

Surface Modified Cow Hair Fibres Reinforced Recycled Low-Density Polyethylene Composites

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ABSTRACT

In Nigeria, Low-Density Polyethylene (LDPE) is widely used for making water sachets and other plastic wraps. After use, non-biodegradable LDPE constitute waste disposal problem and environmental pollution. In the same vein cow hair fibres from tanneries pose disposal challenge. Composites were prepared from the waste materials by melt-mixing and hot compression moulding techniques. In order to increase the adhesion, chemical treatment of the fibres was done with 0.2 M H₂O₂, 0.2 M KOH, and 0.2 M NaOH. Composites of untreated and treated cow hair fibres were prepared with 0 to 50 wt% fibre loading at intervals of 10 wt% and their physical and mechanical properties were evaluated. Results obtained showed significant improvement in the mechanical properties of the composites filled with the chemically treated cow hair fibres.

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INTRODUCTION

In Nigeria, one of the major household applications of Low Density Polyethylene (LDPE) is in the making of 'plastic wraps' for packaging and for making water sachets. Because LDPE is non-biodegradable, water sachets made thereof are seen deposited in tones on waste bins. In effort to create space on waste bins, the LDPE products are commonly destroyed by burning. Burning of which constitute another environmental problem. On the other hand, cow hair fibres which is a major waste in Nigerian tanneries is either disposed off by burning or by chemical degradation into the rivers. Either of the disposal methods poses environmental challenge. In the same vein hair are mostly removed from Nigerian abattoirs by roasting method. The roasting and burning of the hair fibres create another pollution problem.

In order to reduce further damage to an already damaged environment (Pickering, 2015), the waste low density polyethylene further referred to in this work as Recycled Low-Density Polyethylene RLDPE was reinforced with the waste cow hair fibres to produce useful composites. However, the prominent shortcoming of natural fibres in polymeric composites is the poor compatibility between fibres and matrix interface (Elanchezhian *et al.*, 2018). Hence, a better understanding of fibre-matrix interface and the ability to transfer stress from the matrix to the fibre is highly essential for developing natural fibre-reinforced polymeric composites (Tim Huber and Jörg Müssig, 2008). To improve the adhesion between the fibre and matrix, there is a need to modify the surface properties of the matrix or that of the reinforcement or of the both.

In this work, alkaline and oxidative treatment of the cow hair fibre were used to modify the surface properties of the hair fibre for improved adhesion. A study on cow hair fibres by Isiaka *et al.* (2015) reveal that chemical modification of the cow hair fibres will improve compatibility with polymer matrices. Materials Researchers have in recent times worked intensely 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 expenses pumped into the development of synthetic fibres (Himanshu and Niranjana, 2015).

Natural fibres are integral part of our day to day life and they are appreciably ample all over the earth (Nagaraja and Rekha, 2013). They include 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 inexpensiveness 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 (Nagaraja and Rekha, 2013; Malkapuram *et al.*, 2009) They are subdivided based on their origins, coming 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 (.Ho *et al.*, 2012).

MATERIALS AND METHODS

Materials

White Fulani Cow hair (Hair procured from Zaria abattoir, Nigeria), Waste Low Density

Polyethylene (collected from Ahmadu Bello University Campus waste bins), H₂O₂, NaOH, and KOH (chemicals purchased from Sigma Aldrich, Germany).

Equipment

Motorised Monsanto Tensometer (9875), Vickers Hardness Tester (MV1-PC), Two-Roll Mill (U.S.A Model 5189), Hydraulic Hot Press (U.S.A Model 3851-0), Electronic weighing balance.

METHODS

Chemical Treatment of Cow Hair

The cow hair were thoroughly washed with detergent and rinsed with distilled water ensued by drying at room temperature for 24 hours to remove impurities and blood stains from the fibres. The cleaned fibres were separated into two portions for chemical treatments and controlled experimentations. The fibres to be chemically

treated were dipped in separate containers containing 0.2M H₂O₂, 0.2 M NaOH, and 0.2 M KOH.

The containers were placed inside a shaker water bath maintained at 50°C for 4 hours to effectively remove lipids from the surfaces of the fibres in order to improve wettability and interfacial adhesion between the fibres and the matrix. The chemically treated fibres were then rinsed with distilled water to remove any residual chemicals left on the surfaces of the fibres and this was ensued by oven drying at 50°C (Oladele *et al.*, 2015).

Composite Preparation

Composites were prepared by hot compression moulding technique. Composites filled with treated and untreated cow hair fibre with 10 %, 20 %, 30 %, 40 %, 50 % weight of the matrix (RLDPE) were prepared as shown in the table 1.0 below.

