Communication in Physical Sciences, 2022, 8(2): 172-178

Study on the Mechanical Properties of Low- Density Polyethylene Cow Horn Powder Composite

Uche Ibeneme, Paul A. P. Mamza, Casmir E. Gimba and S. A. Yaro

Received: 02 March 2022/Accepted 29 April 2022/Published online: 30 April 2022

Abstract: *Composite formulation has a significant impact on the mechanical properties of polymer materials. This study describes the mechanical properties of cow horn powder reinforced with waste low density polyethylene. The study was performed by recycling waste low density polyethylene and compounding it with the ground cow horn (the white Bororo cow horn). Mechanical and Fourier Transformed infra-red (FTIR) analysis was investigated for various compositions by weight of the formulated samples. The results obtained indicated that the properties of the composites varied with identified properties of the filler reinforcements. The results also showed that the control sample, (which consisted of 150 Mics WLDPE/CH 100/0) had the least tensile test and yield strength of 14.40 Mpa and 3.60 Mpa respectively, while the 150 Mics WLDPE/CH 90/10 had the optimum elastic modulus of 17.54 Mpa and the lowest elongation at break of 359.71%. The infrared spectra of the filler samples revealed absorption peaks within the ranges 4000-650 cm^{-1}. The characteristic absorption peaks for the stretch and bend vibrations for the treated and untreated cow horn fillers were 3678 cm^{-1} and 3652 cm-^{1}. Our results gave evidence that composite combinations of low-density polyethylene have enhanced mechanical and morphological properties.*

Keywords*: Waste low-Density Polyethylene, Cow Horn Powder. Elastic Modulus, Tensile strength, Polymers.*

Uche Ibeneme
Nigerian Institute of Leather and Science Technology, Samaru-Zaria, Kaduna State, Nigeria
Email: ucheibeneme2016@gmail.com
Orcid id: 0000-0001.6274-7685

Paul A. P. Mamza
Department of Chemistry, Ahmadu Bello University, Samaru-Zaria, Kaduna State, Nigeria
Email: paulmamza@yahoo.com

Casmir E. Gimba
Department of Chemistry, Ahmadu Bello University, Samaru-Zaria, Kaduna State, Nigeria
Email: gimbace@yahoo.com

S. A. Yaro
Department of Metallurgical and Materials Engineering. Ahmadu Bello University, Samaru-Zaria, Kaduna State, Nigeria
Email: yaroaliyu@yahoo.com

1.0 Introduction

Polymer composites are materials that consist of two or more chemically and physically different phases separated by a distinct interphase (Josmin *et al*., 2012). In polymer composite, different systems are carefully combined to achieve a system with more useful structural or functional properties, which may not be attainable by either of the constituents (Josmin *et al*., 2012). Composites can be said to be a wonderful material and are being applied as an essential part of today`s materials because of their advantages such as low weight, high fatigue strength, corrosion resistance and very fast assembly (Shaw *et al*., 2010). The properties of polymer systems can be improved when the polymer is combined with a reinforcing material as filler and through this way a composite is produced. The properties of the composites are strongly dependent on the characteristics of the filler such as its size, geometry, composition, light weight, fatigue life, corrosion resistance, reduced cost, surface coating and increase in water resistance (Sharma, 2011; Ebewele, 2000). Polymer composites with the size of the filler in the nanoscale have been found to be effective in the production of polymer nano-composites with commendable properties (Shen *et al*., 2010; Cole & Kirwan, 2011). The chemical structure of polymers can also influence their mechanical properties, their glass transition temperature and the rate of cooling (Josmin *et al*., 2012)

Some studies directed towards the enhancement of the mechanical properties of polymers have been widely reported. For example, a research on the rheology, mechanical properties, and thermal stability of maleated polyethylene-filled nanoclay was carried out by (Abdulhada & Al-juhani, 2015). Maleated polyethylene (MAPE) was used as a model matrix for hosting hydrophobic nanoclay and hydrophilic nanoclay. It was observed that the hydrophobic nanoclay had better dispersion and was much superior to the hydrophilic nanoclay for enhancing the mechanical properties and thermal stability of MAPE. The structure-property relationship of polymer filled with mechanochemically grafted nanoparticles was investigated by (Ruan *et al.*, 2004; Onuoha *et al.*, 2017). The researchers observed that there were interfacial interactions of the grafted nano-particles and also the results showed an improvement in the crystallinity of the polymer matrix. In their research studies, they also compared the effects of fillers on the mechanical properties of reinforced low-density polyethylene composites. Based on our knowledge, the use of cow horn to enhance the mechanical properties of low-density polyethylene has not been deeply reported elsewhere. Therefore, the aim of this study is to study the mechanical properties of low-density polyethylene cow horn powder composite.

