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Effect Of Fiber Content On The Physio-Mechanical Properties Of Irvingia Gabonensis Shell Fiber Reinforced Polyester Composite

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***Abstract:** This research presented a detailed study of the effect of fiber content on the physio-mechanical properties of irvingia gabonensis shell fiber reinforced polyester composite for various engineering applications using standard technique. The fibers were treated with 5% sodium hydroxide (NAOH) solution for 2hours at 40^{o}C after which they were ground to particle size of 100µm. Varying amounts of fibers (10%wt, 12%wt, 14%wt, 16%wt. 18%wt and 20%wt) were mixed with other raw materials (polyester and additives) in a mini mixer equipped with an electric motor that rotates at 3000 rpm. The pre-form samples were heated to a temperature of 160°C using propane gas flame and compacted by compression moulding technique. The physical and mechanical properties (moisture uptake, specific gravity, hardness and impact strength) of the developed composites were determined. Also, the functional groups of the developed composite were analyzed using Bulk Scientific Infra-red Spectrophotometer (model number M530). The results of the study showed that the moisture uptake and hardness value of the composites increased and decreased respectively with increase in fiber content. The hardness value of the developed composite increased with decrease in moisture uptake. It was also observed that the sample containing 10%wt irvingia fiber gave the optimum hardness value and lowest moisture uptake. Composite sample (IFC$_5$) containing 18%wt irvingia fiber gave the optimum impact strength while IFC6 sample with 20%wt fiber has the maximum specific gravity. Finally the functional groups of the developed irvingia fiber reinforced polymer composite were revealed.*

***Keywords:** Irvingia gabonensis shell fiber, composites, additives, polyester, moisture uptake, specific gravity, FTIR*

I. INTRODUCTION

In the recent few years, there has been a growing interest for natural fibers as a substitute for glass. This is motivated by potential advantages of weight saving, lower price of raw materials, and ecological or thermal recycling advantages of using resources which are renewable. From the previous studies, composites material reinforced with natural fibers has been found to possess better electrical resistance, chemical resistance; good thermal and acoustic insulating properties. Composite materials are widely used for the production of brake-shoes, pads, tires and the diesel piston aircraft. Various researchers have revealed that Agricultural wastes such as wheat husk, rice husk and their straw, hemp fiber and shells of various dry fruits can be used to prepare fiber reinforced composites for commercial use. Most common concerns about the use of these fibers are their coupling with a polymeric matrix, which need to be compatible with the cellulose contained in the fiber.

Irvingia gabonensis is a species name for bush mango, African mango, wild mango or Dikanut plant. It is made up of tree trunk (stem), leaves, roots and fruits. The fruit comprises a fleshy part and the nut, which consists of a hard shell and the kernel/seed. Its seeds have an outer brown testa (hull) and two white cotyledons (Ekpe, Umoh and Eka, 2007).

Ivingia gabonensis shell fiber (IGSF) is one of the agricultural wastes materials in Nigeria. These agricultural wastes can be used to prepare fiber reinforced polymer composites for commercial use. Most common concerns about the use of these fibers are their coupling with a polymeric matrix, which need to be compatible with the cellulose contained in the fiber.

