Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 7, Issue, 04, pp.14460-14464, April, 2015

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

MECHANICAL PROPERTIES OF LUFFA CYLINDRICA REINFORCED BIO-COMPOSITE

***Salawu Asipita Abdulrahman, Ekemhe Emmanuel Aiyejina and Ubi Ateb Paschal**

Department of Mechanical Engineering, Federal University of Technology, Minna, PMB 65, Niger State, Nigeria

ARTICLE INFO

Article History:
Received 25th January, 2015
Received in revised form
16th February, 2015
Accepted 20th March, 2015
Published online 28th April, 2015

Key words:
Bio-composite,
Cassava starch,
Luffa fibre.

ABSTRACT

The favourable properties exhibited by synthetic polymers and ceramics have made them become the most commonly sort engineering materials in recent years. Despite the excellent properties exhibited by these synthetic polymer materials, the problem of biodegradability and sustainability makes it necessary to research into fully biodegradable composites which are green in every way. In this research, green composites were developed using cassava starch as matrix material and luffa cylindrica fibre as reinforcing material. The weight of the reinforcing material was varied at a step of 10 g from 10 g to 50 g during the bio-composite fabrication. 4% (0.1 mole) sodium hydroxide was used to treat the luffa cylindrica fibres at room temperature for 24 hours to enhance the interfacial bonding interaction between the cassava matrix and the bio fibre. Characterisations carried out on the treated bio fibre were; Fourier Transform Infra-Red Spectroscopy (FTIRS), X-Ray Diffraction (XRD) and X-Ray Fluorescence (XRF). Tests including impact test, shore-D hardness test, moisture absorption, and bulk density determination of the developed composites were performed after the development of the bio-composites. The characterisations showed that the sodium hyrdroxide treatment effectively modified the fibres. Results from the mechanical tests showed that the bio-composite with 9:1 matrix to filler ratio absorbed the highest impact energy of 6.425 j while the 5:5 samples gave the least percentage moisture absorption value. A bulk density of 0.67 g/cm^3 was obtained for the 7:3 (matrix to filler ratio) samples and the highest density value for the samples was obtained for the 9:1 sample with a corresponding value of 1.68 g/cm^3.

INTRODUCTION

Modern engineering practice requires materials with unusual combination of properties that cannot be met by conventional alloys, ceramics and polymer materials, thus giving rise to emerging varieties of materials which are eco-friendly for use in manufacturing of products across different applications. Metals have been the dominant engineering material for centuries, however over the past few decades plastics, ceramics and composites owing to their individual excellent properties have become more commonly used in engineering applications. Composites in practice today are developed to achieve better properties through combination of various engineering materials (Callister, 2007). This paper looks into bio-based fully green composites of luffa cylindrica fibre as the reinforcement material and cassava starch as the matrix material. Cassava starch is an attractive source and a potential material for the development of green composites, owing to its eco-friendly/biodegradability, abundance and relatively cheap characteristic. Regular synthetic polymer composites are non-biodegradable and pollute the environment (Kalia *et al*., 2011).

****Corresponding author: Salawu Abdulrahman Asipita***
Department of Mechanical Engineering, Federal University of Technology, Minna, Nigeria.

Due to the environmental and non-biodegradability problems associated with such engineering materials, it is necessary to undertake scientific research in favour of new alternatives that would replace traditional polymer composites (La Mantia and Morreale, 2011). Researches that have been performed using luffa cylindrica as reinforcement material has shown that the bio fibre exhibits reasonable mechanical properties in composites, thus making it a cheap substitute to non-biodegradable fillers (Paschal and Salawu, 2015; Tanobe *et al*., 2014; Saw *et al*., 2013; Siqueira and Bras, 2010; Ghali, 2009; Oboh and Aluyor, 2009). Starch which is a biodegradable polymer, abundant in plants and cheap (Rosa and Lenz, 2013) when subjected to the proper curing time, temperature and pressure conditions serves as an excellent bio-derived matrix materials for green composite development. This paper discusses the development and mechanical properties of luffa cylindrica reinforced cassava starch bio-composites.

