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MECHANICAL PROPERTIES OF CHEMICALLY TREATED SISAL FIBER REINFORCED LOW DENSITY POLYETHYLENE COMPOSITES

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Abstract: This research investigates the effect of chemical treatment on the mechanical properties of sisal fiber reinforced low density polyethylene (SFR-LDPE) composites. The sisal fiber was sourced from its plantation and was extracted by soil retting process. In order to study the effect of chemical treatments on the resultant properties of the SFR-LDPE composites, NaOH, KOH, NaCl and KCl were used to modify the fibers in a shaker water bath at 50 ºC for 4 hours. The treated fibers were cut into 10 mm lengths and were used for the production of randomly dispersed short fiber/LDPE composites in predetermined proportions. Tensile and flexural tests were carried out on the developed SFR-LDPE composites from where it was observed that, alkali treated SFR-LDPE composite samples gave the best flexural and tensile properties compared to composites developed from chloride salts.
Keywords: Sisal fiber, composite, chemical treatment, mechanical properties, water absorption properties

INTRODUCTION

The interest in natural fiber reinforced polymer composites is growing rapidly due to significant processing advantage of been eco-friendly, low production cost as well as low density [1-3]. Natural fibers are renewable resources, cheap, pose no health hazards and as well provide solution to environmental pollution by finding new uses for waste materials [4-6]. Besides, natural fiber reinforced polymer composites form a new class of materials that can possibly be used as a substitute for scarce wood and wood based materials in structural applications. However, it has been predicted that by the beginning of next century wood will be scarce for the whole world due to its increasing demand [7].

The choice of sisal fiber for this research was informed by its availability and good strength. Sisal fiber is a member of the agavaceae family. It is biodegradable and environment friendly. Research is ongoing using sisal fiber as reinforcement in different polymers like; low-density polyethylene, polyester, epoxy, polypropylene, urea-formaldehyde phenol-formaldehyde, polyvinyl-acetate, and starch-based polymers [8-13]. It is generally accepted that the mechanical properties of fiber reinforced polymer composites are controlled by factors such as nature of matrix, fiber-matrix interface, fiber weight fraction and aspect ratio [14].

Plant fibers comprised of three major chemical components, namely cellulose, lignin, and hemicelluloses. The pre-treatment of fibers changes the composition and ultimately changes not only its properties but also the properties of composites. The treatments usually enhanced the properties of fibers but occasionally, its effects on the fibers may not be favorable to the fiber properties if the operating conditions are not properly monitored.

The treatments tend to aid interfacial adhesion between the fibers and polymer matrix. Commonly used methods for the enhancement of interfacial adhesion between fiber and matrix are maleated coupling agents, acrylation, acetylation and benzoylation [1, 15]. In this study, comparative investigation of the influence of alkali and saline treatments were examined. Chemicals that were used for sisal fiber treatment are potassium hydroxide (KOH), sodium hydroxide (NaOH), sodium chloride (NaCl) and potassium chloride (KCl). In agreement with previous work [11, 16], this research investigated the best chemical treatment for soil retted sisal fibers targeted for improving the mechanical properties of the developed composites. Soil retting was used as process route for the extraction of sisal fiber since it has been employed in the extraction of other natural fiber where the needed resources; land and water are readily available. The process is expected to yield fiber with better tensile properties as it eliminates the mechanical beaten that characterized mechanical decortication process in which the fiber tensile properties may likely to be low due to induced stress. The stress is as a result of the compressive force that is being applied during the extraction. The process is also environmentally friendly as it eradicates dusts that are associated with decortication process. A lot of works on decorticated sisal fibers are available in the literature but not much have been reported on soil retted sisal fibers which is one of the reasons for carrying out this research.Low density polyethylene (LDPE) was used as matrix while sisal fibers serve as reinforcement to produce the sisal fiber reinforced low density polyethylene composites (SFR-LDPE).

