Nigerian Journal of Textiles (NJT)

A Publication of Textile Researchers Association of Nigeria (TRAN)
Volume 5 August 2019
http://tran.org.ng

Evaluation of the Mechanical Properties of Chemically Modified Cow Hair Fibres Filled Recycled Low-Density Polyethylene Composites

*Muktari, S., Ishiaku, U.S. and Lawal, A.S.
Department of Polymer and Textile Engineering, Ahmadu Bello University, Zaria, Nigeria
*Corresponding Author: smuktari@abu.edu.ng +2348090389396

ABSTRACT

Composites were prepared from recycled low-density polyethylene (RLDPE) and cow hair using melt mixing and compression moulding technique. The fibres were treated with 0.2M H_2O_2 for improved adhesion. Composites of untreated and treated cow hair fibres were prepared with 0 to 50 wt% fibre loading at intervals of 10 wt% and their mechanical properties were evaluated. Results obtained show a remarkable increase in the tensile strength, tensile modulus, flexural strength and flexural modulus of the composites filled with H_2O_2 treated cow hair fibres. At 30% filler loading of the treated fibres the tensile strength improved from 7.45 MPa to 9.62 MPa. The Tensile Modulus increased from 4.4 MPa to 33.58 MPa at 40 % filler loading. The Flexural strength and flexural modulus markedly improved from 13.29 MPa to 24 MPa and from 67.44 MPa to 292.26 MPa respectively. SEM micrographs of the tensile fractured surfaces revealed enhanced fibre-matrix interfacial adhesion with the modified hair fibres.

Keywords: *Recycled low-density Polyethylene, Cow hair fibres, Hydrogen peroxide, Mechanical properties, Morphology*

INTRODUCTION

As the concern of an over polluting environment is increasing day-by-day, the need of the present time is to develop such materials which are sustainable and at the same time energy efficient in nature so as to minimize and reduce further damage to an already damaged environment [1]. As a result of this, environment friendly and non-toxic materials are gaining popularity among researchers and industry. Intensive research in adopting natural fibres as reinforcement in polymeric composites with an objective to take advantage of nature's gift to mankind and reduce the huge resources pumped into the development of synthetic fibres, has intensely attracted the interests of contemporary materials' scientists and engineers [2].

Natural fibres have found wide applications and they are abundant in nature [3]. Examples of natural fibres are; cotton, coconut fibre, straws of wheat, hemp, sisal, silk, avian fibre, horse hair, alpaca hair, human hair, cow hair and more. Their availability, renewability, low density, and being inexpensive as well as satisfactory mechanical properties render them an eye-catching ecological substitute for glass, carbon and man-made fibres that have been conventionally used for the manufacturing of composites [4]. They are subdivided based on their origins; from plants, animals, or minerals. The predominant ones exploited, are those of plant origins, due to their wide availability and renewability in short time with respect to others [5]. However, this present study concentrates its pivotal point on the animal fibre; specifically cow hair.

In most tanneries in Nigeria, animal hair are heaped in large quantity and usually disposed off by burning. The burning process creates environmental pollution. In the same vain, burning method is widely adopted in the removal of hair from the body of cattle slaughtered for meat in Nigeria. In the cause of burning off, the smoke generated also create environmental pollution.

In order to add value to the cow hair, this work employed it as filler for composite making.
A composite consists of two phases i.e. a continuous phase and a discontinuous phase [6]. The continuous phase is known as the matrix while the discontinuous phase is the reinforcement [7]. In this work Recycled Low Density Polyethylene (RLDPE) is used as the continuous phase and cow hair as the discontinuous phase.

In Nigeria, one of the major domestic applications of Low-Density Polyethylene (LDPE) is in its use for packaging and for making water sachets. These plastic wrap and water sachets are not biodegradable and hence create disposal problems. The usual way of eliminating them from the environment is to burn them off. Increase in burning is hampering efforts to keep the environment green.