Table 1.0: Composite composition.

| Composite of Untreated Cow Hair (CHU) | | Composite of Cow Hair treated with NaOH (CH_NaOH) | | Composite of Cow Hair treated with KOH (CH_KOH) | | Composite of Cow Hair treated with H ₂ O ₂ (CH_H ₂ O ₂) | |
|---------------------------------------|-----------|---|-----------|---|-----------|--|-----------|
| Cow hair (%) | RLDPE (%) | Cow hair (%) | RLDPE (%) | Cow hair (%) | RLDPE (%) | Cow hair (%) | RLDPE (%) |
| 0 | 100 | - | - | - | - | - | - |
| 10 | 90 | 10 | 90 | 10 | 90 | 10 | 90 |
| 20 | 80 | 20 | 80 | 20 | 80 | 20 | 80 |
| 30 | 70 | 30 | 70 | 30 | 70 | 30 | 70 |
| 40 | 60 | 40 | 60 | 40 | 60 | 40 | 60 |
| 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |

Density

The ASTM D 792 standard method of determining density of composites was used.

Tensile Test

The tensile strength was carried out in accordance with ASTM D638 on a motorized Monsanto tensometer (9875) maintained at a cross head speed of 10mm/min.

Flexural Test

Flexural strength was measured under a three-point bending approach according to ASTM D790.

Hardness Test

Hardness tests were carried out with computer-controlled Vickers hardness tester in accordance with ASTM E384.

Scanning Electron Microscopy

A PHENOM ProX SEM with field emission gun and accelerating voltage of 15 KV was used to collect 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

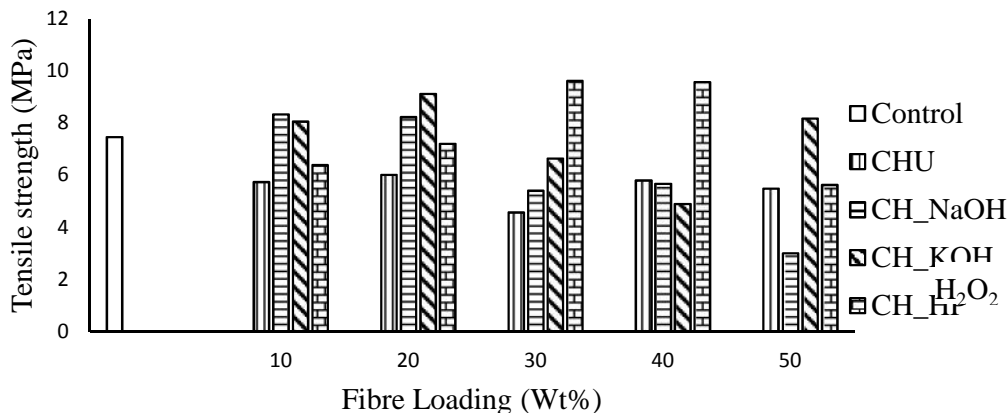


Fig. 1.0: Tensile strength versus fibre loading of cow hair filled RLDPE composites.

Incorporating untreated cow hair fibres into Recycled Low-Density Polyethylene (RLDPE) did not improve the tensile strength of neat RLDPE (control). The control has tensile strength of 7.45 MPa, addition of untreated cow hair fibres decreased the tensile strength for all the variation of fibre loadings used. This decrease in tensile strength by the addition of untreated CHF is due to poor adhesion between the fibres and the matrix (RLDPE).

When 10 wt% of CHF treated with NaOH was introduced into the matrix, the tensile strength increased from 7.45 MPa to 8.33 MPa which is 11.81% improvement. Similarly, there is an improvement of 8.19% when 10 wt% of CHF treated with KOH was incorporated into RLDPE. At 20 wt% fibre loading there is an improvement of 10.6% and 22.3% with treated fibres of NaOH and KOH respectively.

The best result obtained is with the incorporation of 30 wt% and 40 wt% of CHF treated with H₂O₂. The tensile strength improved from 7.45 MPa to 9.62 MPa and 9.57 MPa at 30 wt% and 40 wt% respectively corresponding to 29.13% and 28.46%.

Isiaka *et al.*, (2015) studied the effects of chemical treatment on the tensile properties of cow hair fibre. They found out that chemical treatment of cow hair fibres will increase the fibres tensile properties. The increase in the tensile strength of the chemically modified CHF/RLDPE composites as discussed from the results above is due to the removal of lipids, waxes, and oil from the surface of the cow hair and roughening the hair surface for increased adhesion between the hair and the matrix.

