



Mechanical Behavior of Agricultural Waste Fibers Reinforced Vinyl Ester Bio-composites

A. O. Ogah^{1*} and Timothy Ukeme James²

¹*Department of Industrial Chemistry, Faculty of Science, Ebonyi State University, P.M.B. 053, Abakaliki, Ebonyi State, Nigeria.*

²*Department of Polymer and Textile Engineering, Faculty of Science, Nnamdi Azikiwe University, PMB 5025, Awka, Anambra State, Nigeria.*

Authors' contribution

Both authors designed, analyzed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/AJOPACS/2018/35841

Editor(s):

(1) Maurizio D'Auria, Professor, Dipartimento di Scienze, Università della Basilicata, Italy.

Reviewers:

(1) Ahmad Adlie Shamsuri, Universiti Putra Malaysia, Malaysia.

(2) Carlo Santulli, Università di Camerino, Italy.

Complete Peer review History: <http://www.sciencedomain.org/review-history/22992>

Original Research Article

Received 31st July 2017

Accepted 18th January 2018

Published 5th February 2018

ABSTRACT

Agricultural waste fibers have great potential in composite due to its high strength, eco-friendly nature, low cost, availability and sustainability. The agricultural waste is one of the most important problems that must be resolved for the conservation of the global environment. In this study, the potential of agricultural wastes such as bagasse, oil palm, coconut, cornhusk, groundnut shell and rice husk fibers as reinforcements in vinyl ester composites was investigated. The necessity of this work is to respond to the social demands for the disposal of environmentally problematic agricultural wastes and property improvement. Hence, the effects of four levels of fiber loadings (5, 10, 15 and 20 wt. %) on the mechanical properties of the composites were studied. For overall trend, as the percentage of fiber loadings increased the ultimate tensile strength, tensile modulus and hardness of the composites substantially improved, whereas the tensile strain decreased compared with the pure vinyl ester matrix with a verge point value at 10 wt. % reinforcement. In general, oil palm fibrous waste showed superior mechanical properties due to its chemical characteristics. This study has shown that the ultimate tensile strength, tensile modulus, tensile strain and hardness of the composites varied substantially based upon the type of fiber utilized and the fiber loadings, with a maximum value at 10 wt. % agro fiber content.

*Corresponding author: E-mail: anselmogah@gmail.com;

Keywords: Mechanical properties; agricultural waste; vinyl ester; reinforcements; composites.

1. INTRODUCTION

Plenty of wastes are generated as a result of the increased activity in the modern agricultural sector which represents a serious threat to the environment. Meanwhile, dwindling supply of raw materials is causing concern and in this context, the agro waste can be seen as a good alternative material for the local timber industry to produce value-added product, such as bio-composites. Utilization of natural fibers especially agricultural waste fibers needs further development as a long-term strategy to develop the tremendous wealth of natural plant fiber that is currently underutilized [1].

Cellulose fibers from palm pressed fibers have been used as fuel [2]. The corn husk has also been used for the biodegradable film [3], heat insulator from coconut fibers [4], rice husk ash and coconut fibers in concrete [5]. Natural fibers from banana's tree as fillers into polymers composites [6]. Rice straw and bagasse fibers used as writing and printing papers [7]. In addition, oil palm fronds, bamboo fibers, coconut fibers, rice-husks and sugar cane-dregs are used to make cement boards [8,9]. In the past few years, several studies have reported natural fibers as a reinforcing material in bio-composites thermoplastics and thermoset matrices. Coir, banana and sisal agricultural wastes can be used as reinforcement for polymer composites for commercial use [10-14].

Dealing with the growing demand for the renewable resources, agricultural and plantation wastes are considered as the promising and the suitable material. Biomass material is one of the important sources of alternative material for the production of bio-composites products [15,16,14,17]. An increasing global awareness about environmental issues is acting as the driving force behind the utilization of biomass material as valuable products.

Thousands of tons of agricultural waste materials are produced globally on annual basis. These wastes could be used as the potential resources for reinforcing materials in bio-composites applications. The use of such resources will not only provide the sustainable and less expensive material but at the same time will contribute to the waste disposal management as well as overcoming the environmental problems [18].