In order to divert the raw burning of the two waste materials and minimise burning, composite material was made by bringing the waste-LDPE and Cow Hair Fibres (CHF) together.

However, the prominent shortcoming of natural fibres in polymeric composites is the poor compatibility between fibres and hydrophobic matrix interface [8, 9]. The cow hair fibres were treated with 0.2 M H_2O_2 because of its effective ability in removing lipids, waxes, and oils from the surface of animal fibres. This will roughen the surface of the fibres and improve mechanical anchorage of the fibre and matrix.

MATERIALS AND METHODS

MATERIALS

Cow hair of white Fulani species of cattle was collected from Zaria abattoir, Waste LDPE was collected from waste bins of Ahmadu Bello University, Zaria, Nigeria. H_2O_2 procured from Sigma Aldrich. Two-Roll Mill (U.S.A Model 5189), Hydraulic Hot Press (U.S.A Model 3851-0), Instron 1195 universal materials testing machine were used to characterise the composites.

METHODS

Chemical Treatment of Cow Hair Fibres

The cow hair fibres were thoroughly washed with detergents and rinsed with distilled water and then oven dried at 50 °C. Fibres were immersed in a 2000 cm^3 beaker containing 0.2M H_2O_2. The beaker was placed in a shaker water bath maintained at 50 °C for 4 hours to effectively remove lipids from the surface of the fibres. After four hours the fibres were thoroughly rinsed with distilled water and oven dried at 50 °C.

Composite Preparation

Melt mixing and hot compression technique was used to prepare the composites. Two sets of composites were prepared with cow hair untreated (CHU) and cow hair treated with H_2O_2 (CHHO). In each set same filler loading of 10, 20, 30, 40, and 50 wt% were used. A control sample made of only waste low-density polyethylene was prepared.

Composite Characterisation

Tensile Strength Test

Tensile strength test was carried out according to ASTM D3039 standard for testing the tensile strength of composite materials using Instron 1195 universal testing machine. The dimensions of the samples were 100 mm x 20 mm x 3 mm, maintained at a cross head speed of 10 mm/min. Five samples were tested in each case and the average recorded.

Flexural Strength

Flexural strength was measured under a three-point bending approach using Instron 1195 universal testing machine according to ASTM D790. The dimensions of the samples were 100 mm x 20 mm x 3 mm. The distance between the spans was 40 mm, and the strain rate was 5 mm/min. Five samples were tested in each case and the average recorded.

Hardness Test

Hardness test was carried out with computer-controlled Vickers hardness tester in accordance with ASTM E384. Average of five samples were taken in each case.

Scanning Electron Microscopy

A PHENOM ProX SEM with field emission gun and accelerating voltage of 15 KV was used to obtain SEM images for the tensile fractured composite samples. The samples were made conductive by coating with Osmium with the use of vacuum sputter coater and the fractured surfaces were viewed.

RESULTS AND DISCUSSION

Tensile Strength

Figure 1 shows that incorporating cow hair fibre (CHF) into Recycled Low-Density Polyethylene (RLDPE) without modifying the surface of the hair will reduce the tensile strength. This decrease in tensile strength is due to the poor adhesion between the untreated filler and the matrix. The untreated hair fibres have lipids and waxes on their surfaces capable of impairing proper adhesion with the matrix [10]. Treatment of the hair fibres with H_2O_2 steadily increased the tensile strength from 6.39 MPa to 9.57 MPa at 30% fibre loading in contrast to the untreated hair fibres which generally exhibit low tensile strength. The increment however superseded the tensile strength of the RLDPE matrix at filler loading of 30 wt%

and 40 wt% only. The tensile strength of the RLDPE at these points improved by 29.13% and 28.46 % respectively. These improvements are likely due to the effective removal of lipids from the surface of the hair fibres thus creating stronger adhesion between the filler and the matrix via improved anchorage. This result agrees with the findings of Supri *et al*. [11]. The improved interfacial bond had a positive impact on the stress transfer, hence reducing the chance of interfacial de-bonding which will otherwise reduce the strength. Above the 40 wt% filler loading the tensile strength of the composites markedly decreased by 24.43 % of the RLDPE matrix. The major functions of a matrix in composites are to help hold the filler together and transfer stress onto the filler [12]. However, as the amount of filler increases and the amount of matrix decreases inadequate wetting begins to set in. At this point, the extent to which the matrix holds the fillers together decreases thus stress transfer from the matrix to the filler becomes weak [13].

