NILEST JOURNAL OF SCIENCE, TECHNOLOGY, AND MANAGEMENT
(NIJOSTAM) VOLUME 2, ISSUE 1, MARCH, 2024, pp. 205-213
eISSN: 3027-2580 www.nijostam.org

STUDY ON THE TRIBOLOGICAL, HARDNESS, AND MORPHOLOGICAL PROPERTIES OF RECYCLED LOW-DENSITY POLYETHYLENE FILLED WITH SISAL FIBRE PARTICLES

Aiyejagbara M.O., Onyemachi D.I., Ibeneme U., Uteno J.E. and Simon C.E.
Nigerian Institute of Leather and Science Technology (NILEST), Zaria, Nigeria
Correspondence: aiyemosun2@gmail.com

ABSTRACT

This study investigates the tribological, hardness and morphological properties of recycled lowdensity polyethylene filled with sisal fibre particles polymer composite. The sisal fibre was treated with 6% (w/v) NaOH solution and milled into particles size of 250µm. The composite was produced using a two-roll mill for mixing and hydraulic press for curing. Six samples A, B, C, D, E and F were prepared with composition of recycled low-density polyethylene and sisal fibre in the ratio 100:0g, 90:10g, 80:20g, 70:30g, 60:40g and 50:50g respectively. A tribometer was used to conduct the wear and friction test. The wear rate result revealed that there was a decrease in wear rate at minimum of 0.001 mm³ of sample C and thereafter an increase to a maximum of 0.022 mm³ of sample F. The result for friction shows that there was an increase of 0.311 of sample D and a decrease was observed at minimum value of 0.098 of sample F. Result for hardness showed a significant increase in hardness properties with increase in filler loading. The morphological property in form of the SEM micrograph shows better adhesion and surface toughness for sample F of 50g filler loading compared to sample A with no filler.

KEYWORDS

Recycled low density polyethylene, sisal fiber, tribological properties, morphological properties

ARTICLE HISTORY:

Received: September, 2023
Received: in revised: October, 2023
Accepted: December, 2023
Published online: March, 2024

INTRODUCTION

The increasing use of polymeric materials can be observed in our daily life in uncounted consumer goods around us. However, the production and use of plastics has a range of environmental impact. Plastics require significant quantities of resources, primarily fossil fuels, both as raw materials and to deliver energy for the manufacturing process. The disposal of plastic products also contributes significantly to their environmental impact. This is because most plastics are non-degradable; they take a longer time to breakdown, possibly up to hundreds of years. With more and more product, particularly plastic packaging, being disposed of, soon after their purchase the landfill space require by plastic waste is a growing concern. Thereby the interest on recycled materials developed from post-consumers polymers has gained an increasing attention. The largest fraction of polymers waste consists of polyolefin, such as polyethylene (PE) and polypropylene (PP) therefore recycling is an alternative destination of these materials. (Jayaraman 2003; Rahimi & Garcia 2017).

Sisal fiber (Agave sisalana) is a coarse and strong fiber which is extracted from leaves of plant belonging to the Agave family. It is used in making various items such as mating, rough hand bags, ropes etc. The commercial use of sisal fiber in composite has increased due to its strength, low density, environmental friendliness and cost effectiveness. Sisal fiber can be combined with materials such as polymers to produce a composite. Polyethylene is a thermoplastic made from the monomer ethylene. The first grade of polyethylene was produced in 1993 by imperial chemical industry using high pressure processes via free radical polymerization. Manufacturers still employs the same method till date, 57% of polyethylene is recycled despite competition from modern polymers.

Composite is a multi-phase material formed from combination of two or more materials in which one of the materials is reinforcing phase (fibers or particles) and the other matrix phase (metal, polymer, or ceramics). Composite materials are usually classified by type of reinforcement such as polymer composite, cement and metal matrix composite. The different materials which are bonded together retain their individual properties but the composite has a superior property over those material. (Nishino *et al.,* 2003).

This study focuses on investigating the tribological and morphological properties of recycled lowdensity polyethylene filled with alkaline treated sisal fibre. The result of this investigation will determine the area of application of the composite produced.