As a result of the worldwide demand for fibrous materials, global decline of trees in many locations, and environmental consciousness, research into the development of composites prepared with various agro waste resources is being actively pursued. Among the promising substitutes is the development of composites utilizing agricultural wastes (such as stalks of most cereal crops, rice husks, coconut fibers, bagasse, corncobs, peanut shells, and other wastes) is presently at the focus of interest [19, 22,17].

Although there are some useful studies in the literature on agricultural wastes in composites [23,24,25,21], there are still many gaps in information and knowledge of composites from agricultural wastes, which must be closed in order to encourage commercial production of these novel materials.

The scope of the present work is to utilize sugarcane bagasse, oil palm, coconut, corn husk, groundnut shell and rice husk agro wastes to evaluate and compare their suitability as reinforcing materials for composite applications. Aside from the importance of property improvement, an additional incentive was to respond to the social demands for the disposal of environmentally problematic agricultural wastes.

2. EXPERIMENTAL

2.1 Materials

Six types of agricultural residuals were used in the study viz.:- sugarcane bagasse, oil palm, coconut coir, cornhusk, groundnut shell and rice husk fibers. The important chemical components and fiber morphology of agricultural waste fiber materials used in this study are given in Tables 1 and 2 respectively. These parameters are important as they influence the resulting mechanical properties of the composites.

2.1.1 Preparation of sugarcane bagasse fibers

The sugarcane bagasse fiber (SBF) was sourced locally within the Abakaliki town from the sellers. Cleaned and dried bagasse was initially washed with water to remove the sand and other impurities. Subsequently, the bagasse was dried under the sunshine for three days to ensure that it was well dried. The dried fibers were pulverized using Denver laboratory ball mill. The particles from the process were sieved with sieve shaker 16155 Model into 75 μm sieve size.

Table 1. Chemical composition of selected agricultural waste fibers

Type of fiber	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Ref
Bagasse	57.4	24.5	26.3	[26]
Oil palm	65.1	10.2	17.5	[27]
Coconut coir	47.7	25.9	17.8	[28]
Corn husk	40.3	32.2	21.5	[29]
Groundnut shell	35.7	18.7	30.2	[30]
Rice husk	31.3	24.3	14.3	[31]

2.1.2 Preparation of groundnut shell fibers

The groundnut shell was sourced locally within the Abakaliki metropolis. Clean and dried groundnut shells were initially washed with clean water to remove the sand and other impurities. Subsequently, the shells were dried under the sunshine for three days to ensure that it is well dried. The dried shells were ground and sieved with sieve shaker 16155 Model into 75 μ m sieve size.

2.1.3 Preparation of rice husk fibers

Finely milled rice husks were collected from the Abakaliki Rice Mill in Ebonyi State, Nigeria. The milled rice husks contain many impurities like dust, small rice particles, and fine sand particles. Therefore, it needs to be cleaned in order to get pure rice husk. After cleaning with water, the rice husks were dried directly under the sun for 8 h. The dried fibers were pulverized using Denver laboratory ball mill. The particles from the process were sieved with sieve shaker 16155 Model into 75 μ m sieve size.

2.1.4 Preparation of oil palm fibers

The oil palm fiber (OPF) was collected from the rural farmers of Ebonyi State, Nigeria. The fibers were soaked in hot water with detergent for three days in order to remove the residual oil and other impurities. The fibers were dried in the sun for one week to obtain a dry mass. A 40-mesh Wiley grinder was used to reduce the fiber to smaller particles. The particles from the process were

sieved with sieve shaker 16155 Model into 75 μ m sieve size.

2.1.5 Preparation of cornhusk fibers

Corn husk fibers (surrounding the ear of corn/maize) were obtained from a local farmer Market in Kpirikpiri Market, Abakaliki, Ebonyi State, Nigeria. The corn husk was dried, ground and sieved with sieve shaker 16155 Model into 75 μ m sieve size.

2.1.6 Preparation of coconut coir fibers

Coconut fibers were extracted from exocarp washed and dried under the sun for three days. After being ground in a mill and sieved with sieve shaker 16155 Model into 75 μ m sieve size. Furthermore, the fibers were washed with clean water and dried in an oven at 100°C for 24 h.