Tensile Modulus

Tensile modulus of the neat RLDPE improved with the incorporation of both the untreated and treated filler at filler loadings of 10 wt% - 40 wt% beyond which the tensile modulus began to drop. At filler loading of 40 wt% where there is maximum improvement for both the untreated and treated filler, the untreated CHF improved the tensile modulus by 527.7% while the treated CHF improved the tensile modulus by 663.18%. This indicates that the rigidity of the RLDPE will be improved by about five times its value when incorporated with unmodified CHF and about seven times its value when incorporated with CHF treated with 0.2 M H_2O_2. Similar result was obtained by George *et al*. [14]. The presence of the fibres reduced ductility and increased the stiffness of the material.

Elongation at break

Results obtained show that as the rigidity of the composites increased, the elongation at break decreased. This is because of the bond strength between the fibre-matrix interface. The elongation at break of the neat RLDPE decreased significantly when both untreated and treated CHFs were incorporated into the matrix. There was however, a more rapid decrement with the treated hair fibres. The addition of hair fibres decreased the ductility of the matrix. Similar trend has been reported by other researchers [11, 13 , 14 & 15]. They found out that the presence of filler decreased the flexibility of low-density polyethylene matrix.

Flexural Strength

Flexural strength measures the composite's level of resistance to bending forces. The higher this value, the more resistance the composite has for bending forces and vice versa. The flexural strength like the tensile strength is a function of the bonding strength of the fibre-matrix interface.

When CHFs were incorporated into the RLDPE its flexural strength improved for both the untreated and treated filler. The maximum increase by the untreated filler is at 10 wt% of the filler loading by 49.48 % of the control. At the 10 wt% of filler loading, the treated CHFs improved the flexural strength of the control by 67.19%. Beyond 10 wt% fibre loading with the untreated hair, the flexural strength began to steadily decrease and finally dropped below the flexural strength of the control. This decrease in flexural strength is due to weak adhesion as discussed in the case with the tensile strength. The treated fibres improved the flexural strength beyond 10 wt% filler loading with maximum improvement at 30 wt% filler loading by 80.59% of the control. This indicates that the stiffness of the RLDPE will be improved by about its own value when incorporated with 30 wt% of CHFs treated with 0.2 M H_20_2.

Flexural Modulus

The flexural modulus of the RLDPE maximally increased at 10 wt% by the untreated CHFs from 67.44 MPa to 176.87 MPa corresponding to 162.26% improvement over the RLDPE. At 10 wt% fibre loading where the untreated hair was best with a value of 176.87 MPa the treated fillers had a value of 198.80 MPa which is 194.78% of the control. Unlike with the untreated fibre the flexural modulus steadily improved with increase in filler loading of the surface modified fibre. The maximum improvement being at 30 wt% of the filler loading. Here the flexural modulus was improved to 333.33% of the value of the control. The presence of the fibre decreased the molecular chain mobility of the low-density polyethylene matrix [15].

Hardness

The hardness of the composite material is seen to increase on a general note for all the fibre loading with both the untreated and treated CHFs. At 10 wt% untreated filler loading the hardness value increased from 7.50 HV to 12.17 Hv which is 62.27% improvement. Incorporating 10 wt% of the H_2O_2 treated filler improved the hardness by 139.6%. The hardness value improved steadily in all cases with the highest been at 40 wt% of fibres treated with H_2O_2. The hardness value here improved by 285.73%. This marked improvement is due to the corrosiveness of H_2O_2 which must have removed lipids and waxes from the surface of the hair fibres roughening the surface for improved adhesion of the fibre-matrix interface.