MATERIALS AND METHODS

» Materials

Low density polyethylene granules with melt flow index of 2.25 g/min and density of 0.923 g/cm^3 was used as the matrix while sisal fiber from the plant leaves wasused as the reinforcement. Potassium hydroxide (KOH), sodium hydroxide (NaOH), hydrochloric acid (HCl), sodium chloride (NaCl) and distilled water were used for the treatments of the fiber.

» Sisal Fiber Extraction and Treatment

The sisal fiber was obtained from sisal plant and was extracted by soil retting process. In soil retting process, the green leaves were buried in the soil for 3 weeks. During this period, water was used to wet the buried sisal leaves. The fermented leaves were exhumed, washed in flowing water to remove sand and dirt. It was then sun dried for 5 days as shown in Figure 1.

Figure 1: Extracted Sisal Fibers

The dried fibers were divided into 4 portions of equal weights. Each of the portions was treated with 1 molar solution of NaOH, KOH, NaCl and KCl, respectively in a shaker water bath at a temperature of 50 ºC for 4 hours. Afterwards, the fibers were washed with ordinary water before washing them with distilled water to ensure neutralization status and then sun dried for 5 days. The dried fibers were cut into 10 mm lengths. The average value of the sisal fiber diameter was 0.09 mm before the treatment and, hence, the aspect ratio value for the used sisal fiber was 111.11.

» Composites Production

Sisal fiber reinforced LDPE composites were produced via heating compression moulding machine. Randomly dispersed fiber orientation was used with varied fiber content of: 2, 4, 6, 8 and 10 wt%. The treated sisal fibers were mixed with low density polyethylene (LDPE) in the mould before transferring to heating compression moulding machine. The mixture was placed in the compression moulding machine maintained at 170 ºC for 10 minutes. The composites were formed in flexural and tensile moulds separately and were allowed to cool before detaching them from the moulds. The flexural mould has a dimension of 150 x 50 x 3 mm while the tensile mould has a dog-bone shape and 3 mm thick. Three samples each were produced from the representative samples that were considered.

» Mechanical testing

– Tensile test

Tensile test was performed on universal testing machine (INSTRON 3369 model) with a maximum load cell capacity of 50 KN at a fixed crosshead speed of 10 mm/min. All Samples were prepared in accordance to ASTM D3039-14 [17], standard test methods for tensile properties of polymer matrix composite materials. Three samples were tested for each representative samples from where the average values for the test samples was used as illustrative value.

– Flexural test

Flexural test was carried out according to ASTM D 790-98 [18], standard test method for flexural properties of polymer matrix composite materials. The flexural test was performed at a span length of 100 mm and at a crosshead speed of 2 mm/minon an INSTRON machine. Three samples were tested for each representative samples from where the average values for the test samples were used as the illustrative values.

RESULTS AND DISCUSSION

– Flexural Test

Figure 2 revealed the variation of flexural strength at peak against for the various samples. Flexural strength at peak is the strength at a particular cross section and not the load carrying capability of the overall beam.

From the graph, it was observed NaOH treated sisal fiber reinforced LDPE composites in all the percentage composition used gave better strength than the unreinforced LDPE matrix that serves as control except at 4 % where they both have the same value. This was followed by NaCl treatment in which all except 6 % reinforcement gave better results, KOH treated samples followed with less values at 6 and 8 %.

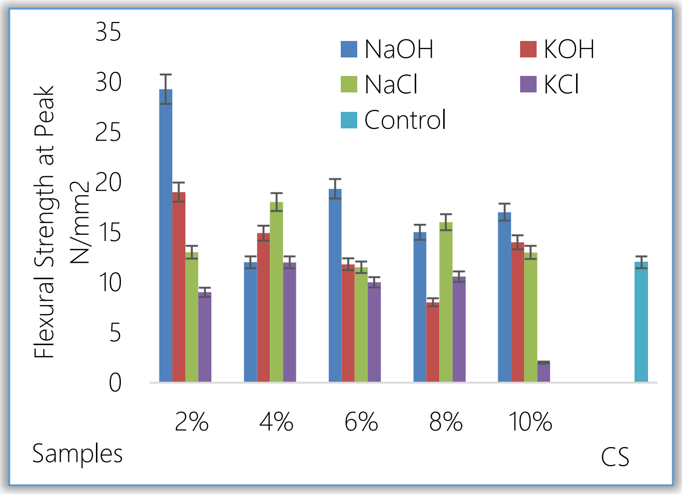

Figure 2: Charts for the variation of flexural strength at peak for the developed composites and the control sample