2.1.7 Vinylester resin

Vinyl ester uses a polyester resin type of cross-linking molecules in the bonding process and is tougher and more resilient than polyesters. The ester groups in vinyl ester molecules are vulnerable to water degradation by hydrolysis, which means that vinyl esters exhibit better resistance to water and many other chemicals. A vinyl ester resin has excellent physical and mechanical properties and is well known for its versatility as a composite matrix. With the development of a promising room temperature molding technique, the processability of vinyl ester resins at low temperatures has attracted considerable attention from the composite

Table 2. Dimensions of selected agricultural waste fibers

Type of fiber	Fiber length (mm)	Fiber width (μ m)	Aspect ratio (L/D)	Ref
Bagasse	1.24	22.9	54	26
Oil palm	1.3	21.7	60	27
Coconut coir	1.22	24.4	50	28
Corn husk	1.18	25.1	47	29
Groundnut shell	0.8	17.8	45	30
Rice husk	0.5	12.5	40	31

industry. The vinyl ester resin used in this work was procured from Juneng Nig. Ltd. in Enugu, Enugu State, Nigeria. The density of the vinyl ester is 1.05 g/cm³ with heat distortion temperature of 125°C. The specification of the vinyl ester used in the study is shown in Table 3.

2.2 Composite Preparation

The prepared agro waste fibers were mixed with the vinyl ester resin for one hour by using stirrer. The accelerator used was methyl ethyl ketone peroxide (2% of weight for each composite) and catalyst cobalt naphthalate (1% of weight for each composite) was added after stirring process. Once accelerator and catalyst were added, the curing reaction started immediately at room temperature. The mixture was transferred to a silicon rubber mold size and polyethylene sheet in the dimension of 300 × 300 × 5 mm. After the curing process, the material was taken into the compression molding machine. The weight percentage of fiber reinforcement was varied as (0%, 5%, 10%, 15% and 20%) shown in Table 4. The mixture was stirred for about 5-7 minutes until there were proper wetting and soaking of the particles by the vinyl ester resin. The homogenous slurry was poured into the mold and pressed at 10,000 psi pressure at 90°C for 15 min and allowed to cure at room temperature for 24 h. Finally, the composites were placed in an oven at 100°C for 2 hours for post curing before the mechanical tests were carried out.

2.3 Mechanical Testing

The tensile mold of gauge length 25 mm of a dumb-bell shape was used for the production of tensile samples. Following the molding of the composites, samples were prepared for tensile and hardness tests. These tests were carried out as follows:

2.3.1 Determination of the tensile properties of the materials

In the present study, tensile tests were performed on INSTRON 1195 at a fixed crosshead speed of 10 mm min⁻¹. Samples were prepared according to ASTM D412 (ASTM D412 1983), and tensile strength of the standard and conditioned samples were calculated. Five specimens for each sample were tested and the tensile strength and tensile modulus were expressed as:

$$\text{Tensile strength (MPa)} = P/bh \quad (1)$$

$$\text{Tensile modulus (MPa)} = \sigma/\epsilon \quad (2)$$

Fig. 1 shows the specimens prepared for the tensile test. The testing is done using UTM to measure the force required to break a polymer composite specimen and the extent to which the specimen stretches or elongates to that breaking point.

2.3.2 Determination of the hardness property of the materials

The samples were indented using microhardness tester following ASTM procedure No.D2240. The reading is noted from the calibrated scale. Five readings were taken for each sample and the average value was used.



Fig. 1. Tensile test specimens

2.4 Morphological Study

Studies on the morphology of the composites were conducted using a TESCAN model WEGA-II scanning electron microscope (SEM). The fracture surfaces of the specimens after tensile test were sputter-coated with gold before analysis in order to eliminate electron charging.

Table 3. Specification of the vinyl ester used in the research

Materials	Specifications
Vinyl ester	Density = 1.05 g/cm ³ HDT = 125°C

Sample preparation calculations:

1. Density of vinyl ester (ρ) = 1.05g/cm³
2. Volume of the mold (V) = 300 x 300 x 5mm
= 450000 mm³
= 450 cm³
3. Mass of resin (m) = Volume of mold x density of resin
= 450 cm³ x 1.05 g/cm³
= 472.5 g ≈ 500 g

Table 4. Samples preparation calculation for agro residuals/Vinyl ester Composites

Sample	% wt of fiber	% of resin	Mass of fiber	Mass of resin	Total mass
A	0	100	0	500	500
B	5	95	25	475	500
C	10	90	50	450	500
D	15	85	75	425	500
E	20	80	100	400	500