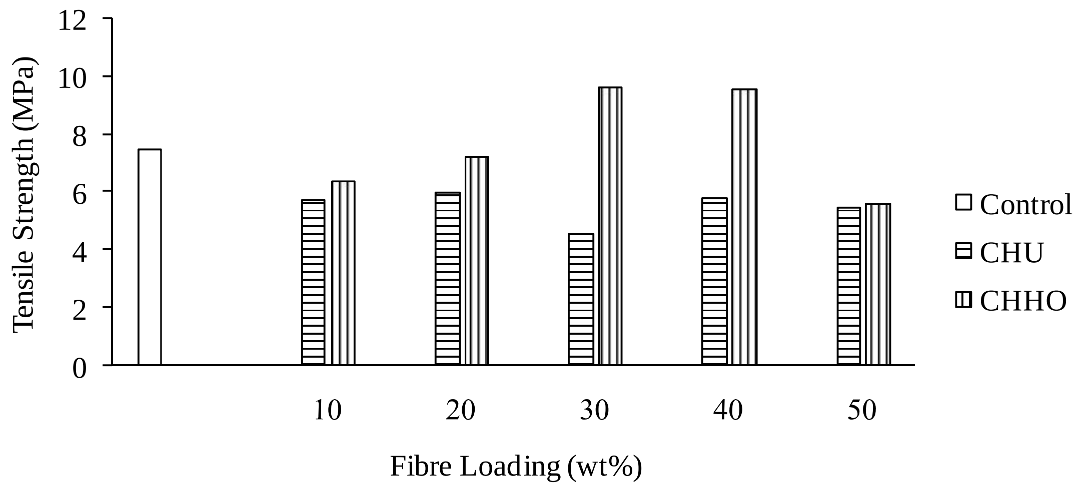


Figure 1: Effect of H_2O_2 Treatment on the Tensile Strength of CHF/RLDPE Composites at Different Fibre Loadings.

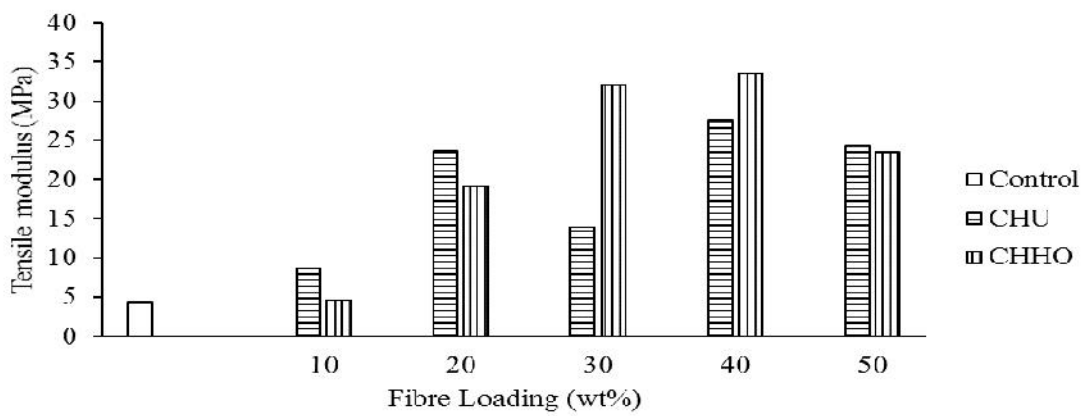


Figure 2: Effect of H_2O_2 Treatment on the Tensile Modulus of CHF/RLDPE Composites at Different Fibre Loadings.