MATERIALS AND METHODS

Luffa fibre preparation

Luffa cylindrica fruits were obtained from farms in Osara, Kogi State, Nigeria. The luffas were cut open along its axis and

the seeds removed from them. The fibres were further cut to approximately 25 X 25 mm, length by breadth. The cut samples were treated with 4% wt. (0.1 mole) sodium hydroxide concentration. Researchers have reported that the treatment of natural fibres with sodium hydroxide enhances and gives a better fibre to matrix interfacial interaction, better bonding characteristic and composite strength which are usually observed for treatments with sodium hydroxide concentrations of between 4% to 8% wt. (Paschal and Salawu, 2015; Meheddene, 2014; Karthikeyan and Balamurugan 2013; Rokbi *et al*., 2011; Gomes *et al*., 2004). The luffa fibres were fully immersed in the sodium hydroxide solution and the treatment was carried out for a period of 24 hours under normal room temperature and pressure conditions after which the luffa fibres were thoroughly rinsed in distilled water until a neutral pH of the rinsing solution was attained. The luffa fibres were dried under direct sunlight to remove the moisture content after which the cut luffa fibres were weighed and stored in specimen packs appropriately.

Luffa/cassava starch bio-composite development

Raw cassava starch and the treated luffa fibres were thoroughly mixed with 50 mL of water until a homogeneous mix was obtained. The volume of the water used in mixing the starch was kept constant for all the formulations used in the preparation of the bio-composites. The mixed materials were introduced into a 150 x 150 x 5 mm mould corresponding to the luffa cylindrica fibres for varying weight fractions of 10 to 50 grams with a step of 10 grams. The moulds containing the mixed bio-composites materials were cured at room temperature at a pressure of 13.7895 MPa using a hydraulic press for a period of 80 minutes to aid the setting of the composite. The mould was then removed from the hydraulic press and placed in an oven with temperature set to 150 ^{o}C for a period of 120 minutes after which the mould was brought out of the oven and post-cured under direct sunlight for a period of 60 minutes.

Tests and characterizations

All tests were carried out at room temperature and pressure conditions. The tests and characterisations that were performed in this research include:

- Density Determination: the method B of the ISO 1138 standard was used to determine the density of the developed bio-composites.
- Moisture Absorption: The cut specimens of the developed bio-composite were fully immersed in distilled water for a period of 24 hours and the moisture absorption determined in accordance with the ISO 62 standard.
- Hardness Test: the hardness test was performed using a durometer for measuring the shore-D hardness of polymers in accordance with the ISO 868 standard.
- Impact Test: a charpy izod impact testing machine was used to determine the energy absorbed by the specimen. The specimen used for this test was cut to 80 X 15 X 4 mm with a v-notch cut in the middle at 45^{o} and a depth of 2 mm across the longer part of the specimen. The energy of the hammer used was 15 joules at a pendulum speed of 2.887 m/s.
- X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD) and Fourier Transform Infra-Red Spectroscopy (FTIRS) Characterisations.

RESULTS AND DISCUSSION

The properties of the developed composite are presented in the Table 1.

Table 1. Properties of the luffa fibre reinforced cassava starch bio-composite

Sample	Impact Energy Absorbed (j)	Shore-D Hardness	Bulk Density (g/cm^3)	Moisture Absorbed (%)
0/100	-	67.67	1.93	116.21
10/90	6.425	63.00	1.68	95.74
20/80	4.325	93.00	0.78	279.41
30/70	2.100	91.33	0.67	110.00
40/60	1.475	72.00	0.91	194.12
50/50	0.800	83.00	1.51	90.20

Table 2. XRF Characterisation of the 4% wt. treated luffa fibre.