3. RESULTS AND DISCUSSION

3.1 Tensile Properties

Figs. 2 and 3 illustrate the ultimate tensile strength and modulus respectively, of fiber/vinyl ester composites made with various fiber types. Maximum tensile strength and modulus of the fiber/vinyl ester composites were observed at 10 wt. % of fiber loading for all the composites. In other words, the ultimate tensile strength (UTS) increased as the fiber weight content increased up to a verge point of 10 wt% before experiencing reduction. This was expected to happen because as the fiber content increased, the propensity for the fiber/matrix bonding strength to decrease was high. As shown, 5-10 wt% reinforcement gave better results than 15-20 wt% for the UTS because at low fiber content, the fibers are wetted properly by the vinyl ester and it is little or no fiber in contact with one another. However, at higher fiber content, the reverse was the case, the fibers were touching one another thereby reducing proper fiber wetting and bonding between the fibers and the vinyl ester matrix. This actually results to the reduction of the strength of the composites at this higher fiber content.

The result of the effect of fiber content on the tensile modulus was shown in Figure 3 where similar trends to that of the UTS were observed. However, there were slight differences in the trend as the modulus for the 15 wt% fiber reinforced sample has a higher value than the 5 wt% reinforced sample. The tensile modulus for 10 wt% reinforced sample emerged as the best with a value of 1015.1 N/mm² for oil palm fiber compared to unreinforced vinyl ester matrix with a value of 318.30 N/mm².

The boost in the UTS and modulus at the presence of cellulosic fibers was expected as the mechanical properties of the composites are determined by several factors, such as nature of the reinforcement fiber, fiber aspect ratio, fiber-matrix interfacial adhesion, and also the fiber orientation in the composites. One of the most important parameters controlling the mechanical properties of short fibers composite is the fiber length or more precisely its aspect ratio (length/width). A high aspect ratio is very crucial to fiber reinforced composites, as it indicates potential strength properties. As can be seen from Table 2, oil palm fiber has high fiber length and aspect ratio compared to the other cellulosic fibers.

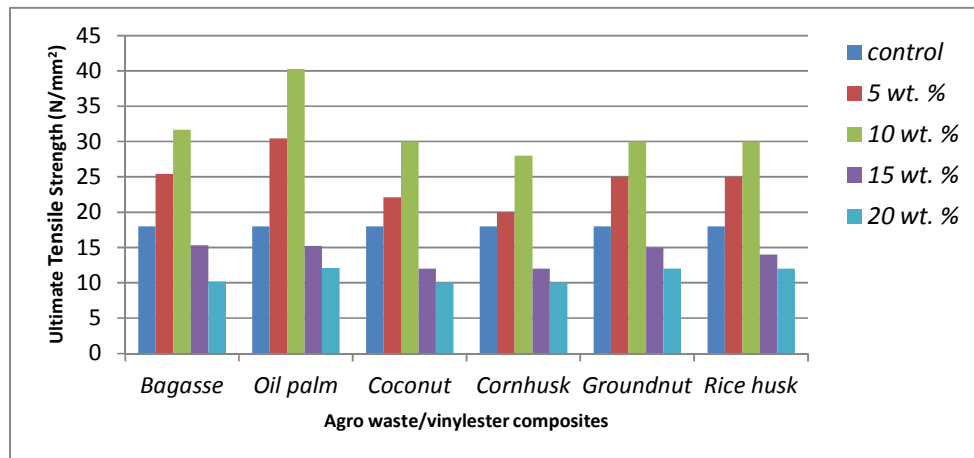


Fig. 2. Comparison of ultimate tensile strength of composites as function of fiber weight content