Tensile modulus

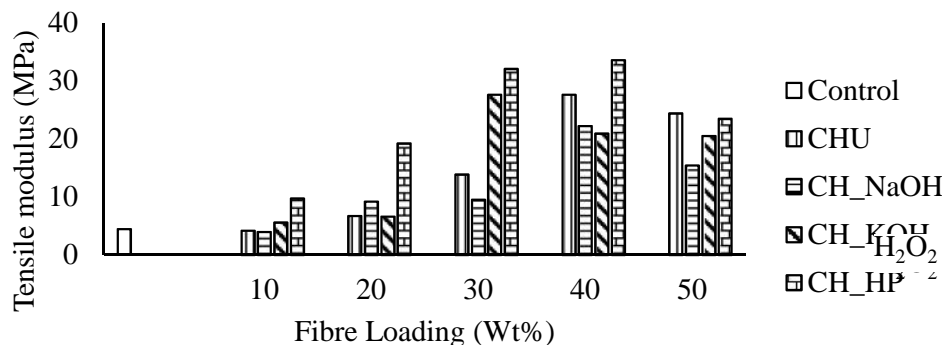


Fig. 2: Tensile modulus versus fibre loading of cow hair filled RLDPE composites.

The results for the tensile modulus as in Fig. 2 show a general increase in the tensile modulus of the neat RLDPE when incorporated with both the

untreated and treated cow hair fibres. The untreated cow hair fibres improved the tensile

modulus of the control by five times its value at 40 wt% filler loading. The most increment been at 40 wt% of fibres treated with H₂O₂. At this point the tensile modulus

was increased by almost seven times the tensile modulus of neat RLDPE. This rapid increment is due to the high stiffening of the composite by the filler resultant of the increase in fibre matrix adhesion.

Elongation at break

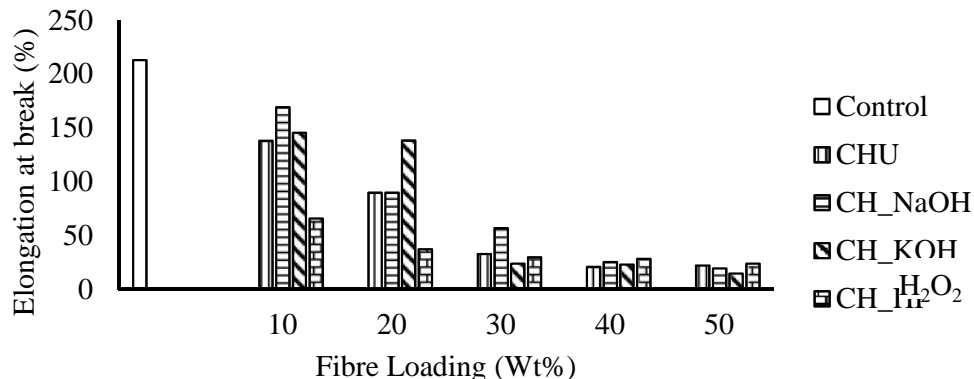


Fig. 5: Elongation at break versus fibre loading of cow hair filled RLDPE composites

Results obtained show a general decrease in the elongation at break for all the tested composite samples as seen in Fig. 5. Researchers have shown in their works on natural fibre filled polymeric composites that increase in fibre loading decreases the elongation at break of composites (Ahmad *et al.*, 2010). As material is hardened its

strain per unit length when pulled decreases, hence the ultimate stress will be markedly increased while the elongation suffers a decrease (Muktari *et al.*, 2018). The elongation at break of the neat RLDPE decreased steadily from 213% down to 15% of 50 wt% CHF treated with KOH.

Flexural strength

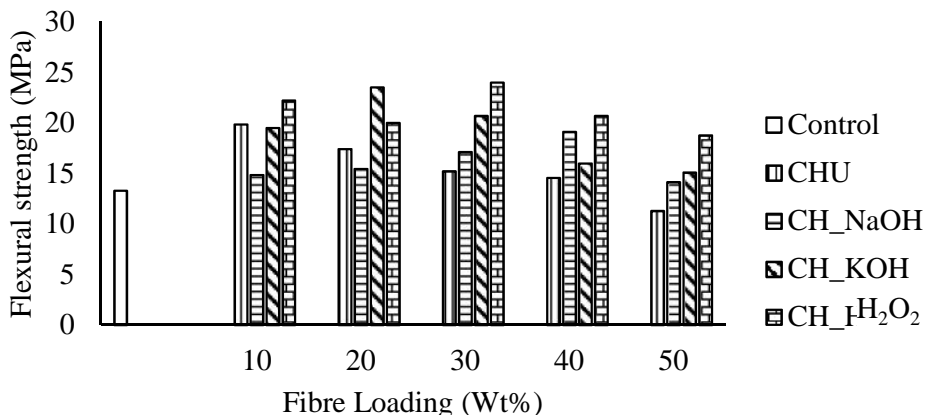


Fig. 3: Flexural strength versus fibre loading of cow hair filled RLDPE composites.

