

# Characterization of the Thermo-Mechanical behavior of *Momordica angustisepala* Fibers intended for the Manufacturing of Polymer Composites.

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## ABSTRACT

Momordica Angustisepala (MA) fibers are from the plant of *Momordica angustisepala*. The MA fibers are produced in abundance globally. The effective, conducive and eco-friendly utilization has always been a challenge for scientific applications. This paper mainly deals with characterization of MA fibers as a potential material for polymer composite materials using spectroscopic and tensile strength analysis. The characterization of the MA fibers was investigated through X-ray diffractometer (XRD), thermogravimetric analysis (TGA/DTA). The density and tensile properties of the MA fibers were also investigated. The various results obtained are comparable with natural fibers commonly used in polymer composites production. This work confirmed that MA fibers show potential as a material for polymer composites production.

(Keywords: Momordica angustisepala, density, thermal, thermogravimetric analysis, tensile strength, X-ray diffraction, XRD, TGA, DTA)

## INTRODUCTION

Research and development of natural fibers as reinforcement for polymer is a growing interest to scientists and engineers. Nowadays, natural fibers form an interesting option for the most widely applied fibers in the composite technology. Many studies on natural fibers such as keraf, bagasse, jute, ramie, hemp, and oil palm have been investigated (Goda and Cao, 2007; Aziz and Ansell, 2004).

Increased environmental awareness and consciousness throughout the world have developed an increasing interest in natural fibers and its applications in various fields. Natural fibers are now considered as serious alternative to

synthetic fibers for use in various fields (Herrera-Franco and Valadez-González, 2005; Yu et al., 2006). The use of natural fibers as reinforcing materials in both thermoplastic and thermoset matrix composites provides positive environmental benefits with respect to ultimate disposability and best utilization of raw materials [6]. Currently, studies on use of lignocelluloses bio-fibers in place of synthetic fibers as reinforcing materials are being pursued vigorously (John and Thomas, 2008; Bodros et al., 2007). These bio-fibers are being extensively used for the production of cost effective ecofriendly bio-composites (Davies and Bruce, 1998).

The advantages of natural fibers over traditional reinforcing materials such as glass fiber, carbon fiber, etc. are due to their specific strength properties, wide availability, light weight, ease of separation, enhanced energy recovery, high toughness, non-corrosive nature, low density, low cost, good thermal properties, reduced tool wear, reduced dermal and respiratory irritation, less abrasion to processing equipment, renewability, and biodegradability (Gassan and Bledzki, 2001). The properties of natural fibers can vary depending on the source, age, and separating techniques of the fibers.

The largest advantages to using natural fibers in composites are the cost of materials, their sustainability and density. Natural fibers can cost as little as \$0.50/kg, and can be grown in just a few months. They are also easy to grow and have the potential to be a cash crop for local farmers. Natural fibers are also significantly lighter than glass, with a density of 1.15-1.50 g/cm<sup>3</sup> versus 2.4g/cm<sup>3</sup> for E-glass (Gassan and Bledzki, 2001).

*Momordica angustisepala* (MA) is a large forest climber of the closed-forest zone known from

Ghana, Nigeria and Cameroun. The thick stems are pounded and impurities are washed out leaving only the white fibers which the Asante of Ghana use as a washing sponge. The English word 'sponge' is derived from the Asante name sapow (Achigan-Dako, 2010; Achigan-Dako, 2008; Aguwa and Mittal, 1983).

After maceration, the stem is also used as filter for palm oil and palm wine. In Nigeria the stem is used for making woven masks for masquerades. The decorticated and washed twigs are chewed in Ghana. The root extract of *Momordica angustisepala* is used as an abortifacient in traditional medicine in South Nigeria (Achigan-Dako, 2010). Despite the availability of these studies, no investigation has been conducted on the application of the MA stem fibers in composite materials. This paper therefore report for the first time the characteristic of MA fibers as a potential reinforcing fibers in polymer composites.

## MATERIALS AND METHOD

### Materials

The material used during the course of this work is: MA stem fibers extracted by the process of retting and decorticated was obtained from the Botanical garden of the University of Nigeria, Nsukka Enugu state, Nigeria (Figure 1).