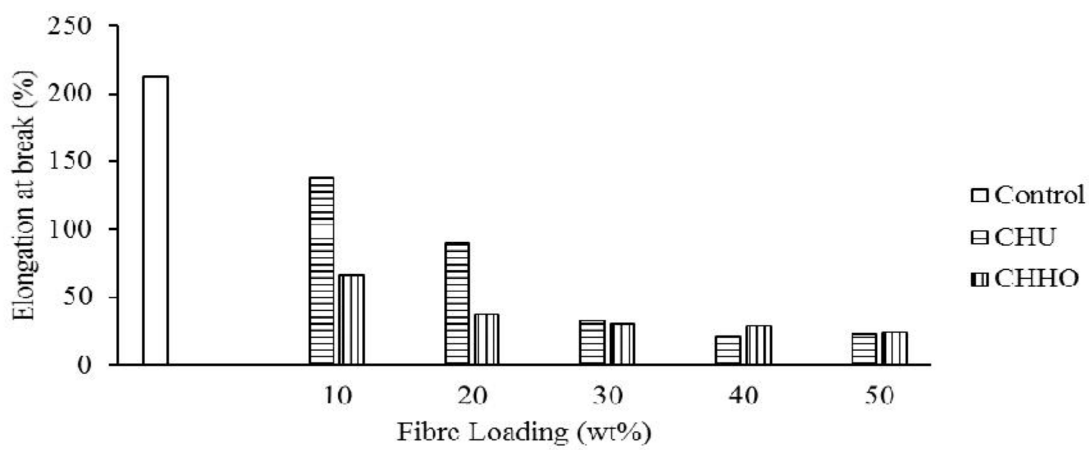


Figure 3: Effect of H_2O_2 Treatment on the Elongation at Break of CHF/RLDPE Composites at Different Fibre Loadings

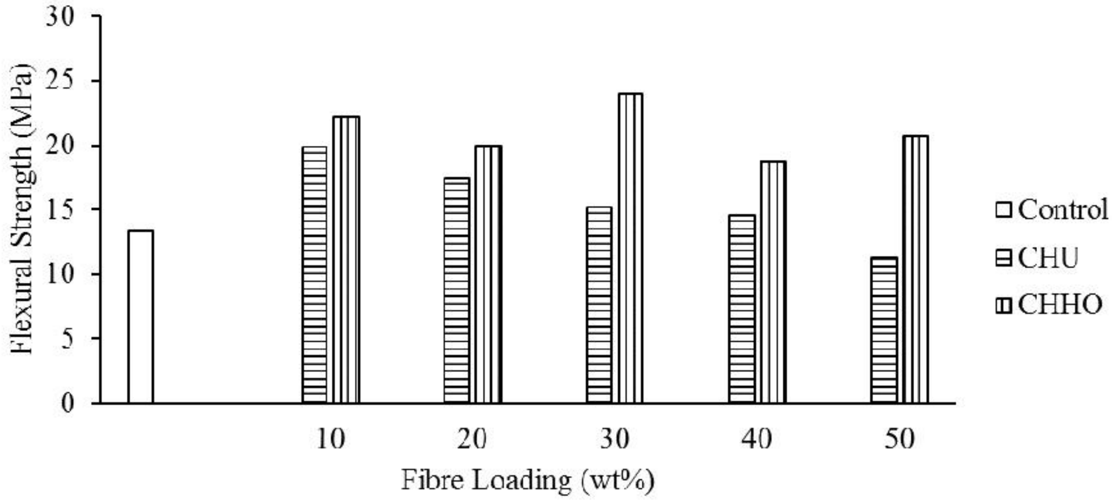


Figure 4: Effect of H_2O_2 Treatment on the Flexural Strength of CHF/R LDPE Composites at Different Fibre Loadings.

