seconds of venting process and 5 min of cooling. Thereafter, a rectangular specimen of 150 mm X 15 mm X 3 mm were cut out for flexural property test using a powered-saw. Test specimens were conditioned in an oven for 21 hrs at 105°C. It should however be noted that reinforcement usually begins at 30% fibre loading while at lower loading, fibres only serve as flaws. This paper is presented to show the potential of various natural fibres in reinforcing polymeric materials.

2.2 Flexural Properties Testing

Flexural measurement of the composite specimens were conducted using a 5kN Bluehill INSTRON universal testing machine according to ASTM D790 as test conditions. 10 mm/min cross head speed and 100 mm span length for the 3-point flexural test was employed.

3.0 Results and Discussion

Figures 1 and 2 delineate the reinforcement effect of these natural fibers in HDPE. Interestingly, reinforcement of the matrix has taken place with properties obtained exceeding that of the neat matrix. Similarly, both flexural strength and modulus of PALF is superior to kenaf because flexural strength and young's modulus of plant fibres increases with increase in cellulose content of the fibre(Idicula et al. 2005). Results obtained

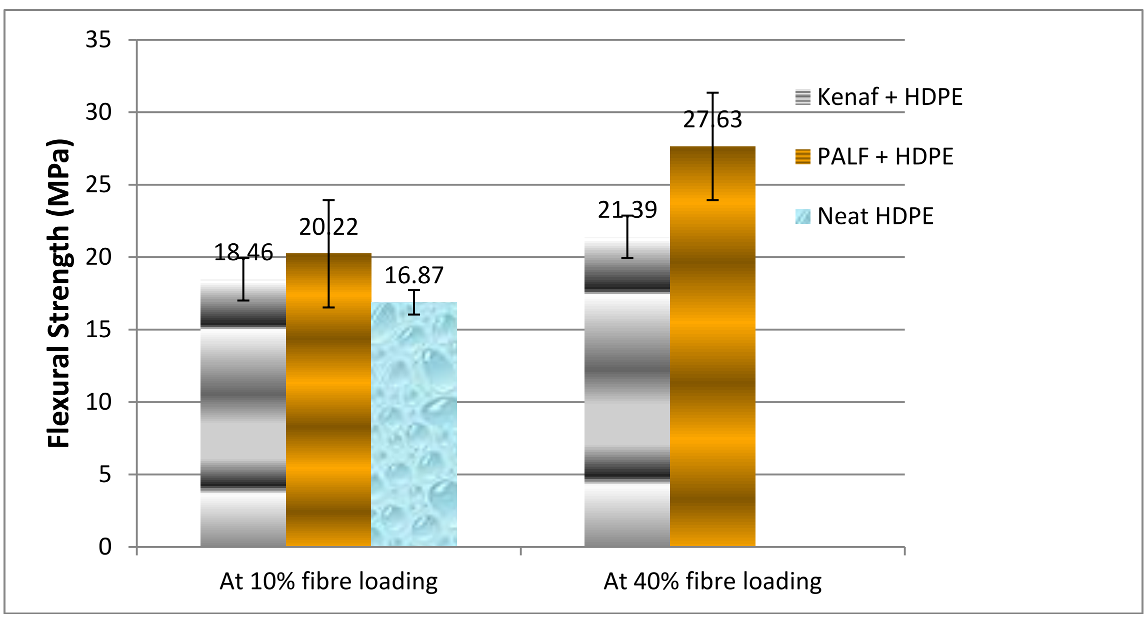

Figure 1: Composite flexural strength

As mentioned earlier, at low fibre content, reinforcement does not really occur because fibres serve only as flaws. In any case, it is necessary that as much fibre as possible is built into the matrix during composite formulation since the percentage of natural fibre in the system is directly proportional to the degradability of the final product after use. Modulus result however showed prominence with higher percentage of PALF in the composite. This goes to confirm the dependence of modulus on the percentage of cellulose in natural fibres.

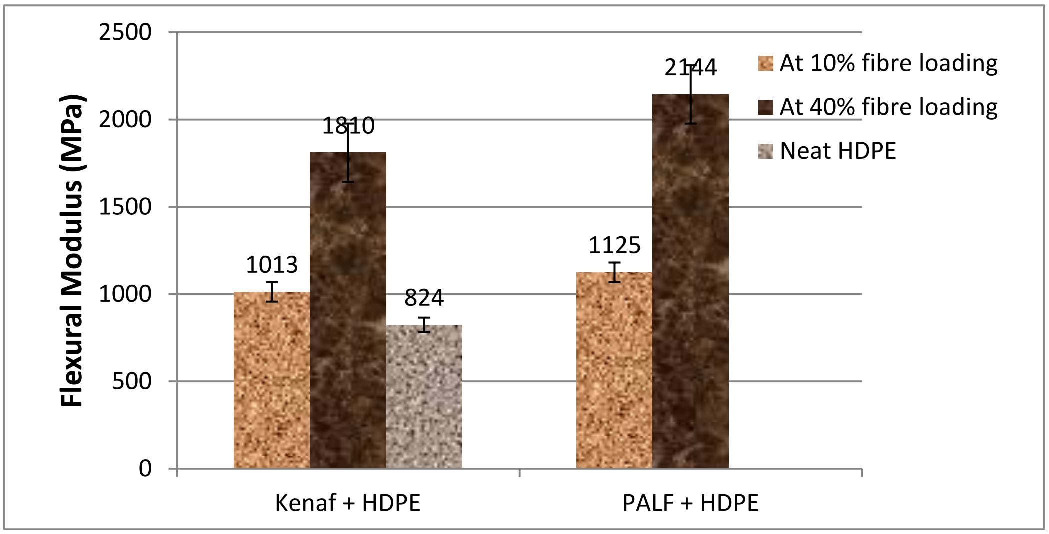

Figure 2: Composite flexural Modulus

Mechanical performance of composite is strategically dependent on the properties of the matrix to be reinforced, and mainly the interaction between the matrix and its reinforcing fiber (Sreekala et al. 2002). Very good interaction will provide enhanced mechanical properties. Adequate mixing of fibre and matrix is what can provide transfer of load from the matrix to the fiber during service and the adhesion efficiency between fibre and matrix is what determines the resulting property of composite. This is expressly reliant upon the nature, shape and surface roughness of the reinforcing fibres(Sreekala et al. 2002). Introduction of natural fibre into the matrix has shown to enhanced the mechanical properties of synthetic matrix, in additional to reducing environmental problem that normally arises in the afterlife of products made from such polymeric materials.

4.0 Conclusion

Natural fibre reinforced HDPE composite has been successfully formulated at both low and high percentage of the fibre in the matrix. Interestingly, reinforcement of the matrix has taken place with properties obtained exceeding that of the neat matrix. Both flexural strength and modulus of PALF is superior to kenaf because flexural strength and young’s modulus of plant fibres increases with increase in cellulose content of the fibre. Introduction of natural fibre into the matrix has shown to enhance the mechanical properties of synthetic matrix, in additional to reducing environmental problem that normally arises in the afterlife of products made from such polymeric materials.

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