**Figure 1:** Photograph of MA Fiber.

### Equipment

The equipment used during the course of this work is listed: Digital weighing balance, sieve, X-ray diffractometer (XRD), thermogravimetric analysis (TGA/DTA), Hounsfield tensometer.

### Methods

The density of the MA fibers was determined by measuring the mass and volume of the sample. A clean sample is weighed accurately in air using a laboratory balance and then suspended in water. The weight of the sample when suspended in water was determined, the volume of the sample was determined from the effect of displacement by water (Archimedean principle). The density of the sample was then estimated from equation below:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

X-ray diffractometer (XRD) analysis of the fibers was carried out to determine the various element and phases distribution in the fibers. The test was carried out on a Philips X-ray diffractometer. The X-ray diffractograms was taken using Cu K $\alpha$  radiation at scan speed of 3°/ min. The samples were rotated at precisely one – half of the angular speed of the receive slit, so that a content angle between the incident and reflected beam is maintained. The receiving slit is maintained in front of the counter tube arm, and behind it is usually fitted a scatter slit to ensure that the counter receives radiation only from the portion of the specimen illuminated by the primary beam. The intensely diffracted at the various angles was recorded automatically on a chart and the appropriate ( $\Theta$ ) and (d) values were obtained. The test was carried out at the University of Witwatersrand, Johannesburg, South Africa.

The scanning electron microscope (SEM) JEOL JSM-6480LV was used to identify the surface morphology of the fiber samples. The samples were washed, cleaned thoroughly, air-dried, and coated with 100 Å thick platinum in JEOL sputter ion coater and observed at 20 kV.

The Hounsfield tensometer was used in determining the elastic modulus. The gauge length of each fiber was 100mm while the lengths of the fibers were the same with varying diameters. Each fiber was fixed unto gripping chucks. A gradual and continuous load

was applied. Tensile strengths of the fibers were then calculated.

Thermal decomposition was observed in terms of global mass loss by using a TA Instrument TGA Q50 thermogravimetric analyzer. This apparatus detects the mass loss with a resolution of 0.1 as a function of temperature. The samples were evenly and loosely distributed in an open sample pan of 6.4 mm diameter and 3.2 mm deep with an initial sample amount of 8-10 mg. Due to different bulk density, the depth of the sample layer filled in the pan was about 1-2 mm. The temperature change was controlled from room temperature ( $25\pm 3^\circ\text{C}$ ) to  $700^\circ\text{C}$  at a heating rate  $10^\circ\text{C}/\text{min}$ . The sampling segment was set at 0.5 second per point.

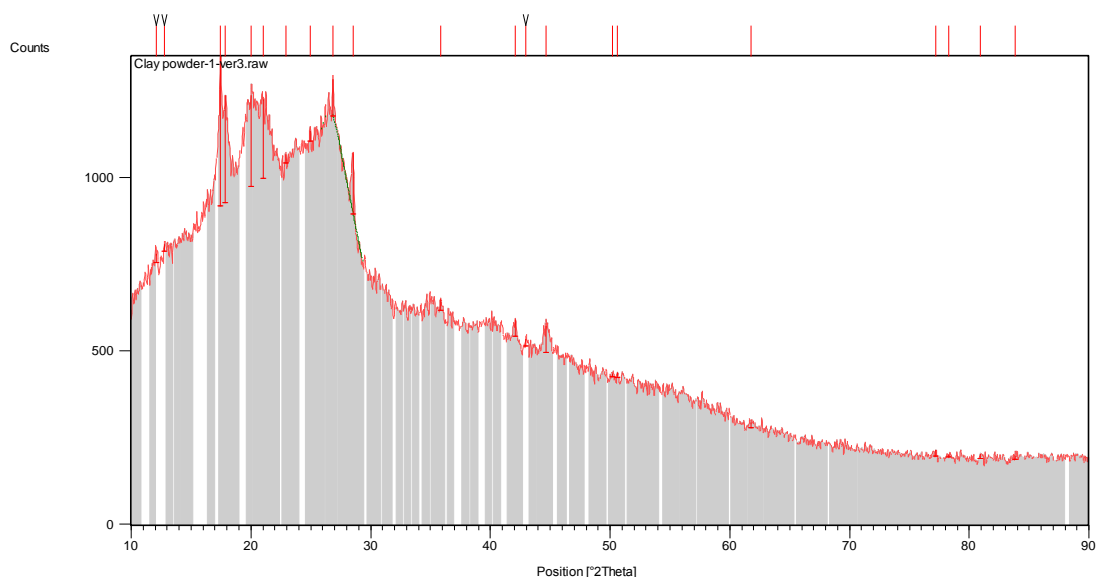
A high purity Argon was continuously passed into the furnace at a flow rate of 60 mL/min at room temperature and atmospheric pressure. Before starting each run, the Argon was used to purge the furnace for 30 min to establish an inert environment in order to prevent any unwanted oxidative decomposition. The TG and DTA curves that were obtained from TGA runs were carefully smoothed at a smoothing region width of  $0.2^\circ\text{C}$  by using least squares smoothing method, and analyzed by using Universal Analysis 2000 software from TA Instruments. The test was carried