MATERIALS AND METHODS

Materials

The main materials used in this research include Sisal fiber obtained from National Research Institute for Chemical Technology (NARICT) Zaria Kaduna State, recycled low density polyethylene (RLDPE) in form of used packaged water sachet, sodium hydroxide from Ideal chemical, India and distilled water.

Methods Raw Material Preparation

The fibres were prepared by treating them with (6 %w/v) NaOH solution, washed thoroughly with distilled water and 1% acetic acid and then dried in the oven at $50^{O}C$ (Venkatachala *et al.,* 2015). The dried treated sisal fibre was then milled with a laboratory milling machine (Thomas Williams lab mill (Model 4) and sieved with a mesh sieve size of 250 micrometer. The used packaged water sachet was washed, dried and shredded using a shredding machine at the polymer recycling workshop Nigeria institute of leather and science technology (NILEST) Zaria Kaduna state.

Formulation and Compounding of Composite

The composite was produced by mixing the main materials on a two-roll mill (Reliable Rubber Machinery Company) at a compounding temperature of 150ºC and pressed using the hydraulic hot press (Wenzhou Zhiguano Machine Co. Ltd) at 130ºC with the formulation given in Table 1.

Table 1. Formulation of the RLDPE – Sisal Fibre Composite

Samples	A	B	C	D	E	F
RLDPE (g)	100	90	80	70	60	50
Sisal Fibre (g)	0	10	20	30	40	50

Tribological Test

The friction and wear tests were conducted on a pin-on-desk type tribometer (DRTB, 70090). The friction and wear test were performed at room temperature, applied load was 8 N, the rotational speed of disc 10 cm/s and the radius was set to be 5mm. To ensure the compatibility of testing results for different specimens, the parameters of the friction tests are set to be the same and it was monitored on a digital screen. Friction coefficient (μ) was calculated by dividing the friction force by the normal force using equation 1. Wear was determined by measuring the change in composites volume before and after adhesion between the composites to determine the weight loss at normal load. Specific wear rate (W) is the rate of material removed from specimen surface as described by Tingting *et al*. (2018) and is expressed in equation 2.

$$\mu = \frac{Ff}{Fn} \quad \text{---} \quad (1)$$

Where μ is friction coefficient, Ff is frictional force and Fn is normal force (applied load).

$$W = \frac{KD\,(M_1 - M_2)}{M_2} \times 100 \quad \text{---} \quad (2)$$

Where W = Wear rate %, K = constant (4.17 x $10^4 mm^{-1}$), D = Diameter of the sample (15mm) M_1 = Weight before test (g) and M_2 = Weight after test (g).

Hardness Test

The hardness test was carried out on the Samples according to ASTM D2240 using a hardness tester (Muverdurometer 5019) and was represented using the dimensionless Shore A hardness scale. The hardness test was repeated three (3) times and the average hardness value was determined.

Scanning Electron Microscopy

Scanning electron microscopy examination was conducted to reveal the morphological features of the polymer specimens utilizing an ultra-high vacuum and high-resolution. For SEM testing, the surface of the composite samples was sputter with gold before their morphological observation. Since the composites are non-conductive, the specimens were sputter coated with an ultra-thin (5 mm) coating of gold, using a JFC-1100E ion sputtering device (JEOL, Tokyo, Japan).

RESULTS AND DISCUSSION Friction Test

Fig 1 shows the coefficient of friction result of the produced composites. From the result, it was noticed that the value of friction coefficient increased steadily as filler loading increases after which there was a decrease. The possible explanation for the observed values is that at the initial stage of rubbing, friction is low and the factors responsible for this low friction are the presence of a layer of foreign material, for instance moisture, oxides etc. on the disc surface (Chowdhurry 2013). The friction force in most cases increases with duration of rubbing and may reach a certain steady state value which allows the values of friction coefficient to remain constant for the rest of the testing time. According to Jia *et al*. (2007), the constant rubbing between two materials causes an increase in heat due to the roughness of the surface when they come in contact.