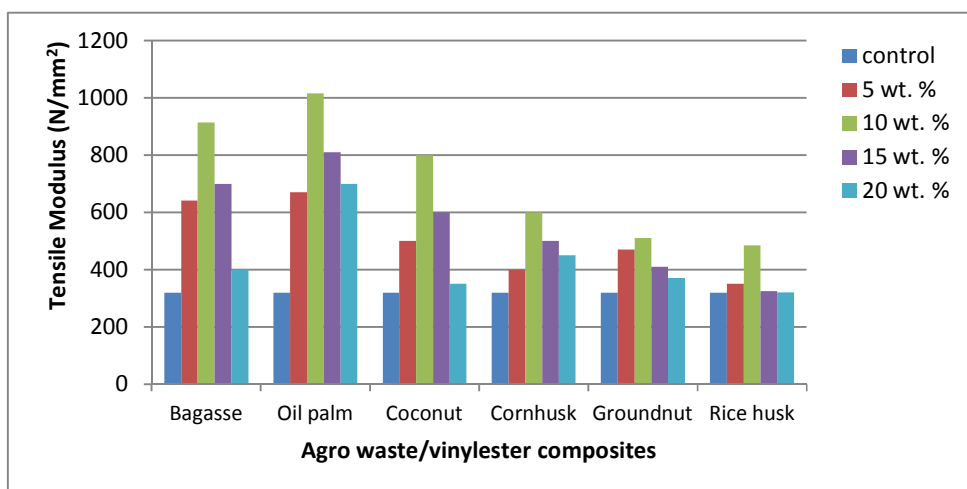


Fig. 3. Comparison of tensile modulus of composites as function of fiber weight content

At high weight fractions of fibers, above 10 wt. % tensile strength decreases due to the filler high volume incorporated into the vinyl ester matrix. The agglomeration and the poor dispersion of the fibers into the vinyl ester matrix had a significant effect on the mechanical properties of the composites compared to the neat matrix strength.

3.2 Tensile Strain

Fig. 4 shows the tensile strain result. It was observed that the unreinforced vinyl ester matrix has the highest tensile strain property of 3.72% followed by 5wt% fiber content reinforced sample with a value of 1.5% for the oil palm fiber/vinyl ester composite. It was observed that the tensile strain property reduced as the fiber content

increases from 5-20 wt% for all the composites. The agro waste fibers provided reinforcements effects in the vinyl ester matrix because the stiffer the material, the greater the strength and modulus as revealed in Figs. 2 and 3 and hence the lower the tensile strain. A decrease in strain as the filler content increased was observed indicating the presence of a poor interfacial adhesion between the hydrophilic fiber and the hydrophobic vinyl ester which does not allow efficient stress transfer between the two phases of the bio-composites.

3.3 Hardness

Hardness property is a measure of the resistance of the materials to surface indentation and wear. Fig. 5 shows the variation of this property with

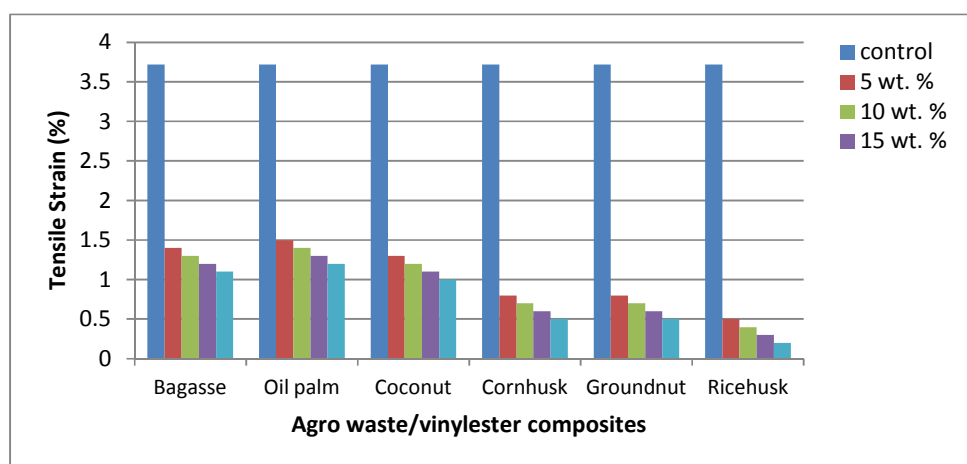


Fig. 4. Comparison of tensile strain of composites as function of fiber weight content

the samples. It was noticed that the reinforcements lead to the enhancement of the hardness property in all the samples produced. The trend was similar to the UTS result. This shows that both the UTS and the hardness were enhanced in the same manner. The result shows that 5-10 wt% reinforced samples gave the best hardness property where the 10 wt% reinforced sample exceeded the 5 wt% reinforced sample with values of 100.2 MPa and 92.7 MPa for oil palm fiber respectively compared to the unreinforced vinyl ester matrix with a value of 30.40 MPa. Improvement of mechanical

properties was possible due to adequate wetting and bonding between the fibers and the vinyl ester.