The flexural strength of neat RLDPE is generally improved with the addition of both untreated and treated cow hair fibre as shown in Fig. 3. The untreated cow hair at 10 wt% improved the flexural strength of RLDPE by 49.59%. Treatment of CHFs with NaOH improved the flexural strength of RLDPE by 43.87% at 40 wt% filler loading.

Treatment with H₂O₂ and KOH gave the best improvements. At 30 wt% of CHF treated with H₂O₂ the flexural strength of RLDPE was improved by 80.59% and treatment with KOH gave an improvement of 77.13% at 20 wt% filler loading. This mark improvement is due to increase in fibre matrix interface bond (Choudhry and Pandey, 2013).

Flexural modulus

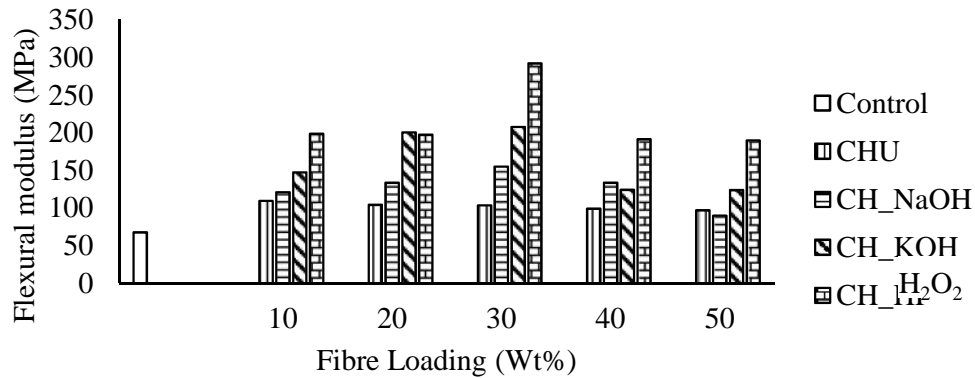


Fig. 4: Flexural modulus versus fibre loading of cow hair filled RLDPE composites

The flexural modulus of the CHF/RLDPE composites increased with increase in fibre loading for both the untreated and treated CHFs as shown in and Fig. 4. Remarkable increment is with the chemically treated fibres. At 10 wt% fibre loading there is the most increment in the flexural modulus with the untreated cow hair fibres. The flexural modulus increased from 67.44 MPa to 109.43 MPa which is 62.26% improvement over the control.

The treatment of cow hair fibres with NaOH and incorporating 30 wt% of the treated

fibres into RLDPE improved the flexural modulus by 130.10%. The flexural modulus of the composite increased by 207.86% when 30 wt% of fibres treated with KOH was added to RLDPE. At 30 wt% filler loading of fibres treated with H₂O₂ the flexural modulus increased by 333.33% of the control. Beyond 30 wt% filler loading, the flexural modulus dropped with all the chemically treated fibres. Hence 30 wt% filler loading is the optimum filler loading where there is maximum wetting and fibre-matrix interfacial strength.

Hardness

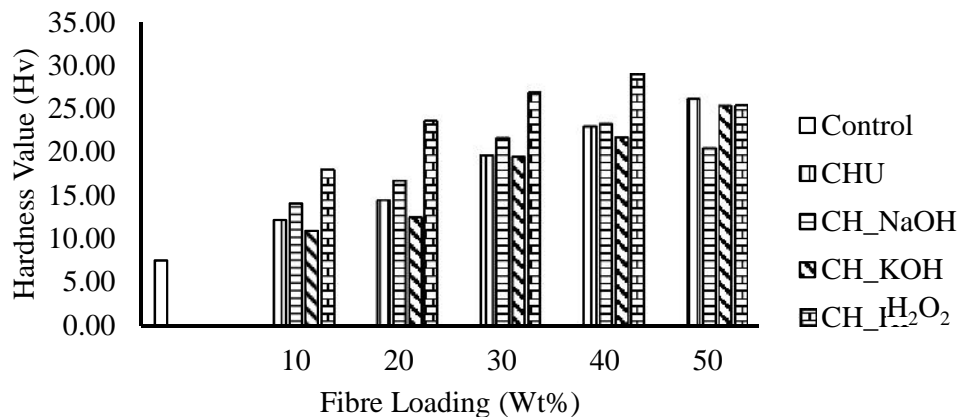


Fig. 6: Hardness value versus fibre loading of cow hair filled RLDPE composites.