out at the University of the Witwatersrand, Johannesburg, South Africa.

## RESULTS AND DISCUSSION

The MA fibers exhibited a bulk density of  $1.11\text{g}/\text{cm}^3$ . The lower density shows that the MA fibers are lighter than some agro-waste fibers used in polymer composites. Consequently, MA fibers are suitable as reinforcement in polymer composites on the account of the overall weight (Herrera-Franco and Valadez-González, 2005).

The XRD pattern (Figure 2) obtained reveal that, the major diffraction peaks were:  $17.47^\circ$ ,  $21.03^\circ$ ,  $24.95^\circ$ ,  $42.09^\circ$ ,  $44.66^\circ$ , and  $78.31^\circ$  and their inter-planar distance were: 5.90, 4.90, 4.14, 2.49, 2.31, and  $1.40\text{Å}$  and phases at these peaks were: 5-Androsten-3GB-ol-17GB-carboxylic acid, Androst-4-en-3-one-17GB carboxylic acid, Silicon Oxide, Aluminum Nitride, Aluminum Silicon, Zeolite Y (partly dealuminated) - artificial, hydrothermal while each of these phases have a score of 100, 52.57, 6.86, 11.10 17.39 and 1.91 (Table 1 and Figure 2). This analysis confirmed that the MA fibers have similar characteristics with other agro-waste presently used in polymer composites.



**Figure 2:** XRD Spectrum of MA Fibers.

**Table 1:** Identified Patterns List.

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula
*	18-1539	32	5-Androsten-3 $\beta$ -ol-17 $\beta$ -carboxylic acid	0.000	0.595	C <sub>20</sub> H <sub>30</sub> O <sub>3</sub>
*	20-1520	37	Androst-4-en-3-one-17 $\beta$ -carboxylic acid	0.000	0.605	C <sub>20</sub> H <sub>28</sub> O <sub>3</sub>
*	38-0651	23	Silicon Oxide	0.000	0.583	Si O <sub>2</sub>
*	87-1053	36	Aluminum Nitride	0.000	0.066	Al N
*	41-1222	21	Aluminum Silicon	0.000	0.147	Al <sub>3.21</sub> Si <sub>0.47</sub>
*	80-2148	17	Silicon Oxide	0.000	0.094	Si O <sub>2</sub>
*	88-2290	9	Zeolite Y (partly dealuminated) - artificial, hydrothermal at	0.000	3.084	( Al <sub>1.28</sub> Al <sub>1.93</sub> Si <sub>9.63</sub> O <sub>24</sub> ). <sub>81</sub>

Complete Mineralogical analysis carried out by X-ray diffraction also revealed that the MA fibers contain each of these elements "H, C, N, O, Al, Si, S and None of: elements = "He, Li, Be, B, F, Ne, Na, Mg, P, Cl, Ar, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Kr, Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe, Cs, Ba, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl, Pb, Bi, Po, At, Rn, Fr, Ra, Ac, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr, D, T" which means that with the absence of all these other elements, the MA fibers do not contain toxic and harmful materials. This is in par with the earlier works of other researches (Herrera-Franco and Valadez-González, 2005).

