2025 Volume: 01 Issue: 03 www.ijrpa.com Research Article

International Journal Research Publication Analysis

Page: 01-12

HARDNESS AND IMPACT STRENGTH CHARACTERIZATION OF COCONUT FIBRE REINFORCED HIGH DENSITY POLYETHYLENE (HDPE) COMPOSITE

[1]Israel Chiwendu Okafor, [2]*Tanko Fwadwabea and [3]Felix Enemona Agada

[1]MSc Student, Sustainable Chemical Engineering, Newcastle University, United Kingdom.

[2]Sustainable Development Centre, University of Abuja. Industrial Inspectorate Department, Federal Ministry of Industry, Trade and Investment, Abuja.

[3]Business Development Expert, Zileck Consult Limited, Abuja.

Article Received: 23 June 2025

Article Revised: 13 July 2025

Published on: 03 August 2025

***Corresponding Author: Israel Chiwendu Okafor**

MSc Student, Sustainable Chemical Engineering, Newcastle University, United Kingdom. Email Id: easybozz@outlook.com

DOI link: https://doi-doi.org/101555/ijrpa.9148

ABSTRACT

The search for materials with superior properties has been ongoing and this study focuses on improving the mechanical properties of high density polyethylene (HDPE) with coconut fibre leading to a novel composite material. In this study, coconut fibre of 1mm particle size was compounded with high density polyethylene (HDPE) on the two-roll mill. The HDPE-coconut fibre composition was varied and the resulting composites were characterized on the basis of durometer hardness and impact strength. As fiber content increases from 0, 10, 20, 30, 40 to 50g, the durometer hardness ranged from 82, 90, 92, 89, 92 to 98 shores; while the vertical impact strength ranged from 0.887J, 1.321J, 0.511J, 0.445J, 0.387J to 0.324J; on the other hand, that of horizontal impact strength ranged from 2.333J, 0.687J, 0.722J, 0.513J, 0.569J to 0.213J. Thus, increase in fiber content increased the durometer hardness of the composites to a maximum of 98 at the 50g fiber content; the vertical impact strength decreased generally as fiber content increases; the horizontal impact strength also decreased as the fiber content increases and a maximum horizontal impact strength of 2.333J was obtained at the 0g fiber content (control sample). The application of the resulting composite is limited to areas requiring low mechanical strength materials.

KEYWORDS: High Density Polyethylene (HDPE), Coconut fibre, Polymer-biofibre composites, Material Reinforcement, Durometer hardness, Impact strength, Mechanical properties, Material characterization, Low-cost fillers, Sustainable materials engineering.

1.0 INTRODUCTION

Material technology gives room for materials with mutual synthesis of properties that cannot be met by the usual class of materials such as metals, ceramics, wood, and polymer etc. As a result, technologist, engineers and scientist are bound to explore unconventional materials to meet the multifaceted services necessities for today's applications. Among the preferred material properties essentials are Low Density, Strong Abrasion, Impact Resistant and corrosion resistant. This material property combination is yet to be broadened by the improvement of composite materials (Brydson, 1985).

A polymer is a substance made of molecules having the features of several repetition of one or more species of atoms or group of atoms connected to each other in amounts enough to provide a set of property that do not differ significantly with the addition or elimination of one or a few of the constitutional unit. A composite on the other hand is a microscopic put together of two or more separate materials having a distinct interface between them, but more importantly, the definition is valid to only materials containing a fibrous or particulate reinforcement substantiated by a binder or matrix material (Hollaway, 1994).

A polymer composite refers to a composite artificially produced from polymer alongside other materials such as fibre (i.e., reinforced composites). These are materials in which a fibre (bio fibres or non-bio fibres) material is implanted into them, yielding an enhanced physico-mechanical property. The components must be chemically and physically disparate and distinguished by a separate interface. The composite is made up of a matrix, which is continuous and envelops the fillers, to give it the required reinforcement such that the resulting composite properties are a function of the properties of both matrix and filler (Katchy, 2000).

In the field of material science and engineering, the quest of developing amazing and awesome composite materials that can stand the test of time has been at the forefront of issues. However, the ever-increasing concern over the replacement of conventional materials such as metal, wood, ceramics and polymers in design and construction is also an arising issue.