Gopinath et al (2014) investigated the mechanical behaviour of alkali treated coir fiber and husk reinforced epoxy composites. The results of the study showed a higher tensile strength and flexural strength in mixing ratio of coir to rice husk (80: 20) respectively. Njokua, Okona and Ikpakia, (2011) investigated the effects of variation of particle size and weight fraction on the tensile strength and young modulus of periwinkle shell reinforced polyester composite. The results of the study showed that the tensile strength and elastic modulus increased with decrease and increase in particle size and particle loading in the range of particle sizes tested. Increase in strength with small particle sizes and increased particle loading was attributed to increase in surface area which enhanced load transfer between the polyester matrix and periwinkle shell particles. The study also revealed negligible effect of periwinkle particle size within the range of particle sizes (400 -1000m) on the young modulus of polyester/periwinkle shell particle composite. Onyechi et al (2015) studied the effect of volume fraction on the mechanical properties of periwinkle shell reinforced polyester composite. The study found that composite made of 400μm particle size at 30% volume content gave the maximum ultimate tensile strength and flexural strength of 24.3MPa 47.4MPa respectively. Additionally, the composite made of 400μm particle size at 50% volume content gave the maximum hardness number (BHN) of 249. The composite made up of 1760μm particle size at 50% volume content yielded the maximum impact strength of $23.2Jm^{-2}$. Isiaka (2014) reported in his study of effect of bagasse fiber reinforcement on the mechanical properties of polyester composites that bagasse particulate fiber in the range of 10 wt% gave the optimum mechanical properties. It was also observed from the study that curing rate for polyester material was improved by the addition of bagasse fiber which increased the production rate. Palla et al (2014) studied the effect of fiber length on tensile properties of polyester resin composites reinforced by the fibers of sansevieria trifasciata. The study showed that the ultimate tensile strength increased with fiber length without effecting the elongation at break of the composite. An optimum ultimate tensile strength was obtained with 10m fiber length. It was also observed that the void, fiber length and interfacial adhesion between fiber-matrix can affect the mechanical properties of the composite. Husseinsyah and Mostapha, (2011*)* investigated into the effect of filler content on properties of coconut shell filled polyester composites, and the results revealed that increase in coconut shell content led to an increased tensile strength, young's modulus and the water absorption. Oladele, (2013) investigated the effect of bone ash and bone particulate reinforced polyester composites for biomedical applications and established that the tensile and flexural properties were enhanced. EL-Tayeb (2008) studied the effect of untreated short baggasse fiber reinforcement on the abrasive wear performance of polyester and the result revealed that wear of SCRP composite was sensitive to variations of load, fiber length and fiber orientation and less sensitive to sliding velocity.

Although many research have been conducted on the mechanical behaviour of natural fiber-reinforced composites, but no known study is available on irvingia fiber reinforced polyester composites. Therefore, the present research work is aimed at studying the effect of fiber content on the physio-mechanical properties of irvingia gabonensis shell natural fiber reinforced polyester composite for various engineering applications.

II. EXPERIMENTAL PROCEDURE

A. MATERIALS

Polyester powder, irvingia gabonensis shell and different additives were the materials used for this research work. The irvingia gabonensis fruit used for this research was obtained from Akiyi Umulokpa in Uzo-Uwani Local Government Area, Enugu State of Nigeria while other materials were bought from Onitsha market in Anambra State, Nigeria.

B. FIBER EXTRACTION AND TREATMENT

The endocarps of the fresh irvingia gabonensis fruits were obtained by manually removing the mesocarps of the fruits and then subjected to sun drying for two months. Subsequently, the endocarps were oven dried at 110 $\pm 1^{o}$C for 72 hours and manually cleaned to remove foreign matters such as; dust, dirt, broken and immature endocarps. The dried endocarps were then manually cracked and separated to obtain the required shells. The extracted shells were subjected to alkaline (mercerization) treatment to increase the surface roughness of the fiber for better mechanical interlocking, increase the amount of cellulose exposed on the fiber surface and create a number of possible reaction sites. The fibers were immersed in 5% sodium hydroxide (NAOH) solution for 2hours at temperature of 40^{0}C after which they were removed from the solution and washed thoroughly with clean water to remove the excess NAOH. They were washed again with water containing little acetic acid and then dried in an oven at 110^{0}C for 24hours. The treated fibers were then ground to a fine powder of 100 μm particle size using hammer mill machine.

Figure 1: Irvingia shell

Figure 2: Irvingia powder

C. COMPOSITES PREPARATION

After alkaline treatment of the fibers, composites of different formulations as shown in Table 2 were prepared using compression moulding technique. The raw materials of required compositions were mixed homogeneously for 1hour in a mini mixer equipped with an Electric motor that rotates at 3000 rpm. The pre-form samples were heated to a temperature of 160°C using propane gas flame and compacted in a mould cavity of dimensions 100 x 35 x 20mm using 3 ton load in 120 seconds holding time in a compression mould. The compaction was performed using a hydraulic press machine under a predetermined temperature and pressure. After compaction, the materials were cured in an oven at a temperature of 150°C for 4 hours. Ejection plate with rubbed candle wax preform was laid inside the mould before the mixture was poured. This was done to ensure easy removal of sample from the mould.