Surface Morphology of MA fibers is seen in back scattered electron (BSE) as shown in Figure 3. MA fibers were observed to be solid in nature, longitudinal and irregular in space. The chemical analysis of MA fibers morphology consists mainly of C, O, and, H as shown in the EDS scan (see Figure 3).

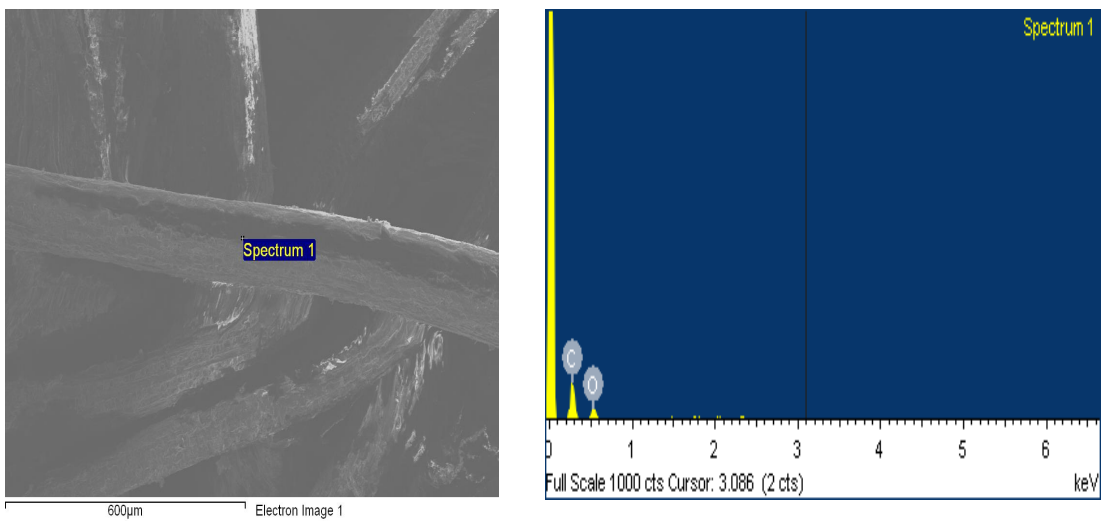
The temperature of destruction ( $T_{des}$ ) of the MA fiber was determined from DTA curves. DTA data were recorded on "Derivatograph OD 102", at heating rate of 20°C/min in argon. The result of the DTA/TGA scan of the MA fiber is shown in Figure 4. From the Figure 4, the TG/DTA curve shows three weight loss steps, while the thermal decomposition

occurs in one stage.

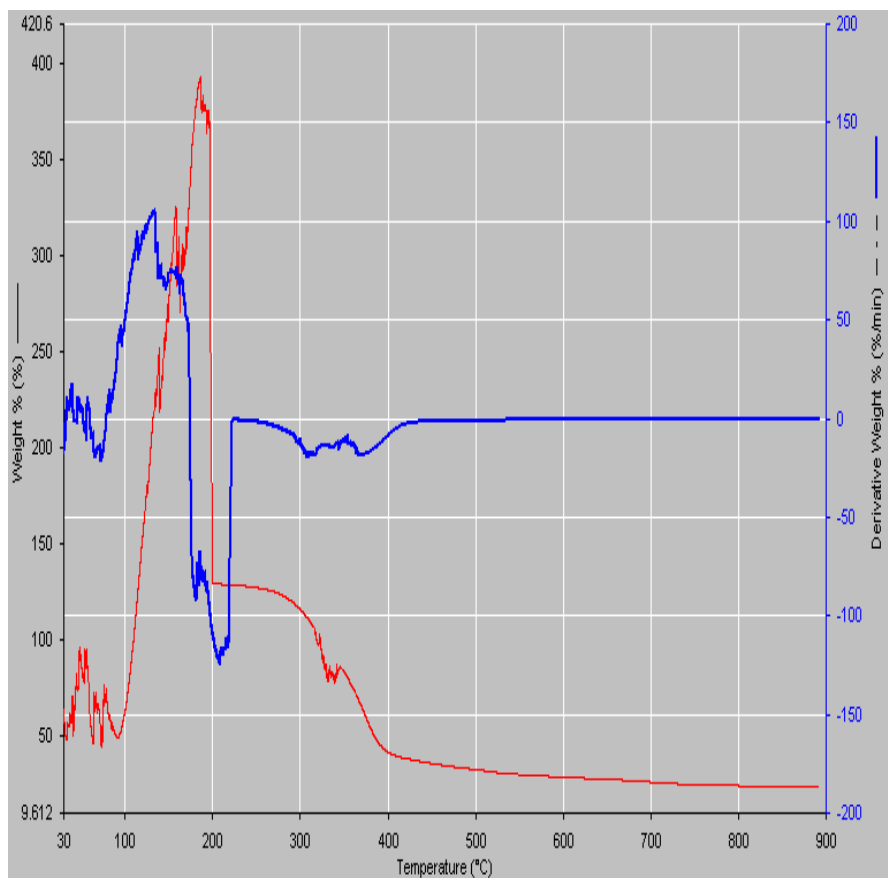
The initial weight loss (~ 5%) observed between 30 and 100°C is attributed to the vaporization of the water from the fiber, while degradation of the fiber started at temperature, precisely after 200°C. Above this temperature, the thermal stability of MA fibers gradually decreased and degradation occurred.