However, all the KCl treated samples possess less value than the control which implies that this treatment has not improved the condition of the fiber for the expected enhancement. Hence, all the developed composites from the chemically modified fibers with the exception of KCl displayed promising potentials for the treatment of sisal fiber for polymer composite development. Composite developed from 2 and 6 % NaOH treated fiber were with the highest bending strength at peak with values 29.27 and 19.32 N/mm^2, respectively. It was also observed from the result that, sample with the best fiber content from both KOH and NaCl treatments were from 2 and 4 %, respectively. It therefore, follows that 2 – 6 % of the fibers are the range of values for optimum production.

The treatment has made the sisal fiber to become stronger, thereby, able to withstand stress transfer from the LDPE matrix effectively [16]. This essentially results in improved flexural strength of the composites. Mechanical properties of composites depend on many parameters like the properties of matrix and fiber, volume fraction of fiber, geometry and orientation of fiber, adhesion between matrix and fiber, fiber agglomeration and fiber breakage.

Therefore, the observed results are the effects of the combinations of the listed factors. Hence, the use of NaOH treated shortsisal fiber that is randomly dispersed in LDPE for the development of polymer composites gave the best surface modification required for good interfacial adhesion between the fiber and the matrix which resulted in 61 % enhancement in flexural strength of the developed composites.

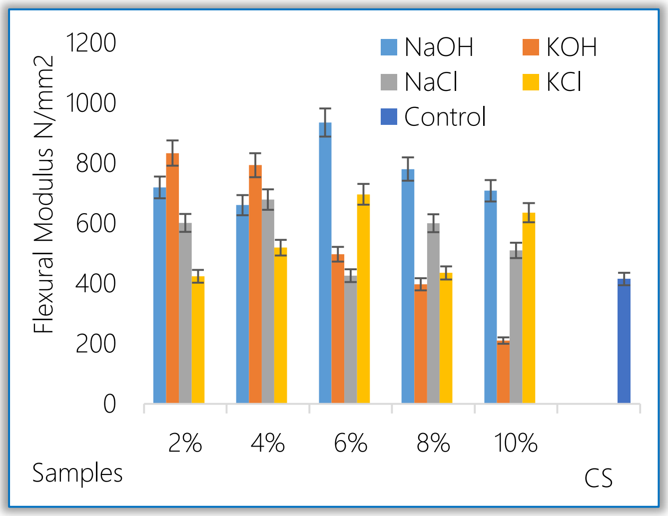

Figure 3: Charts of the variation of flexural modulus for the developed composites and the control sample

The flexural modulus for the various samples was as shown in Figure 3. Flexural modulus is also known as bending modulus and it is a measure of the stiffness of a material when subjected to bending test. The result showed that NaOH treated sisal fiber reinforced samples possesses better modulus than the control in all the fiber content used.

From the graph, it was observed that composite with 6 % NaOH treated sisal fiber has the highest flexural modulus of about 935 N/mm^2 followed by sample with 2 % KOH which has a value of about 833 N/mm^2. Also, it was realized that composites produced from NaOH and KOH treated sisal fibers within the range of 2 - 6 % gave the best reinforcement with respect to other chemically treated sisal fiber reinforced LDPE composites and unreinforced LDPE.

This corroborates the result in Figure 2 in which the same fiber content range gave the best flexural strength at peak results. Since the alkali treated samples emerges as the best in flexural properties, it therefore, follows that, the alkali treatments aid the removal of intra-matrix (hemicellulose and lignin) thereby, improving the interfacial adhesion between the sisal fiber and LDPE matrix. NaOH and KOH treatments were discovered to have led to about 55 and 50 % increment in the bending modulus, respectively. This feat was possible because the fiber strength has been enhanced by the alkali treatments [16].