2.0 Materials and Methods.

2.1 Materials

The materials that were used in this study were cattle horn from white Fulani cows (white Bororo) slaughtered cows in the abattoir at Zango community in Zaria. Samples of low-density polyethylene were obtained from waste water satchets from some shops within the shops in Nigerian Institute of leather and Science Technology and Ahmadu Bello-University, Zaria. The cow-horn was thoroughly washed with clean water and allowed to dry completely under the sun to constant weight. The filler was ground for two hours with the food premier grinding machine and Willey laboratory grinding machine. The grounded samples were sieved using 150 microns siever, before treatment with 5 % sodium hydroxide by dissolving 100 g of sodium hydroxide in 2000 cm^3 of the solution. The hydrophilic nature of the natural filler and hydrophobicity of the polymer matrix leads to phase separation and this may result to weak bonding at the matrix filler interfaces of the natural filler composites. Therefore, the chemical treatment of the natural fillers decreases the inherent hydrophilicity of the fillers and improves the adhesion between the matrix and the fillers (Gholampour and Ozbakkaloglu, 2020) The waste low density polyethylene was washed with water for an hour to remove impurities like sand, iron and stone particles and later spread in the sun for 5 hours to dry completely. The dried low-density polyethylene was crushed using the recycling machine. The weighed samples of the ground filler and the matrix were then mixed and compounded respectively at a temperature of 110^{o}C with the aid of the two-roll mill and then finally compressed with the compression machine. Successful sourcing and recycling of these waste polymers and the bio-fillers would go a long way to create jobs for young school leavers.

3.0 Results and Discussion

Figs. 1 to 3 show plots of the 150 microns WLDPE/CH 100/0, WLDPE/CH 95/5 and WLDPE/CH 90/10 matrix and filler proportions and the various results of a pulling force on the material and the specimen`s response to stress. Point P2 on each of the plots is the proportional limit and this is the point on the stress-strain curve where the linear elastic region transitions into the non-linear plastic deformation region. Rp is the yield point and this is the point at which plastic deformation begins to occur. The various materials deviated from the elastic or linear region from Rp to Fmax. The materials were then stretched to the point of rupture and the % elongation, elastic modulus, tensile strength etc were all recorded as shown in plots of WLDPE 100/0, 150 MICS/WLDPE/CH 95/5 and 150 MICS/WLDPE/CH 90/10.

The experimental results shown in Figs. 1, 2 and 3 showed that increase in the tensile strength of the compositions with bio-fillers are as a result of a better adhesion between the filler and the matrix and this was in line with the research carried out by Ishaq and Mahmound, (2021). There was also an increase in the Youngs modulus when the filler percentage was increased and this was in the same trend with the works done by Ejiogu *et* al., (2019) where they reported that the tensile strength and elastic modulus increased more than the control sample when more filler was introduced into the matrix.