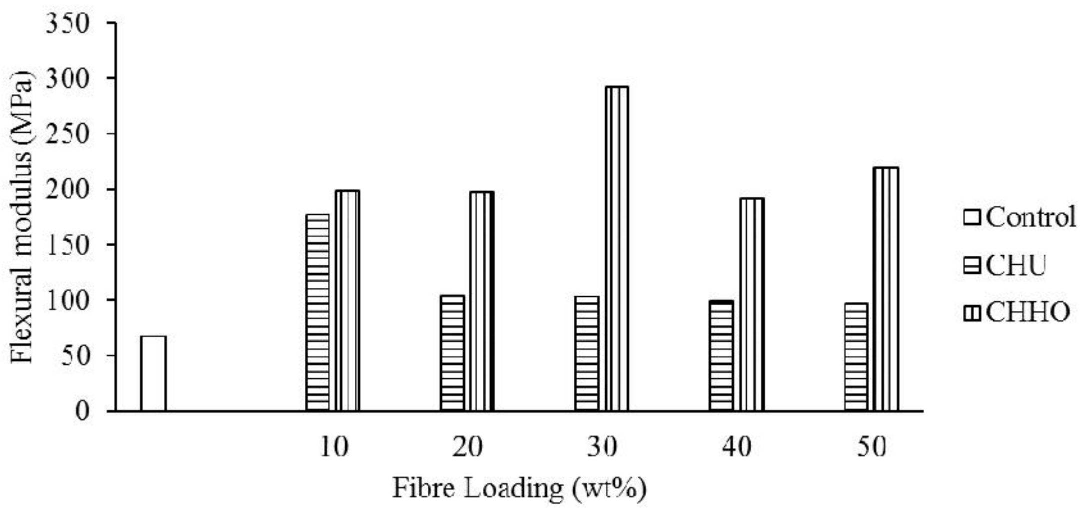


Figure 5: Effect of H_2O_2 Treatment on the Flexural Modulus Of CHF/RLDPE Composites at Different Fibre Loadings.

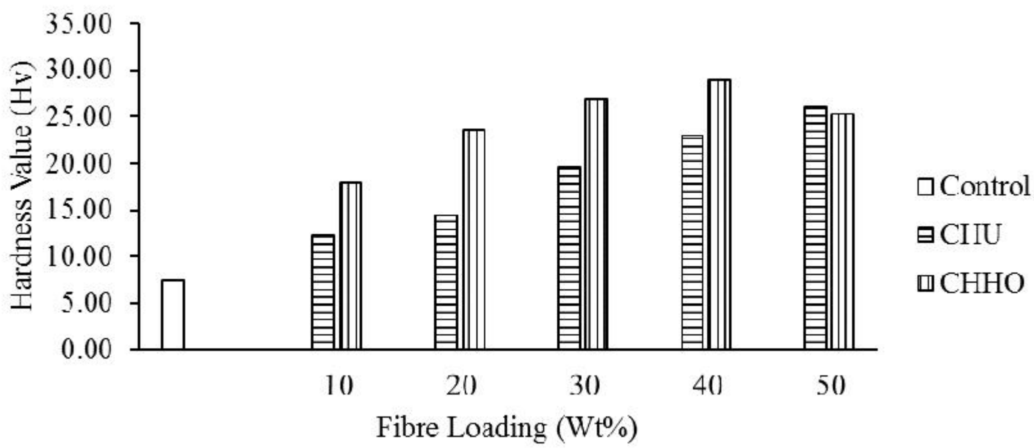
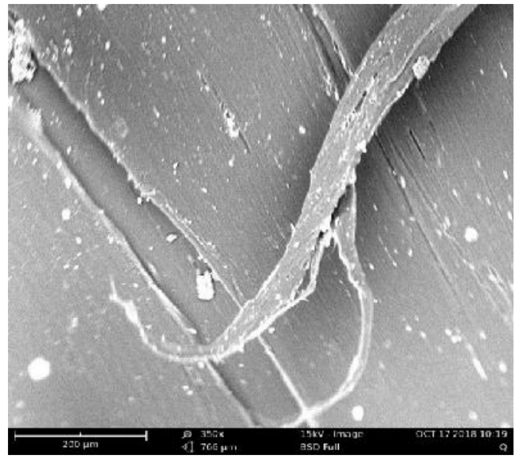