3.4 Morphology Characteristics

SEM is an effective method for the morphological investigations of the composites. Through SEM study the distribution and compatibility between the fibers and the matrix could be observed. The tensile fracture surfaces of the composites at 10 wt. % fibers loading are shown in Fig. 6-11 respectively. In the case of the composite made with oil palm, the filler particles are well

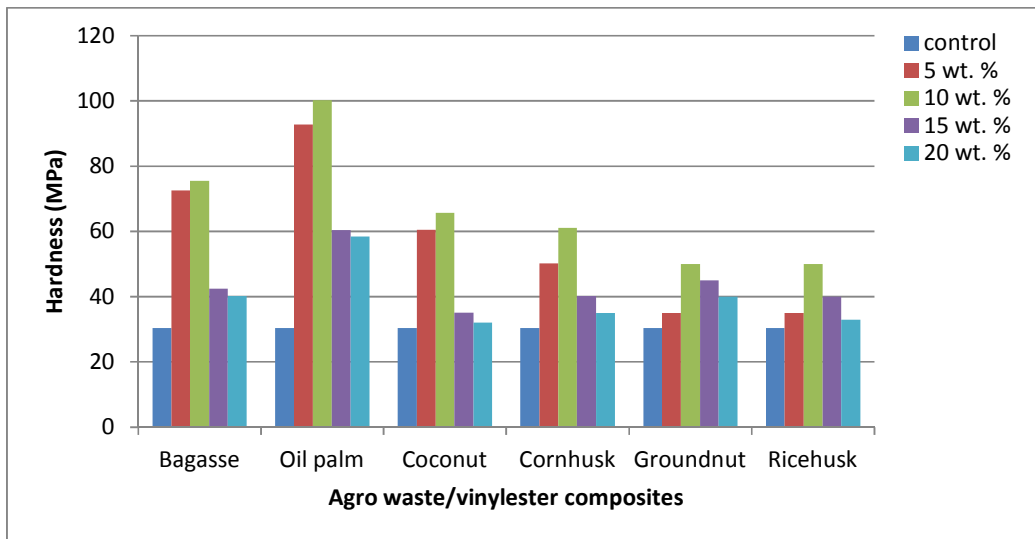


Fig. 5. Comparison of hardness of composites as function of fiber weight content

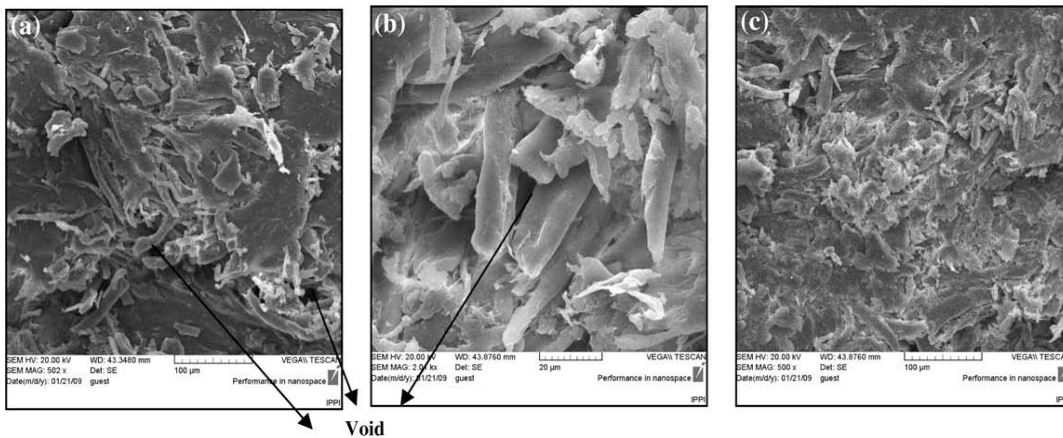


Fig. 6. 10 wt % rice husk fiber, Fig. 7. 10 wt % corn husk fiber, Fig. 8. 10wt % groundnut shell