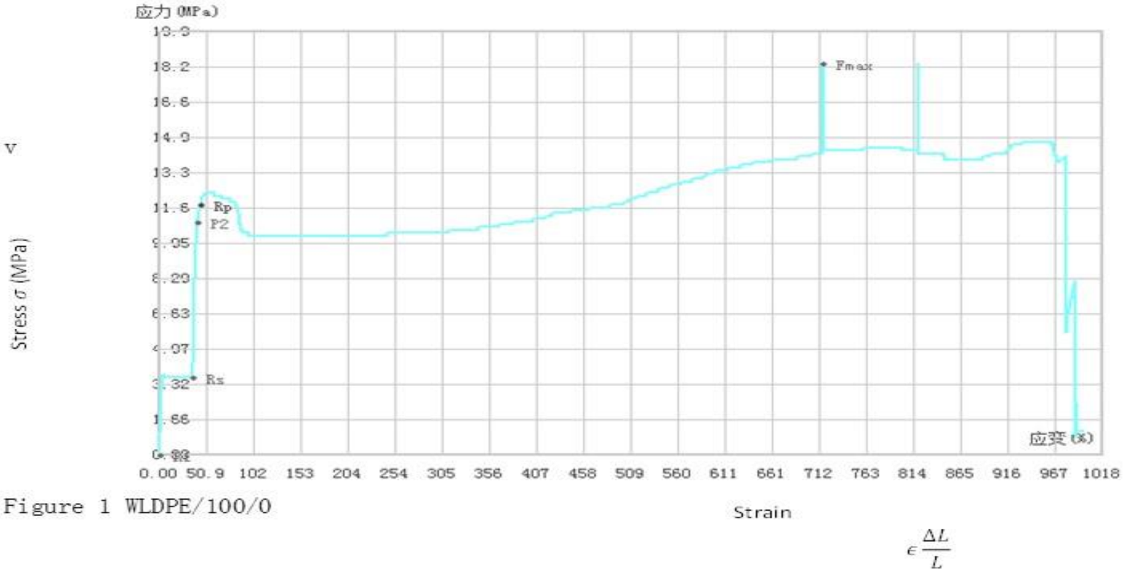
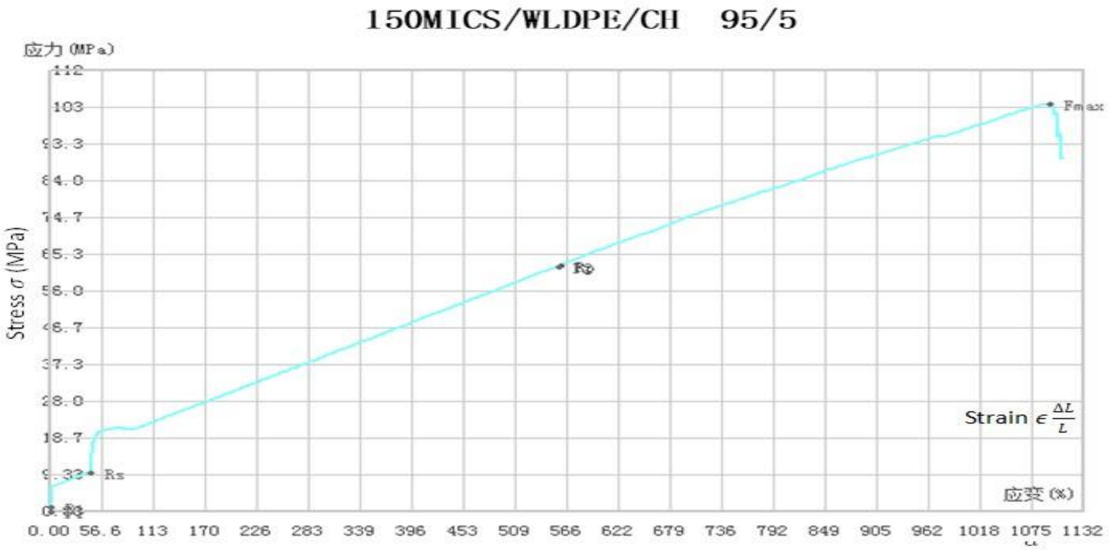