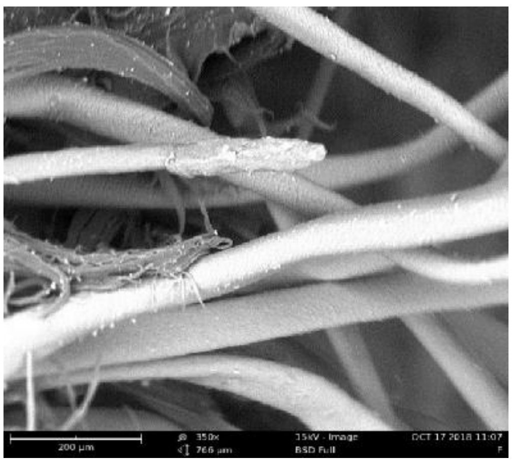
Figure 6: Effect of H_2O_2 Treatment and Fibre Loading on the Hardness of Cow Hair Filled RLDPE Composites at Different Fibre Loadings.

Morphological Study

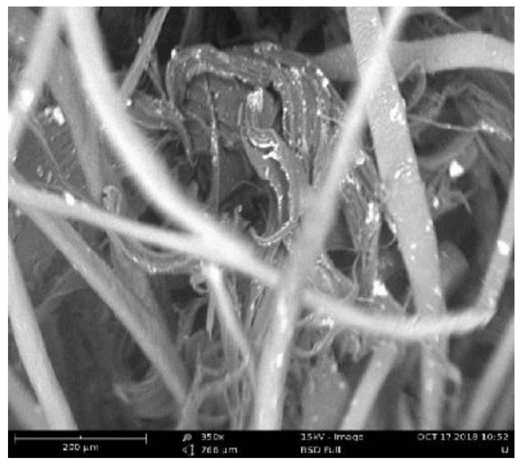
(a)



(b)



(c)



(d)

Plates: SEM micrographs of tensile fractured surface of; (a) untreated CHF/RLDP at 10 wt% filler loading (b) treated CHF/RLDPE at 10 wt% filler loading (c) Untreated CHF/RLDPE at 50 wt% filler loading (d) treated CHF/RLDPE at 50 wt% filler loading

SEM micrographs for all the 10 wt% filled composites show a ductile failure without exposing the fibres. This is expected because of the inherent flexibility of the matrix.

At 50 wt% untreated filler loading there is debonding of the fibre from the matrix and a whole lot of fibre misalignment. This is the reason why the mechanical properties of the composites of untreated fibres at 50 wt% fibre loading was weak.

Chemical treatment of the fibres improved adhesion between the filler and matrix as the degree of fibre misalignment is low compared with the untreated fibres in Plate (c). Fibre alignment factors play a crucial role in the overall properties of composites [15].

Even though chemical treatment removed lipids from the surface of the cow hair fibres and improved adhesion between the fibre and matrix the mechanical properties dropped at 50 wt% fibre loading. This is because of the debonding and fibre pull out as evidenced in Plate (c) and (d). The debonding is attributed to inadequate wetting of the fibres as the filler loading exceeded 40 wt%.

CONCLUSION

Waste Low Density Polyethylene (WLDPE) can be used as matrix and incorporated with 30 wt% cow hair fibres treated with 0.2 M hydrogen peroxide (H_2O_2) to produce useful composites with improved tensile properties. The composites will find applications in areas such as Celine boards, interior wall decorations, and table tops. This will help reduce the environmental pollution caused by Waste low-density polyethylene.

REFERENCES

[1]. Somen, B. Processing and Characterization of Epoxy Composites Reinforced with Short Palmyra Fibres. Research Dissertation submitted in partial fulfilment of the requirements of the degree of Master of Technology, Department of Mechanical Engineering National Institute of Technology Rourkela. 2016.