DTA curve shows that the temperature of maximal decomposition/ destruction was between 200 and 300°C (Figure 4). The presences of endothermic effects in MA fibers are results of two processes – dehydrogenation and evaporation of some cellulosic materials. This conclusion was confirmed by the decreased mass of the sample. DTA curve also confirmed these results. In an inert atmosphere, the final products of the degradation of MA fiber consist of carbonaceous residues and possibly un-degraded. On the analogy of these results it was assumed that the total burning/ degradation of the residual MA fiber took place in this temperature interval (200-400°C), In the last temperature interval the mass loss was minimal (Davies and Bruce, 1998):

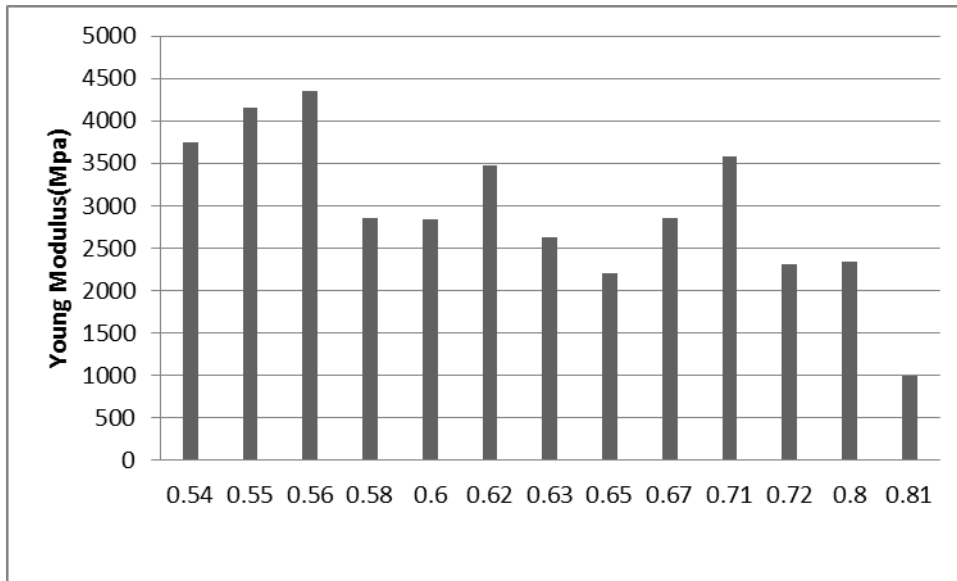
Figures 5-6, show the tensile modulus and tensile strength of the MA fibers. The data collected for the fibers were compared with values taken from the literature relevant to synthetic and natural fibers (Table 2).