Figure 1 WLDPE/100/0

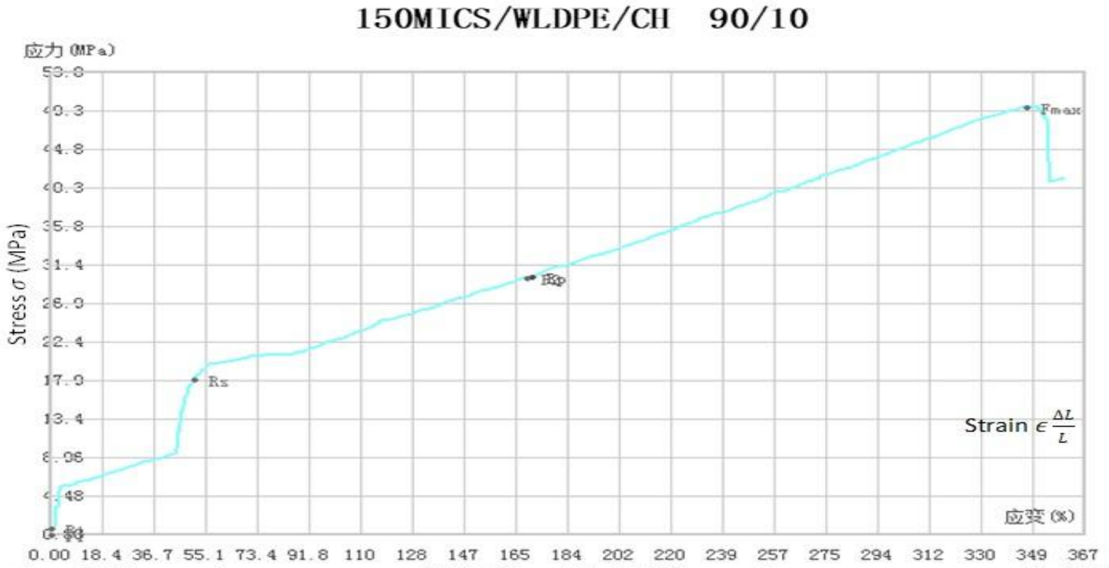
Elastic Modulus	16.14MPa	Upper Yield	0.00MPa
Yield Strength	3.60MPa	Break Strength	1.07MPa
Break Elongation	997.33%	Elongation after fracture	997.33%
Total Elongation	717.15%	Yield Elongation	36.69%
Yield Ratio	19.57%	MaxLoad	0.55kN
Max Elong	398.93mm	Lower Yield	0.00MPa
Tensile Strength	14.40MPa	Reduction of Area	100.00%
Non Proport Elongation	680.47%		

Fig. 1: WLDPE/ 100/0 (Control Sample)



Break Elongation	1109.02%	Elongation after fracture	1109.02 %
Total Elongation	1094.58%	Yield Elongation	44.95%
Yield Ratio	9.40%	MaxLoad	3.11kN
Max Elong	443.61mm	Lower Yield	0.00MPa
Tensile Strength	103.60MPa	Reduction of Area	100.00%
Non Proport Elongation	1049.62%		

Fig. 2: 150 MICS/WLDPE/CH 95/5 Composition.



Total Elongation	346.56%	Yield Elongation	50.97%
Yield Ratio	36.19%	MaxLoad	1.49kN
Max Elong	143.89mm	Lower Yield	0.00MPa
Tensile Strength	49.73MPa	Reduction of Area	100.00%
Non Proport Elongation	295.58%		

Fig. 3:150 MICS/WLDPE/CH 90/10 composition

The yield stress of the two samples with filler loading of 5 % and 10 % were greater than the yield stress without filler (the control sample) and this corresponded with the research carried out by Onuoha *et al*., (2017). They observed that increasing the percentage of the filler content in the matrix leads to a rise in the yield strength of the composites. The percentage elongation dropped with the 10 % filler loading which indicated that the stiffer the material, the lesser the ductility of the material. The current results are in harmony with the result published by Atuanya *et al*., (2014) and Onuoha *et al*., (2017). In their various research works, they observed that an increase in the filler loading of the various matrices elevated the stiffness of the various composites and subsequently reduced the ductility of the composites.

Figs. 4 and 5 presents the FTIR spectra, the treated and untreated cow-horn powder. From the spectra, it is evidence that there is a significant difference between the O-H spectra. The O-H spectra for untreated cow-horn filler was at 3272 cm^{-1}, while that of treated cow-horn filler showed similar a significant peak at 3678 cm^{-1}. The C-X stretching (which extended from 850-515cm^{-1} in the original spectrum) were absent in the treated filler.