Thus, developing a composite material (comprising of high density polyethylene waste and coconut fibre as reinforcement) with an acceptable hardness and impact strength having the properties of both high density polyethylene and coconut fibre combined.

The aim of this research is to investigate and characterize the effect of coconut fibre on the hardness and impact strength of high density polyethylene (HDPE) waste. This will be achieved through the following objectives:

- To utilize coconut fibre as reinforcement on high density polyethylene (HDPE) waste.
- To study the effects of coconut fibre on the properties of the composite.
- To evaluate physico-mechanical properties such as hardness and impact strength.

The justifications for the aim and objectives of this research work include

1. The use of coconut fibres as reinforcement in the composites will help in solving the problem of brittleness, rigidity, and improve the ductility of the material.
2. The coconut fibres are readily available but are rarely utilized as reinforcement in composites and as such using coconut fibres in the production of composites will help generate jobs for the unemployed.

2.0 MATERIALS AND METHOD

2.1 Materials

- High density polyethylene (HDPE)
- Coconut fibre
- Processing oil
- Moulds
- Sieve (1mm mesh)
- Stop watch
- Hack saw
- Scraper

2.2 Equipments

S/No	Equipment	Manufacturer	Model number	Source
1	Two roll mill	Reliable rubber and plastic machinery company	5185	Polymer workshop NILEST
2	Compression machine	Carver Inc., Wabash, U.S.A	3851	Polymer work shop NILEST
3	Hardness tester	Muver durometer	5019	Physical Testing Lab NILEST

4	Weighing balance	A and D instrument	ANDHR-200-BC	Polymer Lab NILEST
5	Impact tester	CEAST Resil Family	6957	Polymer Lab NILEST
6	Milling machine	Arthur H. Thomas company	Model 4	Physical testing lab, NILEST

Figure 2.1: Two Roll Mill Machine.

Figure 2.2: Weighing Balance.

Figure 2.3: Impact Tester

Figure 2.4: Milling Machine.

Figure 2.5: Hardness Tester.

Figure 2.6: Scrapper.

Figure 2.7: Stopwatch.

Figure 2.8: Sieve (1mm mesh).

Figure 2.9: Hack Saw.

Figure 2.10: 8-Station Compression Machine.

2.3 METHOD

The step-by-step procedures describing the details of processing of the composite and the experimental procedures followed for their characterization and evaluation is described in this chapter. The raw material used in this work are;

- Coconut fibre
- High density polyethylene (HDPE) resin

The procedures include

2.3.1 Milling Operation

- The coconut fibre was gathered and dried to reduce moisture content
- It then underwent size reduction by crushing to ease the milling process
- A laboratory mill (model 4) was then used to mill the crushed fibre into fine powdery form with a mesh size of 1mm.

2.3.2 Weighing

- 100g, 90g, 80g, 70g, 60g and 50g of HDPE was measured using a weighing balance and the measurement kept separately.
- The procedure above was repeated for coconut fibre flour (now in powdery form) for 10g, 20g, 30g, 40g and 50g.

2.3.3 Compounding

- The two-roll mill machine was put on and allowed to heat up to a temperature of 150^{o}C for both the rear and front roll and was used to compound the control sample (i.e. 100g of HDPE)
- The first sample of the HDPE-Coconut fibre composite with a composition of 90-10 (i.e. 90g of HDPE and 10g Coconut fibre) was then compounded on the two-roll mill.
- The procedure above was repeated for composites of four different compositions of HDPE- Coconut fibre composites i.e. 80-20, 70-20, 60-40 and 50-50

2.3.4 Heat Pressing

- The temperature of the heavy-duty compression machine was set to 150^{o}C with a pressure of 2.5Mpa
- Processing oil was applied on a mould of thickness 3mm and the sample to be pressed was placed in the mould and covered and put into the machine.
- The samples were preheated for 5 minutes, pressed for 10minutes and cooled using the heavy-duty compression machine.
- Hacksaw was used to cut the specimen into desired shapes and sizes required to carry out the various test.