Oxide	4%wt. NaOH treatment Composition Value
SiO_2	10.02
P_2O_5	13.51
SO_3	9.50
K_2O	24.90
CaO	15.70
TiO_2	0.35
MnO	0.77
Fe_2O_3	4.75
CuO	0.34
ZnO	1.50
Na_2O	16.40
Eu_2O_3	0.77
Re_2O_7	0.22

The 10/90g (filler to matrix ratio) sample absorbed the highest impact energy while the sample with equal amount of reinforcement to matrix ratio gave the least impact energy absorption. The control sample (pure cassava starch) was brittle, therefore no reading could be obtained for the impact tests. It is also noticed from the results that increment in the amount of filler lead to a corresponding decrement in the impact energy absorbed by the developed bio-composite. (Agunsoye and Aigbodion, 2013) also reported a similar behaviour of decrement in impact strength with relation to increasing fibre reinforcement weight fractions. The pure cassava starch with no reinforcement gave the highest density value. Reinforcing the cassava starch gave a lighter and stronger characteristic of the developed bio composite. In contrast to the reports made by (Agunsoye and Aigbodion, 2013) that increasing weight fraction of the fibres increased the bulk density of their fibre, the developed bio-composites in this research showed varying bulk density characteristics for the various fibre weight fractions. This could be as a result of the difference in the materials properties of the bio-composites used. The Table 2 shows the X-Ray Fluorescence characterisation result for the treated fibre. The result reported by ((Benitez *et al*., 2014) in their XRF analysis of natural sisal confirms the presence of the oxides obtained for the luffa cylindrica fibre in this research, though in varying compositions. The predominant oxides in the treated luffa fibre include SiO2, P2O5, CaO, Na2O and K2O. According to