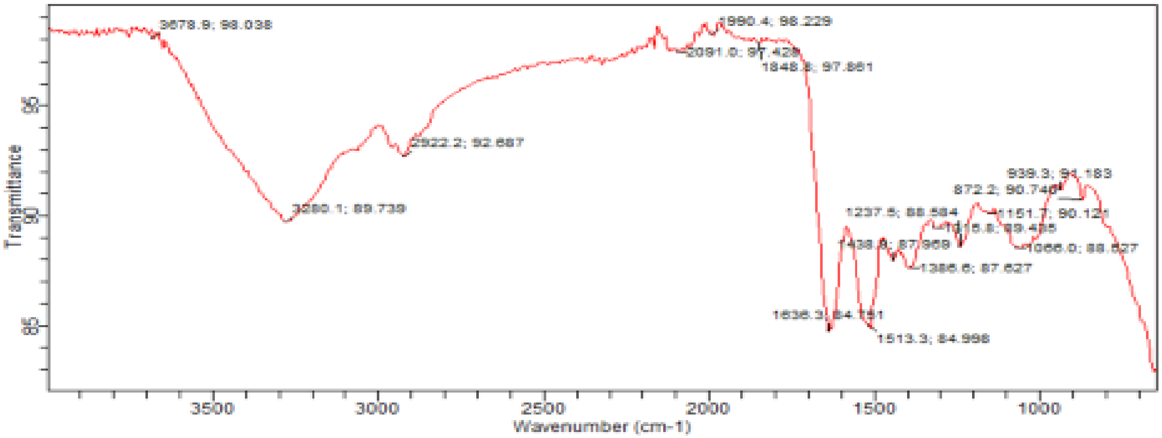


Fig 4: FTIR spectrum of treated cow horn filler.

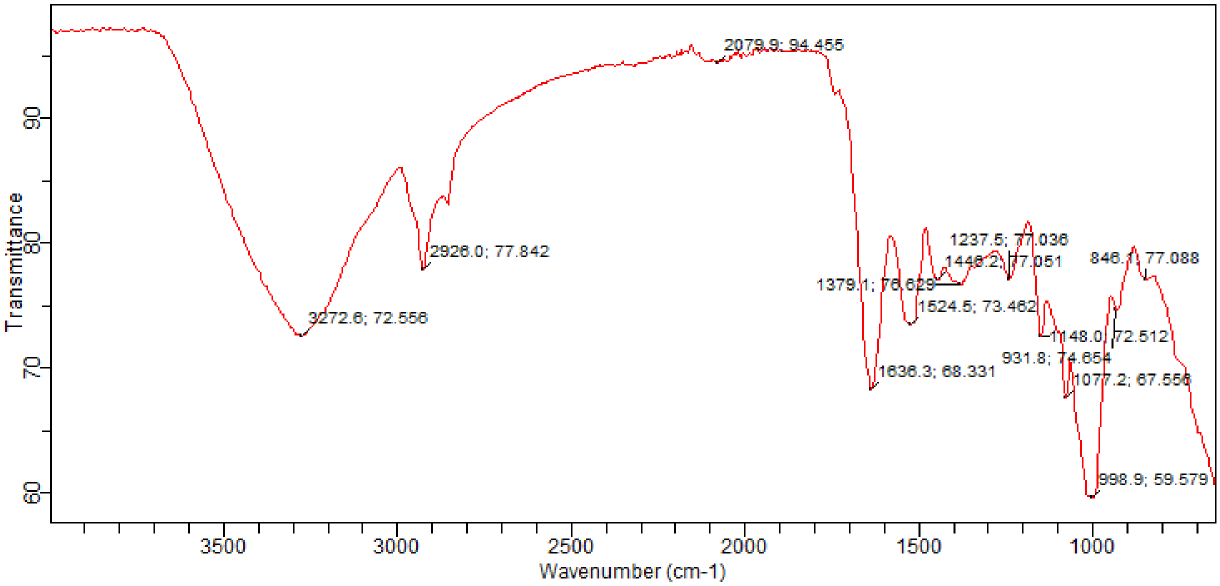


Fig 5: FTIR spectrum of untreated cow horn filler

Table 1: Peaks, frequency and assignments of FTIR absorption by treated and untreated cow horn

Wave number (cm^{-1})		**Functional group**	**Assignment**
Treated	**Untreated**	**Treated**	
3678	3272	O-H	Alcohol
3280		O-H	Carboxylic acid
2922	2926	C-H	Primary amine
1990	1990	C-H	Weak aromatic compound
1638	1636	C=C	Alkene
1513	1524	N-O	Nitro compound
	1440	O-H	Carboxylic acid
1380	1370	C-H	Bending of aldehyde
872		C-C	Strong bending vibration in alkene
	846	C-X	Halogen