[2]. Pickering, K.L. A Review of Recent Developments in Natural Fibre Composites and their Mechanical Performance. http://dx.doi.org/10.1016/j.compositesa.2015.08.038

[3]. Himanshu, k. and Niranjan T. Study on Mechanical Properties of Goat Hair Based Composite. *International Journal of Aerospace, Mechanical, Structural and Mechatronics Engineering.* 2015, *1*(1), ISSN (Online): 2454-4094.

[4]. Isiaka, O. O., Jimmy, L. O. and Adekunle, S. O. Effect of Chemical Treatments on the Physicochemical and Tensile Properties of Cow Hair Fibre for Low Load Bearing Composites Development. *International Journal of Materials Science and Application.* 2015, 4(3), pp. 189-197.

[5]. Ho M-P, Wang H, Lee J-H, Ho C-K, Lau K-T, Leng J. Critical factors on manufacturing processes of natural fibre composites. *Journal of Composites Part B.* 2012, *43*(8),3549–62.

[6]. Malkapuram, R., Kumar, V., Negi, Y.S. Recent development in natural fibre reinforced polypropylene composites. *Journal of ReinforcedPlastic Composite.* 2009, *28* (10),1169–89.

[7]. Nagaraja, B. G. and Rekha, B. A Comparative Study on Tensile Behaviour of Plant and Animal Fibre. *International Journal of Innovation and Applied Studies.* 2013,*2*(4), pp. 645-648 .

[8]. Oladele, I.O., Olajide, J.L., Agbabiaka, O.G. andAkinwumi, O.O. Tensile Properties and Fractographic Analysis of Low-Density Polyethylene Composites Reinforced with Chemically Modified Keratin-Based Biofibres. *Journal of Minerals and Materials Characterization and Engineering*. 2015, 3, 344-352.

[9]. Choudhry, S., and Pandey, B. Mechanical Behaviour of Polypropylene and Human Hair Fibres and Polypropylene Reinforced Polymeric Composites, *International Journal of Mechanical and Industrial Engineering*. 2012, Volume 2, Issue 1, pp. 118-121.

[10]. Isiaka O. Oladele, Jimmy L. Olajide, and Adekunle S. Ogunbadejo.The Influence of Chemical Treatment on the Mechanical Behaviour of Animal Fibre-Reinforced High Density Polyethylene Composites. *American Journal of Engineering Research (AJER)*. 2015, e-ISSN: 2320-0847 p-ISSN: 2320-0936 Volume-04, Issue-02, pp-19-26.

[11]. Supri, A. G., Soo, J. T. and Teh, S. Y. Properties of Chicken Feather Fibre-Filled Low-Density Polyethylene Composites: The Effect of Polyethylene Grafted Maleic Anhydride. *Polymer-Plastics Technology and Engineering*. 2013, 52:5, 495-500.

[12]. Autar K.K. Mechanics of Composite Materials. Taylor & Francis Group, LLC, Newyork. 2006.

[13]. Husseinsyah, S., Chun, K.S., Hadi, A. and Ahmad, R. Effect of filler loading and coconut oil coupling agent on properties of low density polyethylene and palm kernel shell eco-composites. *Journal of Vinyl and Additive Technology*. 2014, 22(3): 200-2005.

[14]. George, J., Bagawan, S.S and Thomas, S. Effect of environment on the properties of low density polyethylene composites reinforced with pineapple-leaf fibre. *Compos. Sci. Technol.* 1997, 58(9), 1471-1478.

[15]. Salmah, H., Koay, S.C., Chan, M.Y. and Azimah, I. Tensile, Thermal and Water Absorption Properties of Corn Stalk Filled Low Density Polyethylene Composites: Effects of Coconut Oil Coupling Agent. *Sains Malaysiana*. 2016, 45(11), 1733-1739