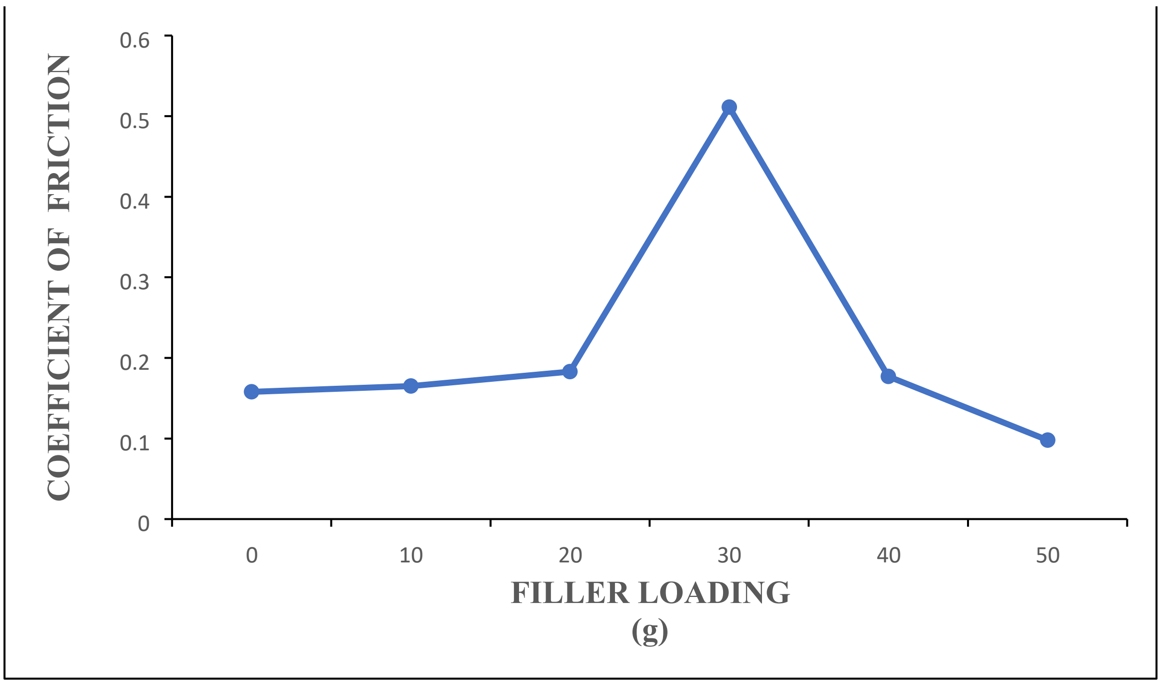
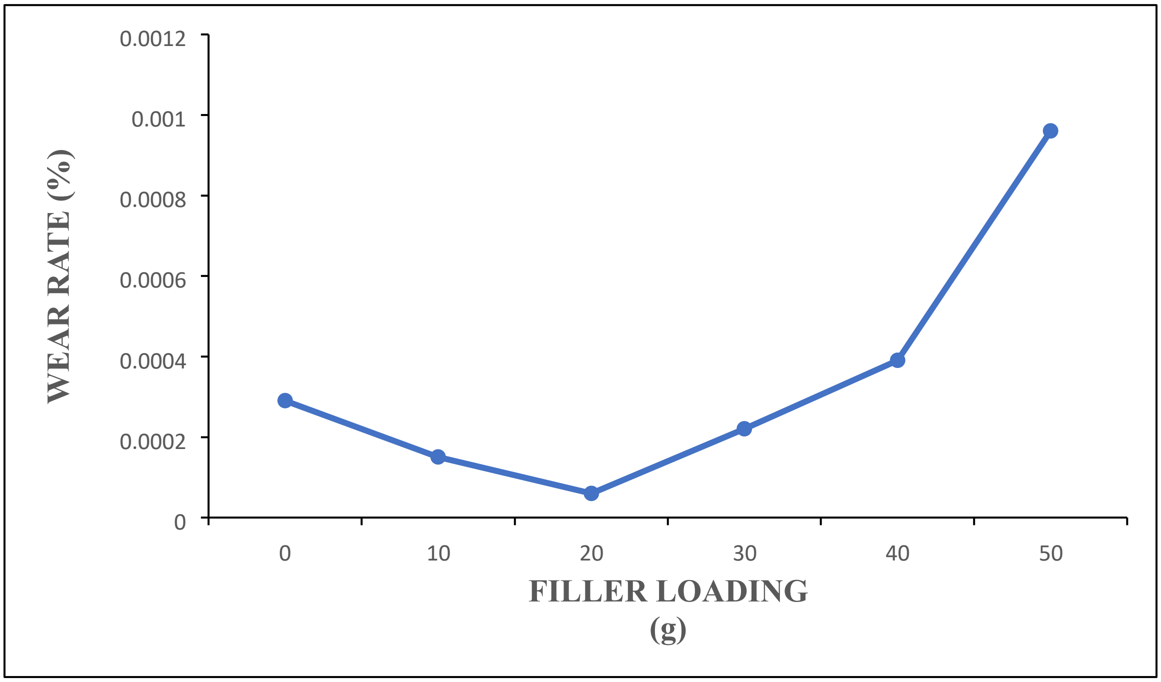