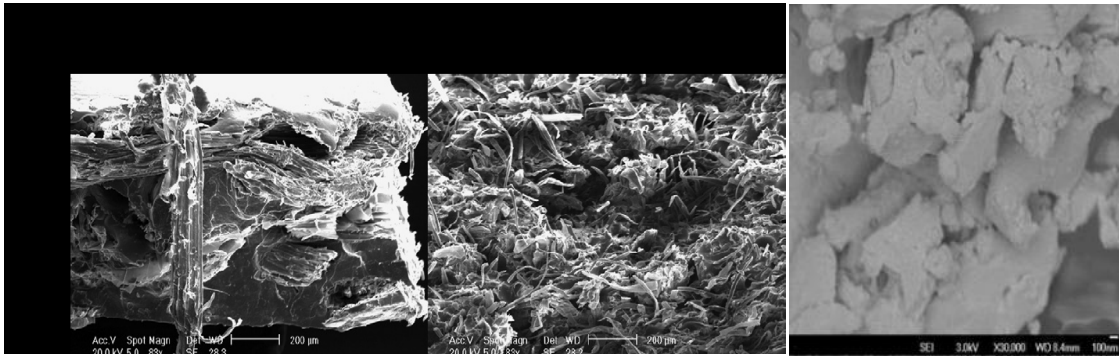


Fig. 9. 10 wt % coconut fiber, Fig. 10. 10 wt % oil palm fiber, Fig. 11. 10wt% bagasse fiber

dispersed in the matrix polymer, as compared with the composites made with the bagasse, groundnut shell, coconut coir, corn husk and rice husk. There are some voids where the fibers have pulled-out. The presence of these voids means that the interfacial bonding between the fiber and the matrix is weak.

4. CONCLUSION

In the present study, morphological and mechanical properties of vinyl ester eco-friendly composites reinforced with agricultural waste fibers have been examined. From the results and discussion presented above, the following conclusions can be made:

- I. This work shows the doing well manufacture of vinyl ester and the agro waste fibers composites by compounding and compression molding.
- II. The microstructural differences of the polymer composite are the most important factor responsible for the improvements in the mechanical properties.
- III. Based on the results, it is suggested that these composites can be used in the manufacture of low strength automotive and other structural applications.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Jawaid M, Abdul Khalil HPS. Effect of layering pattern on the dynamic mechanical properties and thermal degradation of oil palm-jute fibers reinforced epoxy hybrid composites. *Bio Resources*. 2011;6:2309-2322.
2. Arami-Niya A, Daud WMAW, Mjalli FS. Using granular activated carbon prepared from oil palm shell by $ZnCl_2$ and physical activation for methane adsorption. *J. Anal. Applied Pyrolys*. 2010;8:197-203.
3. Norashikin MZ, Ibrahim MZ. The potential of natural waste (Corn Husk) for production of environmental friendly biodegradable film for seeding. *World Acad. Sci. Eng. Technol*. 2009;3:1808-1812.
4. Yuhazri YM, Jihombing H, Jeefferie AR, Mujahid AZA, Balamurugan AG, Norazman MN, Shohaimi A. Optimization of coconut fibers toward heat insulator applications. *Global Eng. Technol. Rev*. 2011;1:35-40.
5. Domke PV. Improvement in the strength of concrete by using industrial and agricultural waste. *IOSR J. Eng*. 2012;2:755-759.
6. Albinante SR, Pacheco EBAV, Visconte LLY, Platenik G, Batista LN. Modification of Brazilian natural fibers from banana's tree to apply as fillers into polymer composites, *Chem. Eng. Trans*. 2014;37: 715-720.
7. Karim MS, Seal HP, Rouf MA, Rahman MI, Talukder MHR, Karmaker PG. Acetic acid pulp from jute stick, rice-straw and bagasse. *J. Agrofor. Environ*. 2010;3:171-174.
8. Hermawan DB, Subiyanto B, Kawai S. Manufacture and properties of oil palm frond cement-bonded board. *J. Wood Sci*. 2011;47:208-213.
9. Harmawan DB, Hatu T, Kawai S, Nagadomi W, Kuroki Y. Manufacturing oil palm fronds cement-bonded board cured