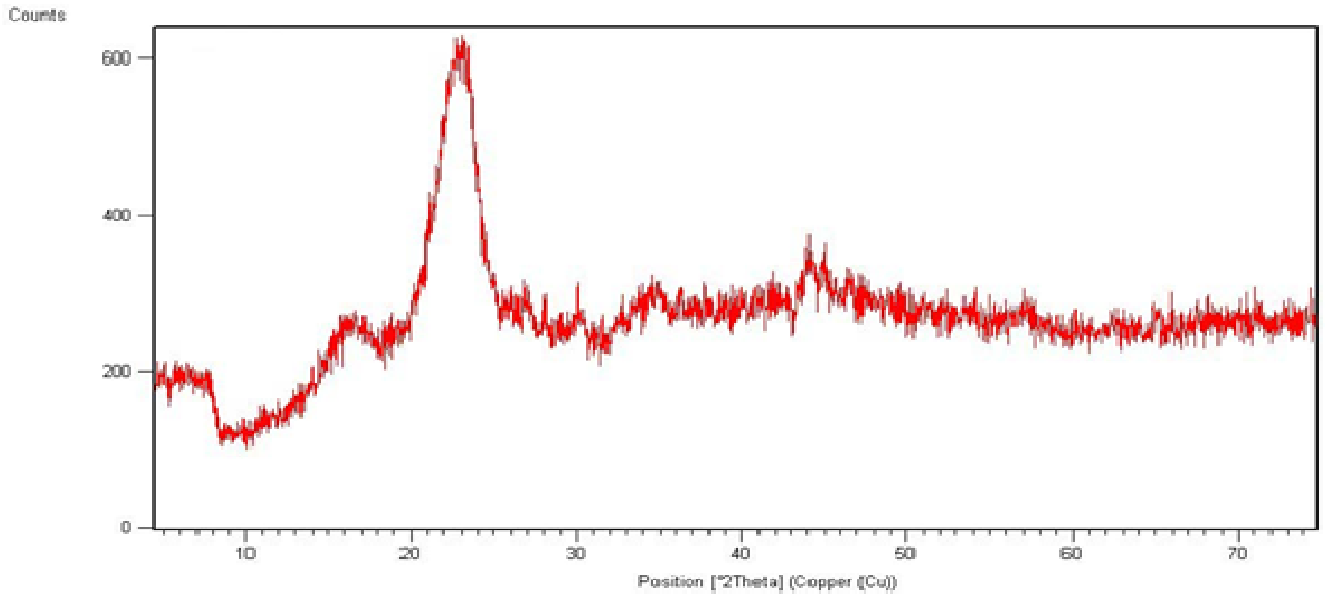

Fig 1. XRD Spectra of the treated luffa fibre

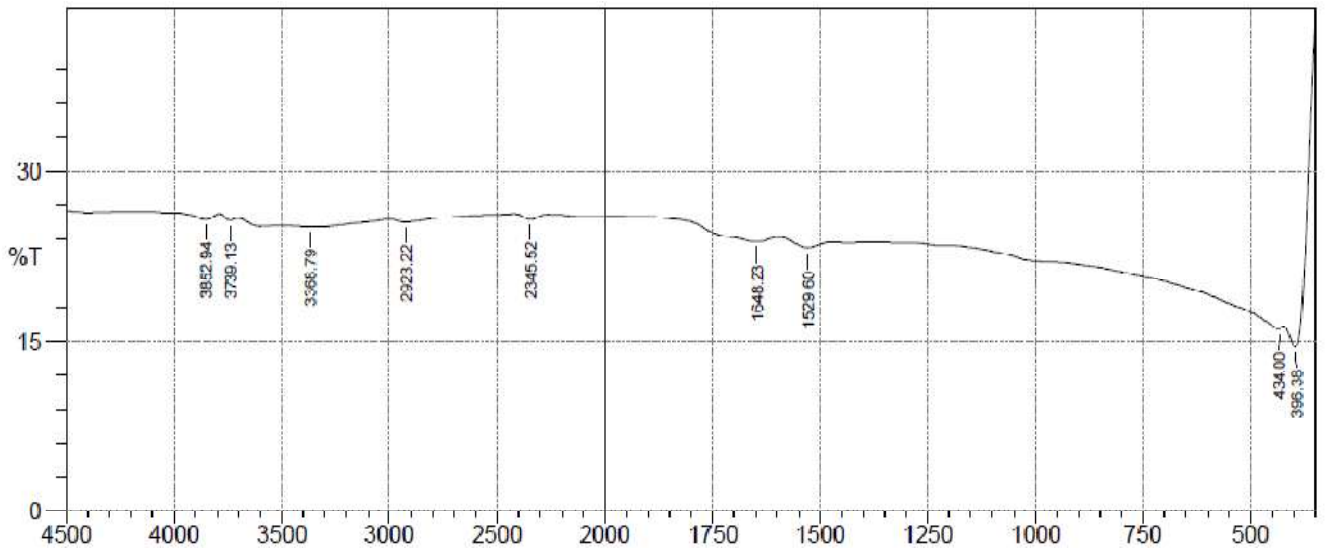

Fig 2. FTIRS characterisation of the untreated luffa fibre

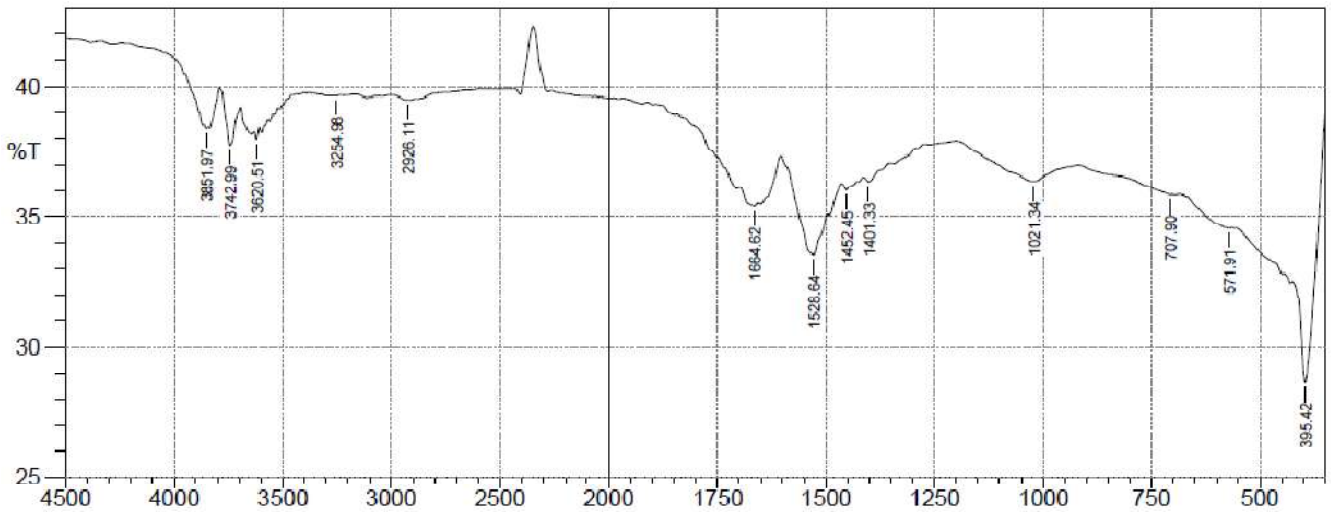

Fig 3. FTIRS Characterisation of the 4% treated luffa fibre

(Aigbodion, *et al*., 2010) and (Agunsoye and Aigbodion, 2013), sodium dioxide, iron oxide and alumina are known to be substances that are very hard. The spectra obtained from the XRD analysis for the treated fibre carried out at the angle 2Θ is presented in the Fig. 1. The degree of crystallinity of the luffa cylindrica fibres was calculated from the x-ray diffractogram to be 65.67%. The highest peak intensity and least peak intensity associated with the crystalline region occurred at 2Θ = 23.01 and 2Θ = 18.902 corresponding to intensities of 639.4 and 219.5 respectively. Tanobe *et al*., 2005 reported an increase in the crystallinity index from 59.1% (untreated luffa fibre) to 62.9% for the luffa fibre treated with 2% NaOH. (Ghali *et al*., 2009) reported that the crystallinity index of untreated luffa cylindrica is 50% while that of the fibres treated with 3% NaOH and 8% hydrogen peroxide at 80 ^{o}C gave a crystallinity index of 66.32% while at 100 ^{o}C with the same conditions, gave a crystalline index of 70.56%. The peaks are more prominent and are indications of high cellulose crystallinity in the treated fibre (Parida *et al*., 2013). Similar XRD patterns for the treated luffa fibres have been observed from literatures and research some of which includes the research by (Siqueira *et al*., 2010) who reported a crystallinity index of 81.3% for 0.1 mole (4%) treated luffa fibres. The Fig. 2 shows the FTIRS characterisation of the untreated luffa fibre. The test run on both samples was neat without the introduction of KBr. For the untreated luffa fibre, the peaks seen at 396cm^{-1} and 434cm^{-1} indicates the presence of the alkyl group. The peak at 1648cm^{-1} indicates the presence of the alkene group, C=C stretch with medium intensity. The absorption at 3368cm^{-1} shows the presence of a broad –OH stretch. The broad absorption band exhibited at 3368cm^{-1} and 3852cm^{-1} is a characteristics of the association of polymers with the –OH group which according to (Saw *et al*., 2013) shows that the –OH stretch vibration is present in the cellulose and the lignin. It can be noted that the broadness of the –OH band decreased more