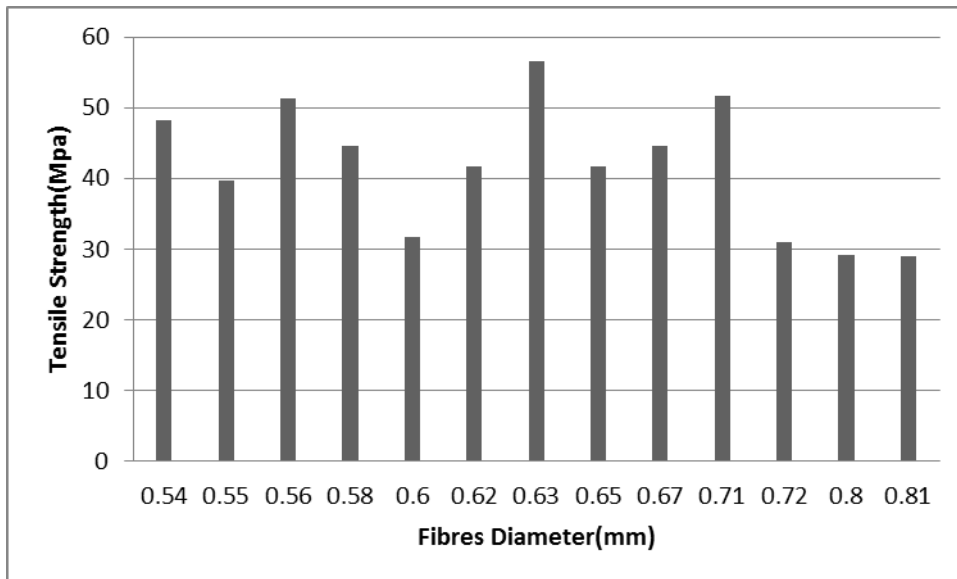
**Figure 3: SEM/EDS of the MA Fibers.**



**Figure 4: DTA/TGA Pattern of MA Fibers.**



**Figure 5:** Variation of Young Modulus with Fibers Diameter.



**Figure 6:** Variation of Tensile Strength with Fibers Diameter.



**Table 2:** Typical Tensile Properties and Density of MA Fibers Compared to their Natural Fibers, Commercial, and Aerospace Counterparts.

Fiber	Density (gm/cm <sup>3</sup> )	Tensile Strength (Mpa)	Tensile Modulus (Mpa x10 <sup>3</sup> )	Range of Elongation (%)
Flax	1.50	75-215	4	2.7-3.2
Hemp	1.47	100	10	2.0-4.0
Kenaf	1.45	135	7.7	1.6
Jute	1.30	55-110	3.8	1.5-1.8
Ramie	1.50	60-135	8.9 – 18.6	3.6-3.8
Sisal	1.50	75- 90	1.4 – 3.2	2.0-2.5
Coir	1.20	85	0.6-0.9	30
Cotton	1.55	60	0.8-1.8	3 – 10
E-glass	2.56	290-350	10	3.0
S-glass	2.57	665	12.5	2.8
Aramid (commercial)	1.44	435-455	9-10	3.3 – 3.7
Carbon (Pan std. Mod)	1.67	580	33-35	1.4 – 1.8
<b>MA fibers</b>	<b>1.10</b>	<b>35-57.93</b>	<b>2-4.4</b>	

The mechanical properties, in particular Young's modulus and the ultimate tensile strength values, are found to be lower than those published in the literature. In the case of Young's modulus, the values may have been underestimated due to approximations and some of the hypotheses used in the calculations. Indeed, it is well known that many difficulties are encountered when characterizing the mechanical properties of natural fibers (Davies and Bruce, 1998). Firstly, as for all biomaterials, the properties of natural fibers are highly dependent on temperature, humidity, test duration and rate, and material heterogeneities.

## CONCLUSIONS

MA fibers were characterized by XRD and SEM/EDS. Their thermal degradation behavior was fully investigated through TGA/DTA curves, the tensile properties and density was determined. The various results obtained are comparable with those other natural fibers commonly used in polymer composites production. The work has confirmed that MA fibers show potential as a material for polymer composites production.

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