4.0 Conclusion

Cow-horn powder and waste low-density polyethylene were the filler and matrix used for the production of the composite. Good adhesion of the filler and matrix yielded an optimal tensile strength of the composite, while increase in the filler loading enhanced the young modulus of the composite. The yield strength of the samples at 5 % and 10 % filler loading was greater than that of the control sample (without filler loading). The C-X stretching was not seen in the treated filler. The composite produced will find wide applications in the insulation of electrical conductors.

5.0 References

Abdulhada, A., & Al-Juhani, J. (2015). Rheology, mechanical properties, and thermal stability of maleathed polyethylene filled with nanoclays. *Journal of Nano Materials.* doi:org/10.1155/2015/792080.

Atuanya, C. U., Edokpia, R. O., & Aigbodo. V. S. ((2014). The physio-mechanical properties of recycled low-density polyethylene/bean pod ash particulate composites. *Results in Physics*, 4, pp. 88-95. http;//dx.doi.org/10.1016/j.rinp

Coles, R & Kirwan, M, J, (2011). *Food and Beverage packaging technology,* 2nd edition, Willey Blackwell, 344.

Ebewele, R. O. (2000). *Polymer science and technology*. CRC Press LLC, N, W, Corporate BLVM BOCA Raton, Florida 33431.

Gholampour, A. & Ozbakkaloglu, T. A. (2020). A Review of natural fiber composites properties, modification and processing techniques, characterization, applications. *Journal of Materials Science*, 55, pp. 829–892, doi.org/10.1007/s10853-019-03990-y

Ishaq, S. & Mahmound, M. A. N. (2021). Chemical treatment of bio-derived industrial waste filled recycled low-density polyethylene. A comparative evaluation. *Journal of Polymers*.doi.org/10.3390/ Polym131626282.

Ejiogu, I. K., Uche, I., Gabriel, O. T., Mark, D. A. & Mosunmade O. A., (2019). Natural fiber reinforced polymer composite (NFRP) from Waste Polypropylene filled with Coconut flour. *International Journal of Engineering Technology and Sciences*, 6, 2. https://doi. Org/10.15282/ijets: v6 I 2.882 2019. 1005.

Josmin, P. J., Sant, K. M., Sabu, T., Kuruvilla, J., Koichi, G, & Meyyarappallil, S. S, (2012). *Advances in polymer composites*: macro and micro composites. Polymer Composites vol. 1. First edition. Pp 133-177, doi :10. 1002/9783527645213. Ch 1

Onuoha, C., Onyemaobi, O. O., Ayakwo, C. N. & Onuegbu, G. C. (2017). Effect of filler loading and particle size on the mechanical properties of Periwinkle shell filled recycled polypropylene composites. *American Journal of Engineering Research (AJER*), 6, 4, pp. 72-79

Shaw, A., Sriamula, S., Gosling, P. D. & Chryssanthopoulo, M. K. (2010). A critical reliability*Composite Part B*. 41, pp. 446-453.

Sharma, B. K. (2011). *Industrial chemistry (Including Chemical Engineering*) Krishna prakashan media (P), India. 6th edition, p 353

Shen, J, Song, X, Qian, F, Yang, F, (2010). Nano fillers for paper making, *Journal of Bioresources*, 5, 3, pp. 1328-1331.

Ruan, W. H., Zhang, M. O. & Rong, M. Z. (2004). Structure-property relationships of polymer nanocomposites filled with mechanochemically grafted nanoparticles. *Journal of Composite Technologies* (*Proceedings of the fourth Asian-Australian conference on composite materials* held on 6-9 July*)*. pp.. 671-676.

Consent for publication

Not Applicable

Availability of data and materials

The publisher has the right to make the data public

Competing interests

There is no competing interests

Funding

There is no source of external funding

Authors' contributions

Ibeneme Uche carried out the mechanical and the FTIR analysis and contributed to the writing of the manuscript and interpretations of the results. Paul Mamza, Gimber Casmir and Yaro Aliyu contributed in the editing of the manuscript.