2.3.5 Hardness Test

- A Durometer (shore A type) with model number 5019, serial number 01554 and ASTM D2240 was used to carry out the hardness test.
- For each specimen, the reading was taken for the top, middle and bottom.
- The results obtained was read and recorded as shown in Table 3.1

2.3.6 Impact Test

- This was carried out using a resil impactor type 6957 with serial number 16650.
- For each specimen clamped to the resil impactor, a vertical and horizontal reading was taken.
- The results obtained for vertical and horizontal impact were read and recorded in Table 3.1.

The results obtained from the tests carried out and their implications are presented and discussed to the next chapter. Plots of impact against fiber loading and hardness against fiber loading are made in next chapter.

3.0 RESULTS AND DISCUSSION

3.1 Results

Table 3.1: Hardness and Impact test of hdpe-coconut fibre composite.

S/N	HDPE-Coconut Composition (g)	Hardness (Shores)				Impart Strength	Impart Strength
		TOP	MIDDLE	BOTTOM	Average	Vertical	Horizontal
1.	100-0	78	86	81	82	0.887	2.333
2.	90-10	87	98	86	90	1.321	0.687
3.	80-20	94	92	91	92	0.511	0.722
4.	70-30	88	90	88	89	0.445	0.513
5.	60-40	95	91	91	92	0.387	0.569
6.	50-50	98	99	97	98	0.324	0.213

Table 3.2: Effect Of Coconut Fibre Content On The Properties Of Hdpe-Coconut Fibre Composite.

S/N	Fibre Content (g)	Impact Strength (horizontal, J)	Impact Strength (vertical, J)	Hardness (Shores)
1	0	2.333	0.887	82
2	10	0.687	1.321	90
3	20	0.722	0.511	92
4	30	0.513	0.445	89
5	40	0.569	0.387	92
6	50	0.213	0.324	98

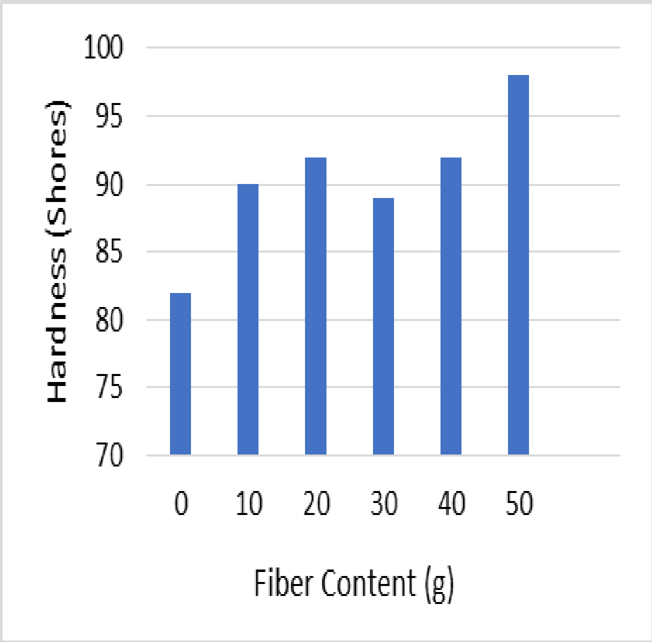

Figure 1: Plot showing hardness against fibre content.

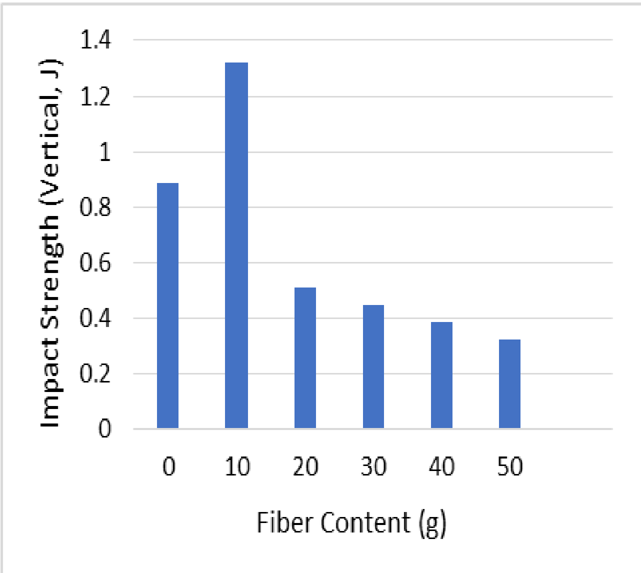

Figure 2: Plot showing Impact strength (vertical) against fiber content.