for the alkali treated fibre when compared with the untreated fibre. For the treated fibres, the intensity of the bands at 1373cm^{-1} from O-H in plane bending was reduced and the reduction is because of the formation of glycoside bonding (Saw *et al*., 2013). The treated fibre was adequately modified and reduced the hemicelluloses and lignin content of the fibres. Several researchers have reported that luffa fibres showed intense characteristic peaks at 1595cm^{-1}, corresponding to a free hydroxyl band, 1740cm^{-1} indicating acid carbonyl absorption, 2750 – 2800cm^{-1} (typical CH2 and CH), 3200 – 3300cm^{-1} showing the O-H stretching band 1100cm^{-1} indicating the C-O-C absorption and at 1000 -1500cm^{-1} showing the aromatic region related to lignin (Tanobe *et al*., 2005; Ali, *et al*., 2001; and Colom, *et al*., 2003). The results obtained from the FTIR characterization showed that the 4% NaOH treated fibres presents a weak absorption at 1735cm-1 corresponding to the carbonyl group:,- O – C= O and there is a band reduction around 1245cm^{-1} (C-H). (Syndestricker, *et al*., 2003) reported that the weak absorption in most FTIR is due to the alkaline treatment on the natural fibres. The FTIRS result showed that most of the lignin and hemicelluloses content of the fibre reduced resulting in a rougher luffa cylindrica fibre surface which facilitated the bonding properties and better mechanical interlocking due to exposure of the hydroxyl groups that became available to the cassava starch matrix, thus causing an increase in the mechanical characteristics of the developed composite. Fig. 3 shows the FTIRS characterisation of the treated luffa fibre. The developed 10/90 g and 20/80 g composite exhibited good physical and mechanical characteristic, however, its brittle and sorbent nature limits its use in certain engineering applications. The developed composite can find applications as materials for electrical insulation, electrical sockets and switches, lamp holders, electrical panels and housings that operate in less humid conditions. Due to its non toxic attributes it can also be used in the manufacture of toys for children and short life span consumer items which are usually disposed after a limited period of use (Dicker *et al*., 2014). The stated potential applications for the developed bio-composites would complement its renewability, low embodied energy, biodegradability, low ductility and low durability properties.