D. CHEMICAL ANALYSIS OF IVINGIA GABONENSIS SHELL

The chemical constituents of Ivingia gabonensis shell fibers were determined using Atomic Absorption Spectroscopy (AAS) and the result is presented in Table 1 below.

S/N	Parameters	Wt%
1	Carbon (C)	50.80
2	Hydrogen (H)	5.62
3	Oxygen (O)	35.61
4	Nitrogen (N)	0.69
5	Sulphur (S)	0.05

Table 1: Chemical constituents of Ivingia gabonensis shell

Composite formulation	Polyester (% wt)	Irvingia SF (% wt)	Additives				
			SiC	Palm Kernel Shell	Al_2O_3	ZrO_2	Phenolic resin
IFC_1	50	10	14	7	10	2	7
IFC_2	48	12	14	7	10	2	7
IFC_3	46	14	14	7	10	2	7
IFC_4	44	16	14	7	10	2	7
IFC_5	42	18	14	7	10	2	7
IFC_6	40	20	14	7	10	2	7

Table 2: Weight Ratio of the developed composite

E. MECHANICAL TESTS

The composite samples were machined to the required dimensions for the various studied physical and mechanical tests such as specific gravity, moisture uptake, hardness and impact strength. The specific gravity, moisture uptake, hardness and impact strength were obtained in accordance with ASTM D792, ASTM D570, ASTM D785 and ASTM D3763 respectively.

F. FTIR ANALYSIS

The FTIR test was carried out on the developed composite to find the functional groups in the material. The test was done by Bulk Scientific Infra-red Spectrophotometer (model number M530). 1g of each of the samples was mixed with 1ml of nujol solvent and pipetted into the instrument sample mould. The instrument was allowed to scan at a wavelength of 600-4000nm to obtain the spectra wavelength of the composites.

III. RESULTS AND DISCUSSION

A. PHYSICAL AND MECHANICAL PROPERTIES OF THE DEVELOPED COMPOSITES

The physical and mechanical properties of the developed composites are presented in bar charts as shown if Figures 4-7.