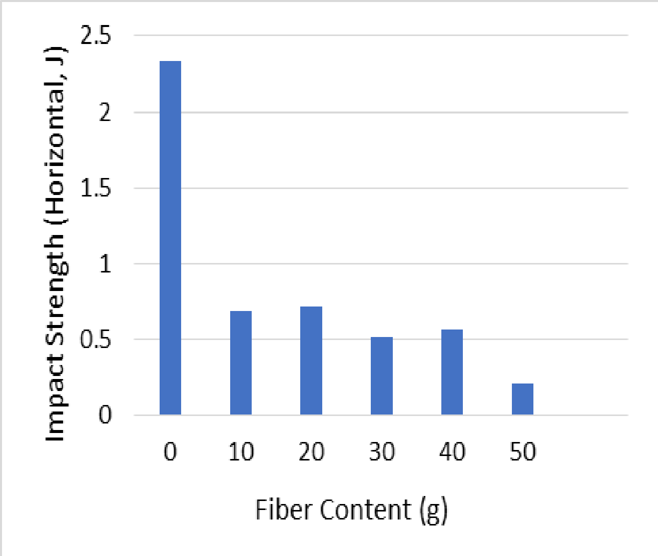

Figure 3: Plot showing Impact strength (Horizontal) against fiber content.

3.2 DISCUSSION OF RESULT

The focus on the mechanical properties is due to its great significant for all bio-filled polymer composites application. The results obtained from the two works (impact, and hardness tests) carried out on the various samples with different HDPE-Coconut fibre composition are given in Table 3.1. it can be seen that as the coconut fibre composition increased from 0, 10, 20, 30, 40, to 50g, the durometer hardness also increased from 82 to 90 to 92, then a decrease to 89 is observed for the 30g fibre content composite followed by an increase to 92 for the 40g fibre content composite and a further increase to 98 for the 50g fibre content composite. The durometer hardness of the control sample (HDPE) is 82, in comparing this with the standard value of 68, an increment is observed. This increment can be as a result of impurities embedded in the HDPE and the various heat treatment it underwent in the course of compounding and heat pressing into moulds. As a matter of fact, blends of polymer exhibit inferior mechanical properties because the hydrophilic character of the biofibre leads to poor adhesion with the hydrophobic polymer. Due to this statement it is expected that the hardness decrease as the fibre content increases due to the poor compatibility between the two phases (i.e. HDPE and coconut fibre). Thus, the results obtained deviate from standard values. This relationship between hardness and fibre content is depicted in Figure 1. It is seen from Figure 1 that despite the irregularity observed the hardness at each fibre content did not go below that of the control sample (i.e. at 0g fibre content).

Also, from Table 3.1, it can be observed that for the vertical impact, 0.887J was gotten at 0g fibre content (control sample) followed by an increase to 1.321J at the 10g fibre content and then a sharp decrease to 0.511J, 0.445J, 0.387J and 0.324J at 20, 30, 40 and 50g fibre content respectively. This result implies that the coconut fibre increases the impact strength of HDPE only at the 10% composition, above that, it reduces the impact strength. This is as result of poor compatibility between the hydrophilic (coconut fibre) and hydrophobic (HDPE) phases. This relationship is shown in Figure 2 where a sharp increase is seen at 10g fibre loading followed by a continuous decrease.

For the horizontal impact strength, the control sample showed high impact strength of 2.333J Subsequently, as the fibre loading increased from 10, to 20, to 30, to 40, and to 50g the impact decreased and increased irregularly from 0.687 to 0.722 to 0.513 to 0.569 and to 0.213J. This irregular relationship is seen in Figure 3.

In general, the irregularities seen in these results can be attributed to poor surface adhesion to hydrophobic polymers, non-uniform filler sizes. It is thus clear that the mechanical incompatibility of the two phases is great and increase in fibre content brought about this behaviour.