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 as seen in Fig. 6. 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 H₂O₂ 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 H₂O₂. The hardness value here improved by 285.73%. This marked improvement is due to the corrosiveness of H₂O₂ 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.

Density

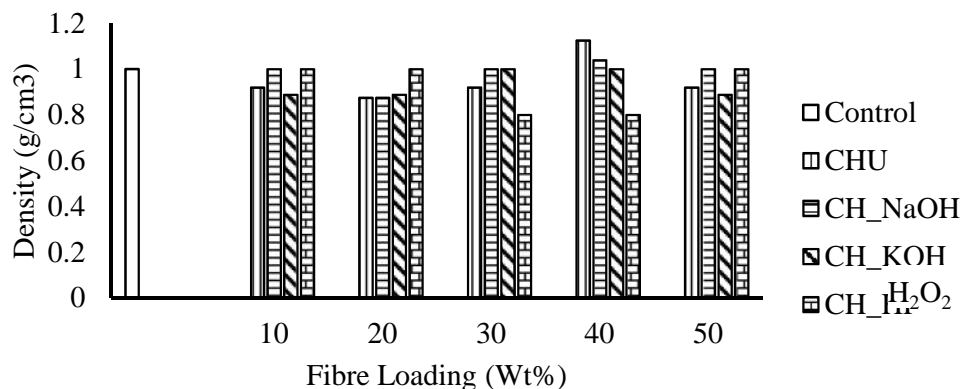


Fig. 7: Density versus fibre loading of cow hair filled RLDPE composites

The density of the control sample is 1 g/cm³, with increase in filler loading for the untreated and treated filler there was no significant increase in the density of the composites beyond that of the control sample. There was a decrease in the density of the composites compared with that of the control at some points due to incorporation of lighter filler. The most significant decrease was seen at 30 wt% and 40 wt% H₂O₂ treated filler where the density of the control decreased by 20%. H₂O₂ have more corrosive effect in removing lipids from the hair fibres and hence making the filler lighter while improving adhesion.

CONCLUSION

The chemical treatment of cow hair fibres with 0.2 M H₂O₂, KOH, and NaOH improved interfacial bonding of the treated fibres with recycled low-density Polyethylene (RLDPE) compared with the untreated cow hair fibres. Hence composites made with the treated fibres had better mechanical properties than their untreated counterparts. The best improvements were given by 0.2 M H₂O₂ followed by 0.2 M KOH, and then 0.2 M NaOH. H₂O₂ was more effective in the surface modification of the cow hair fibres because it removed more lipids from the surface of the hair allowing for better fibre roughening thus better adhesion with the polymer matrix.

The tensile strength of the composites of untreated fibre decreased with all the fibre loadings. With chemical treatment there was significant increase in the tensile strength, most remarkably at 30 wt% and 40 wt% of fibres treated with H₂O₂ where the tensile strength was improved by 29.13% and 28.46% respectively. Similar trend is with the tensile modulus. The flexural strength of the composites of hair fibres treated with KOH improved by 77.13% at 20 wt% filler loading over

that of the control sample. At 30 wt% filler loading of fibres treated with H₂O₂ there was 80.59% increase in flexural strength.

Flexural modulus of composites of untreated fibres was maximum at 10 wt% fibre loading by 62.26% over the neat RLDPE composite. There was remarkable improvement in flexural modulus of the neat RLDPE by 130.10%, 207.86%, and 333.33% respectively with NaOH, KOH, and H₂O₂ treatments at 30 wt% filler loading. Due to increase in the hardness and stiffness of the composite materials as the fillers were incorporated into the matrix, the elongation at break witnessed decrease for all the tested composite samples.

Interestingly, the bulk of the mechanical properties of the composites were best at 30 wt% and 40 wt% filler loading of fibres treated with H₂O₂ with the composite been lighter at these compositions. The density of the composites here decreased by 20% that of the control sample with remarkable increase in mechanical properties. The weight of the material was reduced without compromising the mechanical properties. This phenomenon makes the material useful where light weight with and appreciable mechanical properties are simultaneously desired.

Due to their light weight and improved mechanical properties the composites will find applications in areas such as ceiling boards, table tops, interior wall decorations, where high loading is not required.

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