The flexural properties from Figures 2-3 showed that, the properties tend to decrease as the fiber content increases from 8-10 %.This may be due to the effect of fiber volume fraction and improper adhesion between the fiber and the matrix that causes inadequate transfer of stress from the matrix to the fiber. The results revealed that better effects were obtained between 2-6 % fibers loading. This was in agreement with the work of [10] where it was deduced that low fiber content yielded the optimum properties for the developed composites.

– **Tensile Test**

Figure 4 shows the tensile strength at peak for the various test samples. Strength at peak is the maximum stress the material can withstand before it fractures.

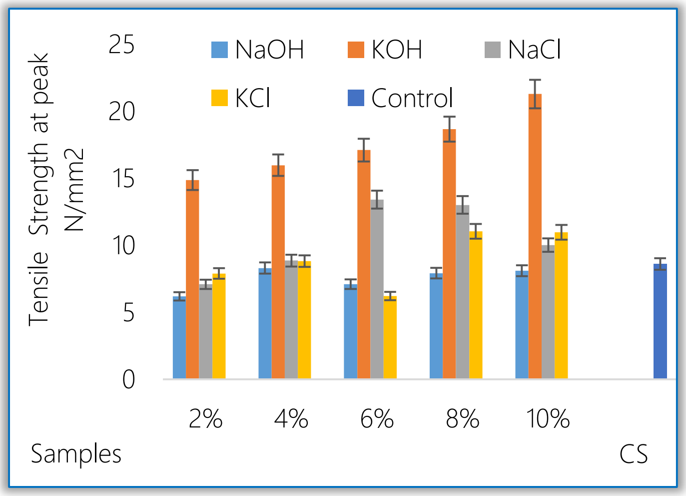

Figure 4: Charts of the Variation of Tensile Strength at Peak for the Developed Composite and the Control Sample

The responses of the developed composites show a different trend from that of flexural properties. Here, KOH and NaCl treated fiber reinforced samples gave the best performance which means that, these treatments can be tailored for usage when tensile strength property is to be enhanced.

While the tensile strength at peak for KOH treated sisal fiber reinforced samples tends to increase as fiber content increases from 2-10 %, the same thing is applicable to that of NaCl which also tends to increase but reach optimum at 6 %. Though, chemical treatments are primarily to enhance interfacial adhesion between fiber and matrix, however, the treatments usually led to different reactions with the fiber constituents. Different chemical treatments tends to modified the fiber constituents; cellulose, hemicelluloses and lignin in diverse ways.

The final products of these reactions may therefore alter the way they respond in service. From the graph, it was observed that composite developed with 10 and 8 % KOH has the highest tensile strength at peak with values; 21.28 and 18.67 N/mm^2, respectively.

CONCLUSIONS

The research outcome revealed that alkali (NaOH and KOH) treatments of sisal fiber are more suitable for the enhancement of flexural and tensile properties of the developed composites than the chloride salts. From the results, it was observed that NaOH gave the best enhancement for flexural properties while KOH gave best enhancement for tensile strength at peak. Low fiber content of between 2-6 % gave the best flexural results while high fiber content of between 8-10 % gave the best tensile strength at peak.

References

[1.] Agbabiaka O.G, Isiaka I.O, Olorunleye P.O. Investigating the Influence of Alkalization on the Mechanical and Water Absorption Properties of Coconut and Sponge Fibers Reinforced Polypropylene Composites, Leonardo Electronic Journal of Practices and Technology 25: p. 223-231. 2014.

[2.] Sahari M, Sapuan S. M. Natural Fiber Reinforced Biodegradable Composites. Reviews on Advanced Materials Science 30: p. 166-170. 2011.

[3.] Aart V. V. Natural fiber composite; Recent development. Technological Advisor Composite Materials Sirris, Katholieke Universiteit Leuven p. 1-32. 2008.

[4.] Bledzki A, Gassan J. Composites Reinforced with Cellulose Based Fibers, Progress in Polymer Science24: 221-274. 1999.