4.0 CONCLUSIONS AND RECOMMENDATION

4.1 CONCLUSION

This report aimed at characterizing various compositions of HDPE-Coconut fibre composites on the basis of hardness and impact strength shows from the result obtained from that the said composites is of low mechanical strength and thus can't be used for applications requiring high mechanical strength. Despite these limitations, it was observed that it is plausible to use this waste (coconut shell) as low-cost filler, but its application is limited to the properties obtained from this report/study. Though these properties can be improved upon by addition of acid based additive and coupling agents to help improve its poor surface adhesion to hydrophobic polymer. Despite the irregularities observed, it can be concluded that the mechanical properties of HDPE decrease with fiber content.

4.2 RECOMMENDATION

Addition of coupling agent and additives to improve the compatibility between the two phases (hydrophilic and hydrophobic) i.e HDPE-Coconut shell to improve its mechanical properties is recommended. Also, reduction of the mesh size of the sieve in the laboratory milling machine (i.e, a mesh size below 1mm) is recommended.

REFERENCES

1. Okele, A. I., Mamza, P. A. P., Nkeonye, P., & Marut, A. J. (2016). Mechanical properties of cashew nutshell powder (CNSP) filled natural rubber vulcanizate. *Indian Journal of Chemical Technology*, *11*(2).
2. ASTM. (1983). ASTM 1510: American Society for Testing and Materials. *Science Journal of Chemistry*, *1*(5), 50–55.
3. ASTM. (2014). *Standard Test Methods for Rubber Property (ASTM D395-14). Book of Standard Volume*.
4. da Costa, H. M., Nunes, R. C. R., Visconte, L. L. Y., & Furtado, C. R. G. F. (2001). Physical properties and swelling of natural rubber compounds containing rice husk ash. *KGK Kautschuk Gummi Kunststoffe*, *54*(5).
5. Egwaikhide, A. P., Okieimen, F. E., & Lawal, U. (2013). Rheological and mechanical properties of natural rubber compounds filled with carbonized palm kernel husk and carbon black (N330). *Science Journal of Chemistry*, *1*(5), 50–55.
6. Egwaikhide, P. A., Akporhonor, E. E., & Okieimen, F. E. (2007). Effect of coconut fibre filler on the cure characteristics, physico–mechanical and swelling properties of natural rubber vulcanisates. *International Journal of Physical Sciences*, *2*(2), 39–46.
7. Aguele, F. O., & Madufor, C. I. (2012). Effects of carbonised coir on physical properties of natural rubber composites. *American Journal of Polymer Science*, *2*(3), 28–34.
8. Ofem, M. I., Umar, M., & Ovat, F. A. (2012). Mechanical properties of rice husk filled cashew nutshell liquid resin composites. *Journal of Materials Science Research*, *1*(4).
9. Chukwu, M. N., Madufor, I. C., Ayo, M. D., & Ekebafe, L. O. (2011). Effect of stearic acid level on the physical properties of natural rubber vulcanisate. *The Pacific Journal of Science and Technology*, *12*(1), May.
10. Okieimen, F. E., & Imanah, J. E. (2003). The characterization of agricultural waste products as fillers in NR formulation. *Nigerian Journal of Polymer Science and Technology*, *3*(1), 210–216.
11. Rahman, M. S., Kasapis, S., Al-Kharusi, N. S. Z., Al-Marhubi, I. M., & Khan, A. J. (2007). Composition characterization and thermal transition of date pits powders. *Journal of Food Engineering*, *80*, 1–10.
12. Ashby, M. F., & Jones, D. R. H. (1998). *Engineering materials: An introduction to microstructures, processing and design* (2nd ed.). Butterworth-Heinemann.
13. Brydson, J. A. (1985). *Plastic materials* (4th ed.). Butterworth.
14. Drivers, W. E. (1979). *Plastic chemist and technology*. Van Nostrand.

15. Ese, J. A. (2000). *An introduction to rubber technology* (1st ed.). Josen Books.
16. Katchy, E. M. (2000). *Introduction to polymer technology* (1st ed.). El Demark.
17. Hollaway, L. (1994). *Handbook of polymer composites for engineers*. Woodhead Publishing.
18. Lubin, G. (1982). *Handbook of composites*. Van Nostrand Reinhold.
19. Ski, K. B. (1970). *Engineering materials: Properties and selection*. Reston Publishing.
20. Waterman, P. J. (2007). The life of composite materials. *Desktop Engineering Magazine*.
21. ASTM. (1983). ASTM 1415: Method for testing hardness of rubber.