Conclusion

The Characterisations showed that the luffa cylindrica fibres were effectively modified. From the results, increasing additions of luffa cylindrica fibres from 0 to 50% wt. to the cassava starch matrix exhibited decreasing impact energy characteristics. The developed bio-composite with the 20% wt. luffa cylindrica fibre resulted in the highest shore-D hardness value while the 30% wt. bio-composites gave the least bulk density value of 0.67 g/cm^{3}. The moisture absorption results obtained in this research showed that the developed bio-composites are hydrophilic in nature and therefore cannot be used in applications operating under high humid conditions. The developed bio-composites can conveniently serve as a substitute to engineering materials used for the manufacture of domestic and industrial electrical insulations, wall sockets and lamp holders.

REFERENCES

Agunsoye, J.O. and Aigbodion, V.S. 2013. Bagasse filled recycled polyethylene bio-composite: Morphological and Mechanical properties study. Results in Physics. 3; pp.187 – 194

Aigbodion, V.S., Hassan, S.B. Ause, T. and Nyior, G.B. 2010. Potential utilization of solid waste (Bagasse Ash). *Journal of Minerals and Materials Characterization and Engineering*; 9: pp. 67–77.

Ali, M. Emsley, A.M. Herman, H. and Heywood, R.J. 2001. Spectroscopic studies of the ageing of cellulosic paper. Polymer 42 (7); pp. 2893 – 2900

Benitez-G, M. López-Beceiro, J. Sánchez-Jiménez, P.E. and Pascual-Cosp, J. 2014. Comparison of thermal behaviour of natural and hot-washed sisal fibres based on their main components: cellulose, xylane and lignin. TG-FTIR analysis of volatile products.

Callister.Jr, W.D. 2007. Fundamentals of Material Science and Engineering, Fifth Edition, John Wiley and Sons Inc., York, pp.596-600.

Colom, X., Carrasco, F., Pages, P. and Canavate, J. 2003. Different treatments on the interface of HDPE/lignocellulosic fibre composites, Composite Science and Technology. 63 (2); pp. 161 - 169.

Corradini, E., Agnelli, J. A. M., De Morais, L. C. and Mattoso, L. H. C. 2008. A Study of Biodegradeble Composites using

Sisal Fibres as the Reinforcing Material, Polimeros: Cienci Technologia, 18 (4), 353 – 358.

Dicker, M.P.M., Peter, F.D., Anna, B.B., Guillaume, F. And Mark, K.H. 2014. Green Composites: A review of material attributes and complementary applications. Composites: Part A, 56; pp. 280 - 289.