Figure 1: **Effect of filler loading on Coefficient of Friction of Composite**

Wear Test

The result of wear test is presented in Figure 2. The result shows a decrease in wear rate as filler loading increases from 0 to 20g respectively. However, there was an increase in wear rate with as the filler loading increases from 30 to 50g respectively. The possible reason for this increase in wear for the control sample may be due to molecular motion (Jia *et al*., 2007) of the sliding surface under dry lubrication because the control sample absorbed no liquid which may have served as lubricant. Lubricants are primarily used to separate two sliding surfaces to minimize friction and wear.



1.1

Figure 2: **Effect of filler loading on wear rate of composite Hardness Test**

Figure 3 shows the Hardness result for the produced composite, the sample B with 10% filler loading has the highest significance to hardness this could be that the sisal fiber in the polymer matrix stiffens the polymer matrix making it more resistance to indentation. It can also be observed that there is a general fluctuation in hardness property as filler loading increases, which could be attributed to improper mixing. This trend was also reported by Malcenji *et al*. (2010). It is generally known that filler increases the hardness property of a material

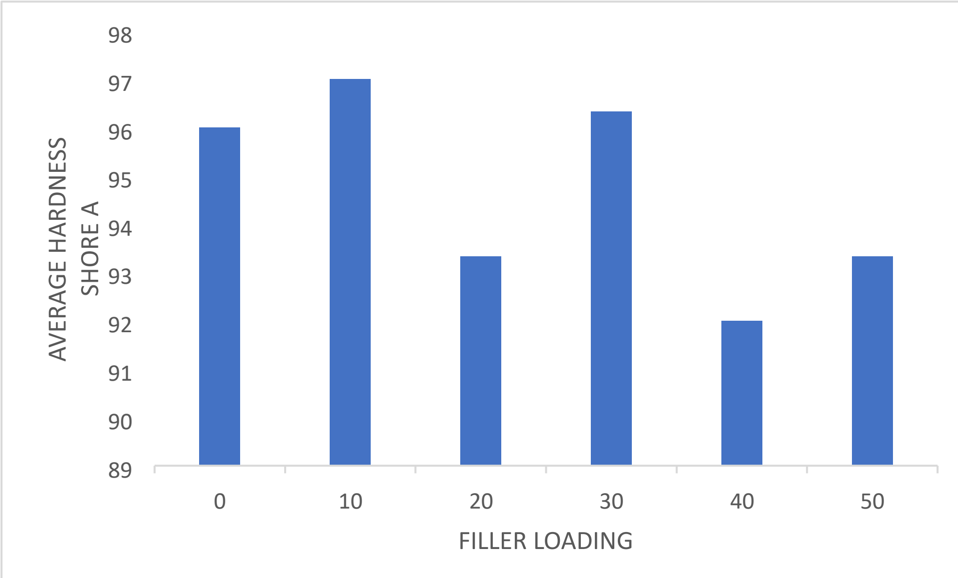
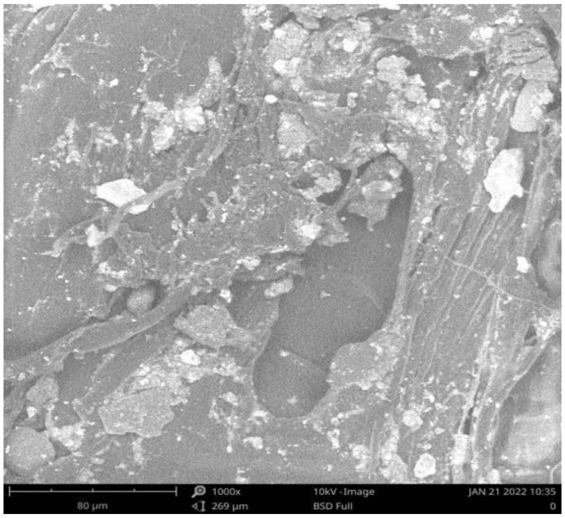