- by gaseous or supercritical carbon-dioxide. *J. Wood Sci.* 2002;48:20-24.
10. Sapaun SM, Harimi M, Maleque MA. Mechanical properties of epoxy/ coconut shell fiber particles composites. *Arab J. Sci. Eng.* 2003;28:171-181.
 11. Yang HS, Wolcott MP, Kim HS, Kimand S, Kim HJ. Properties of lignocellulosic material filled polypropylene bio-composites made with different manufacturing processes. *Polymer Testing.* 2006;25:668-676.
 12. Sakthival M, Ramesh S. Mechanical properties of natural fiber (banana, coir, sisal) polymer composites. *Sci. Park.* 2013;1:1-6.
 13. Abdul Khalil HPS, Aprilla NAS, Bhat AH, Jawaid M, Paridah MT, Rudi D. A jatropa biomass as renewable materials for bio-composites and its applications renew. *Sustain. Energy Rev.* 2013;22:667-685.
 14. Namvar F, Jawaid M, Tanir PM, Mohamad R, Azizi S, et al. Potential use of plant fibers and their composites for biomedical applications. *Bio Resources.* 2014;9:5688-5706.
 15. Abdul Khalil HPS, Firoozian P, Bakare IO, Akil HM, Noor AM. Exploring biomass based carbon black as filler in epoxy composite: Flexural and thermal properties, mater, design. 2010b;31:3419-3425.
 16. Abba HA, Nur IZ, Salit SM. Review of agro waste plastic composites production. *J. Mineral Material Characterization Eng.* 2013;1:271-279.
 17. Ogah AO, Afiukwa JN, Nduji AA. Characterization and comparison of rheological properties of agro fiber filled high-density polyethylene bio-composites. *Open J. Polymer Chem.* 2014;4:12-19.
 18. Dittenber DB, GangaRao HVS. Critical review of recent publications on use of natural composites in infrastructure. *Composites Part A: Applied Science Manuf.* 2012;43:1419-1429.
 19. Georgopoulos ST, Taratili PA, Avgerinos E, Angreopoulos AG, Koukios EG. Thermoplastic polymers reinforced with fibrous agricultural residues. *J. Polymer Degradation & Stability.* 2005; 90:303-312.
 20. Yao F, Wu Q, Lei Y, Xu Y. Rice straw fiber reinforced high-density poly -ethylene composites: Effect of fiber type and loading. *J. Ind. Crop Prod.* 2008; 28:63-72.
 21. Ashori A, Bahraini Z. Evaluation of calotropis gigantean as a promising raw material for fiber reinforced composites. *J. Compos. Mat.* 2009; 43(11):1297-1304.
 22. Wang Z, Wang E, Zhang S, Ren Y. Effects of crosslinking on mechanical and physical properties of agricultural residues/ recycled thermoplastic composites. *J. Ind. Crop Prod.* 2009; 29(1):133-138.
 23. Yang HS, Kim HJ, Park HJ, Lee BJ, Hwang TS. Effect of compatibilization on rice husk flour reinforced polypropylene composites. *J. Composite Structure.* 2007;77:45-55.
 24. Saira T, Munawar AM, Khan S. Natural fiber reinforced polymer composites. *Proceeding of the Pakistan Academic Science.* 2007; 44(2):129-144.
 25. Kim HJ, Eom YG. Thermogravimetric analysis of rice husk flour for a new material of lignocellulosic fiber-thermoplastic polymer composites. *Mokchae Konghak.* 2001;29(3):59-67.
 26. Wahlang BK, Nath K, Ravindra H, Chandu R, Vijayalaxmi K. Processing and utilization of sugarcane bagasse for functional food formulations. *Proceedings of the International Conference and Exhibition on food Processing and Technology, September 22-24, Hyderabad, India.* 2012;106-112.
 27. Abdul-Khalili HPS, Hanida S, Kang CW, Fuaad NAN. Agro-hybrid composite: The effects on mechanical and physical properties of oil palm fiber (EFB/Glass hybrid reinforced polyester composite. *J. Reinforced Plastics Compos.* 2007;26: 203-218.
 28. Sapaun SM, Harimi M, Maleque MA. Mechanical properties of epoxy/cement shell filler particle. *Arab. J. Sci. Eng.* 2003;28:171-181.
 29. Reddy N, Yang Y. Biofibers from agricultural byproducts for industrial applications. *Trends Biotechnol.* 2003;23: 22-27.

30. Raju GU, Kumarappa S, Gaitonde VN. Mechanical and physical characterization of agricultural waste reinforced polymer composites. J. Mater. Environ. Sci. 2012; 3(5):907-916.
31. Bouasker M, Balayachi N, Hoxha D, Al-Mukhtar M. Physical characterization of natural straw fibers as aggregates for construction materials applications. Materials. 2014;7:3034-3048.

© 2018 Ogah and James; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<http://www.sciencedomain.org/review-history/22992>