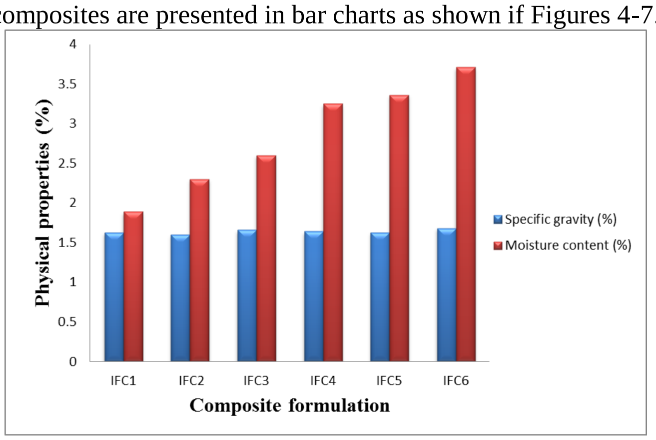

Figure 4: Physical properties of the developed composite

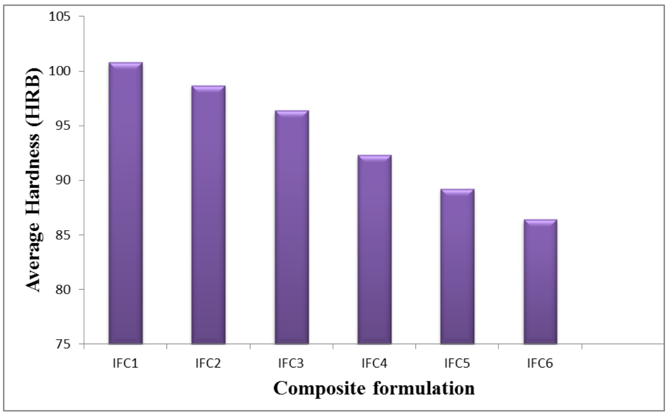

Figure 5: Average hardness of the developed composite

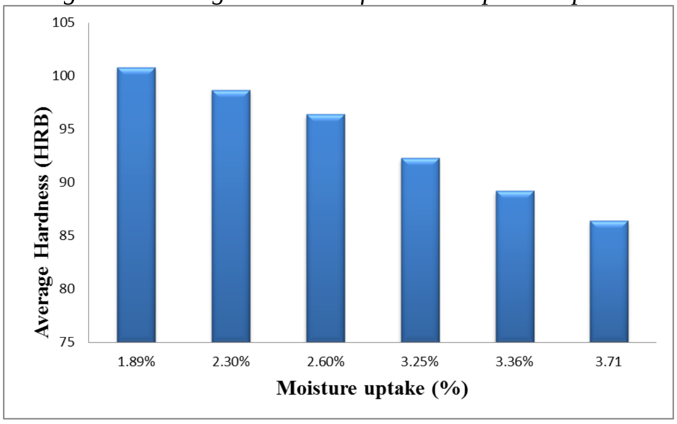

Figure 6: Effect of moisture content on the average hardness of the developed composite

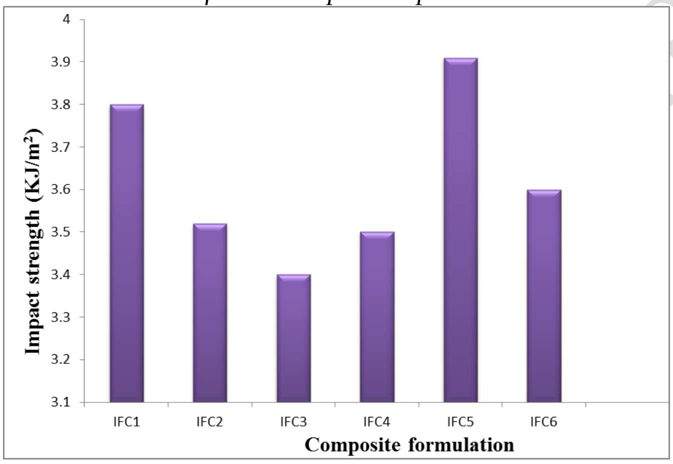

Figure 7: Impact strength of the developed composites.

Figure 4 represents the specific gravity and moisture uptake of the developed composites. Figure 4 shows that the composite sample (IFC_6) containing 40%wt polyester and 20%wt fiber has the maximum specific gravity while the samples (IFC_1 and IFC_5) containing 50%wt polyester and 10%wt fiber; 42%wt polyester and 18%wt fiber respectively have the minimum specific gravity. Figure 4 also shows that the moisture uptake increased with increase and decrease in percentage composition of the fiber and polyester matrix respectively. An optimum moisture uptake is noted on the sample (IFC_6) containing 40%wt polyester and 20%wt fiber (see Figure 4). Figure 5 shows that the hardness value of the composite increased with decrease in fiber content. The sample (IFC_1) containing 50%wt polyester and 10%wt fiber gave the maximum hardness value (see Figure 5). Figure 6 represents the effect of moisture uptake on the hardness of the developed composite. It can be seen from the Figure 6 that the hardness value of the composites developed decreased with increase in moisture uptake. Figure 7 shows that the composite sample (IFC_5) containing 42%wt polyester and 18%wt fiber has the maximum impact strength while the samples (IFC_3) containing 46%wt polyester and 14%wt fiber; has the minimum impact strength .