[5.] Amar K.M, Manjusri M, Lawrence T.D. Natural Fibers, Biopolymers, and Bio-composites, CRC Press, Tailor & Francis, p. 1-3. 2005.

[6.] Singh S. P. Agro-Industrial Wastes and their Utilization. Proceedings of National Seminar on Building Materials and their Science and Technology, Roorkee 15: p. 111. 1982.

[7.] Oladele I.O, Omotoyinbo J.A, Borisade M.P. Mechanical Properties of Mahogany (Swietenia Macrophylla) and Araba (Ceiba Pentandra) Dusts Reinforced PolyesterComposites, Leonardo Electronic Journal of Practices and Technologies, 23(12): 1-18.2013.

[8.] Veluraja K, Ayyalnarayanasubbu R. S, Paul R. Preparation of Gum from Tamarind Seed and its Application in the Preparation of Composite Material with Sisal Fiber. Carbohydrate Polymers, Oxford 34 (4): p. 377- 379. 1997.

[9.] Pavithran C, Mukherjee P. S., Brahmakumar M., Damodaran A. D. Impact Performance of Sisal – Polyester Composites. Journal of Materials Science Letters, London 7: p. 825-826. 1988.

[10.] Oladele I.O, Omotoyinbo J.A, Adewuyi B.O, Kavishe F.P.L. The Effects of Production Processes on the Mechanical Properties of Sisal Fiber Reinforced Polypropylene Composites. Philippine Journal of Science. 142 (2): p.189-198. 2013.

[11.] Oladele I.O, Agbabiaka O.G. Investigating the Influence of Mercerization Treatment on the Mechanical Properties of Sisal Fiber Reinforced Polypropylene Composite and Modeling of the Properties, Fiber and Polymer Journal 16 (3): p. 650-656. 2015.

[12.] Pavithran C, Mukherjee P. S, Brahmakumar M, Damodaran A. D. Impact Properties of Natural Fiber Composites. Journal of Materials Science Letters, London 6: p. 882-884.1987.
[13.] Kalaprasad G, Joseph K, Thomas S, Pavithran C. Theoretical Modeling of TensileProperties of Short Sisal Fiber-Reinforced Low-Density Polyethylene Composites. Journal of Materials Science 32: p. 4261–4267. 1997.
[14.] Pal S, Mukhopadhayay D, Sanyal S, Mukherjea R. Studies on Process Variables for Natural Fiber Composites effects of Peapas Interfacial Agent. Journal of Applied Polymer Science 35: p. 973–985. 1998.
[15.] Ghali L, Aloui M, Zidi M, Bendaly H, M'sahli S, Sakli F. Effect of Chemical Modification of Luffa Cylindrica Fibers on the Mechanical and Hygrothermal Behaviours of Polyester/Luffa Composite, BioResources 6(4): p. 3836-3849. 2011.
[16.] Oladele,I. O, Omotoyinbo, J. A, Adewara J.O.T. Investigating the Effect of Chemical Treatment on the Constituents and Tensile Properties of Sisal Fibre. Journal of Minerals and Materials Characterization and Engineering. 9(6): p. 569-582. 2010.
[17.] ASTM D3039.Standard Test Methods for Tensile Properties of Polymer Matrix Composite Materials. 2014.
[18.] ASTM D790. Standard Test Methods for Flexural Properties of Polymer Matrix Composite Materials. 1998.
[19.] Amuthakkannan P, Manikandan V, Winowlin J. J. T and Marimuthu U. Effect of Moisture Absorption Behavior on Mechanical Properties of Basalt Fiber Reinforced Polymer Matrix Composites, Hindawi Publishing Corporation, Journal of Composites, 8 pages.2014.
[20.] Alomayri T, Assaedi H, Shaikh F.U. A, Low I.M. Effect of Water Absorption on the Mechanical Properties of Cotton Fabric-Reinforced Geopolymer Composites, Journal of Asian Ceramic Societies, 2(3): p. 223–230. 2014.
[21.] Azim S. Effects of Water Absorption on Mechanical Properties of Hemp Fiber Composites, Polymer Composites, 33(1): p. 120–128. 2012.

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