Ghali, L., Msahli, S., Zidi, M. and Sakli, F. 2009. Effect of pre-treatment of luffa fibres on the structural property. Material Letters. 63, pp. 61 – 63.

Gomes, A., Goda, K. and Oghi, J. 2004. Effects of alkali treatment to reinforcement on tensile properties of curaua fibre green composites. *JSME International Journal Series A,* volume 47; pp. 541 – 546

Kalia, S., Dufresne, A., Cherian, B.M., Kaith, B.S., Avérous, L., Njuguna, J. and Nassiopoulos, E. 2011. Cellulose Based Biocomposites and Nanocomposites-A Review, *International Journal of Polymer science*, Vol.1, pp.1-26.

Karthikeyan, A. And Balamurugan, K. 2013. The effect of sodium hydroxide treatment and fibre length on the tensile property of coir fibre reinforced epoxy composites. *Journal of Engineering and Applied Sciences*, 8(5): pp. 156-161

La Mantia, F.P. and Morreale, M. 2011. Green Composites: A Review. Composites, Part A 42; pp. 579 – 588. doi: 10.1016/j.compositea.2011.01.017

Meheddene, M., Hisham, B., Hadi, A,C. and Adel, E. 2014. Alkali treatment of fan palm natural fibres for use in fibre reinforced concrete. *European Scientific Journal,* Vol.10, No.12, pp. 186 - 195.

Oboh, I.O. and Aluyor, E.O. 2009. Luffa Cylindrica - an Emerging Cash Crop, *African Journal of Agricultural Research,* Vol. 4 (8), pp. 684-688.

Parida, C., Dash, S.K. and Das, S.C. 2013. Effect of fibre treatment on mechanical and thermal properties of luffa cylindrica-resorcinol composites*. International Journal of Fibre and Textile Research*. 3(1): pp.13 - 17.

Paschal, A. U. and Salawu, A. S. 2015. Effect of Sodium Hydroxide Treatment on the Mechanical Properties of Crushed and Uncrushed Luffa Cylindrica Fibre Reinforced rLDPE Composites. World Academy of Science, Engineering and Technology, Jeddah Saudi Arabia Conference Proceedings, Jan 26 – 27, 2015. 13(01) Part XIV, pp. 1996 – 2001.

Rokbi, M., Osmani, H., Imad, A. and Benseddiq, N. 2011. Effect of chemical treatment on flexure properties of natural fibre reinforced polyester composite. Procedia Engineering. doi:10.1016/j.proeng.2011.04.346

Rosa, D.S. and Lenz, D.M. 2013. Biocomposites: Influence of matrix nature and additives on the properties and biodegradation behaviour, Chapter 16, pp. 433 – 475.

Saw, S.K., Purwar, R., Nandy, S., Ghose, J. and Sarkhel, G. 2013. "Fabrication, characterisation and Evaluation of Luffa cylindrica Fibre Reinforced Epoxy composites", *Journal of BioResources*, Vol.8, No.4, pp.4805-4826.

Siqueira, G., Bras J. and Dufresne, A. 2010. Luffa cylindrica as a lingo-cellulosic source of fibre, microfibrilliated cellulose and cellulose nano crystals. Bio-Resources. 5(2), pp. 727 – 740

Syndenstricker, T.H.D., Mochnaz, S. and Amico, S.C. 2003. Pull-out and other evaluations in sisal-reinforced polyester bio composites, Polymer Testing, 22 (4), pp. 375 – 380.

Tanobe, V.O.A., Thais, H.D.S., Marilda, M. and Sandro C.A. 2005. A comprehensive characterisation of chemically treated Brazilian sponge-gourds (luffa cylindrica). Polymer Testing 24, pp.474 – 481.

Tanobe, V.O.A., Thais, H.S, Sahagun, F., Amico, S.C., Muniz, G.I.B. and Satyanarayan, K.G. 2014. Sponge gourd (luffa cylindrica) reinforced polyester composites: preparation and properties. *Defence Science Journal*. Volume 64, No.3, pp. 273 – 280.

****