IV. FOURIER TRANSFORM INFRA-RED (FTIR)

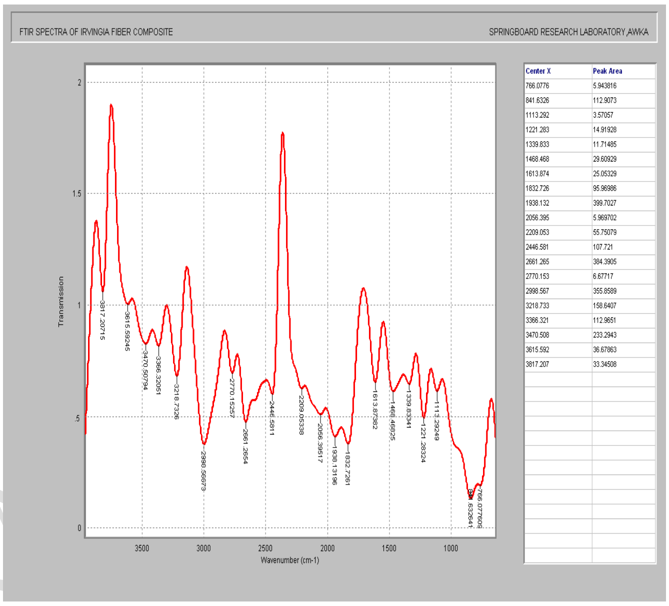

Figure 8: FTIR spectra of the irvingiaIrvingia Fiber Composite

S/N	Wavelenghth (cm^{-1})	Functional Group	Compound
1	766.0776	C-F	Fluoro C-F stretch
2	841.6326	C-Cl	Chloro C-Cl stretch
3	1113.292	R-O-R	Ether C0 stretch
4	1221.283	RNH_3	1^0 amine NH stretch
5	1339.833	CH_3	Methyl CH stretch
6	1468.468	CH_2	Methylene CH symmetric stretch
7	1613.874	R_2NH	2^0 amine NH stretch
8	1832.726	C-O-C	Cyclic ester C0 stretch
9	1938.132	R-S-C≡N	Thiocyanate SCN antisymmetric stretch
10	2056.395	RC00H	Carboxylic acid CO stretch
11	2209.053	R_2C=O	Carbonyl C0 antisymmetric stretch
12	2446.581	R-C≡N	Nitriles CN antisymmetricsterch
13	2661.265	CH_2SH	Thiol SH stretch
14	2770.153	CH_2	Methylene CH symmetric stretch
15	2998.567	R-S-C≡N	Thiocyanate SCN antisymmetric stretch
16	3218.733	R_2NH	2^0 amine NH stretch
17	3366.321	RCHOH	1^0 alcohol 0H stretch
18	3470.508	R_2CHOH	2^0 alcohol 0H stretch
19	3615.592	R_3N	3^0 amine NH stretch
20	3817.207	R_3CHOH	3^0 alcohol 0H stretch

Table 3: Interpretation of FTIR Spectra of Irvingia Fiber Composite

Table 3 represents the spectra wavelength of irvingia fiber composite. From the results obtained above, the weak bands around 766.0776cm-1 and 841.6326cm-1 were due to halogenous compound of chlorine and fluorine. The absorption bands at 1339.833 cm^{-1}, 1468.468 cm^{-1}, and 2770.153cm^{-1} were assigned to CH stretch of methyl and methylene compounds found in the structure of cellulose and hemi-cellulose present in the composite when characterized. The medium band at 1832.726 cm^{-1} and 2056.395 cm^{-1} were due to CO stretch of carbonyl and carboxylic functional group displaced in the lignin and cellulose structure inherent in the composite (John, 2007). The broad band around 3366.321cm^{-1}, 3470.508cm^{-1}, and 3817.207cm^{-1} were due to OH hydroxyl stretch of alcohol present in the structure of lignin, cellulose and hemi-cellulose compounds after pretreatment of the fiber composite, (Ouajai.et al, 2004).

V. CONCLUSION

The following conclusions were drawn from the results of this research work:

- ✓ Addition of irvingia shell fiber as reinforcement to polyester composite significantly improved the physical and mechanical properties of the composites.
- ✓ Composite sample (IFC1) containing 10%wt of irvingia shell fiber has the optimum hardness value and lowest moisture uptake.
- ✓ The hardness of the developed composite increased with decrease in moisture uptake of the samples produced.
- ✓ Composite sample (IFC_5) containing 18%wt irvingia shell fiber gave the optimum impact strength.
- ✓ The developed composite showed outstanding properties in the production of value-added composite panels in the conditions tested due to strong fiber-matrix interface bond created by the chemical treatment of the fiber.
- ✓ Based on the good properties, availability and cheaper cost of irvingia shell fiber reinforced composites studied, the composite can certainly be considered as a very promising material for fabrication of lightweight materials used in automobile body building, office furniture, packaging industry and partition panels.
- ✓ The broad band around 3366.321cm^{-1}, 3470.508cm^{-1}, and 3817.207cm^{-1} were due to OH hydroxyl stretch of alcohol present in the structure of lignin, cellulose and hemi-cellulose compounds after pretreatment of the fiber composite.

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