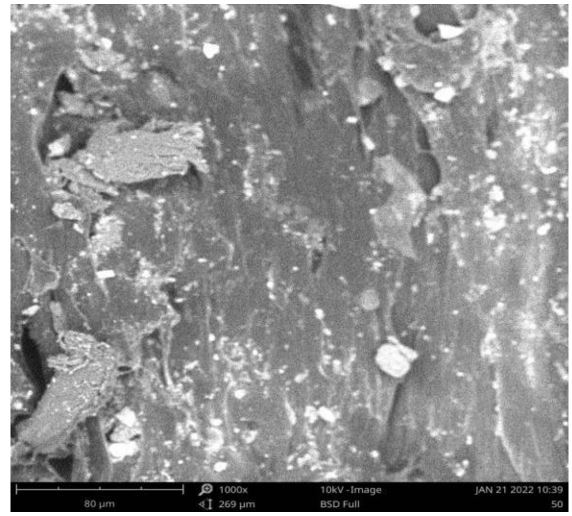
Figure 3: Effect of Filler Loading on Hardness of Composite

Morphological Test

Plate 1 shows the SEM result for the composite samples at 1000x magnification, Sample A with 0% filler loading at 1000x magnification was observed to have more prominent areas of surface roughness and the presence of holes/gaps/voids which can be as a result of poor interfacial adhesion at the interface (Kim *et al,* 2010). At 1000x magnification of Sample F with 50 % filler loading, it shows higher fractured toughness, less voids and better adhesion of the sisal particles for its better properties' performance and reinforcement in the polymer matrix.



Sample A (0 %)



Sample F (50 %)

Plate 1: SEM micrographs for samples A and F at 1000x magnification

CONCLUSION

This study investigated the tribological, hardness and morphological properties of recycled lowdensity polyethylene filled with sisal fibre particles polymer composite. The findings of this study include:

i. The value of friction coefficient increased steadily as filler loading increases with highest value at 30% filler loading, after which there was a decrease.
ii. There was a decrease in wear rate as filler loading increases from 0 to 20g, after which there was an increase from 30 to 50g. Sample C with 20% filler loading as the least wear rate of 0.00006%.
iii. There is a general fluctuation in hardness property as filler loading increases, however sample B with 10% filler loading has the highest hardness value.
iv. Sample A with 0% filler loading was observed to have more prominent areas of surface roughness and the presence of voids compared with sample F with 50% filler loading which shows less voids and better adhesion of the sisal particles.

REFERENCES

Chowdhurry, M. A., Nuruzzaman, D., Roy, B. K., Islam, A., Hossain, Z., Hassan, M. R. (2013). Experimental investigation of friction coefficient and wear rate of stainless steel 202 sliding against smooth and rough stainless steel 304 counter-face. *Friction Wear Research, 1*(3), 34-41.

Guitierez, J. (2015). What is sisal. www.naturalarea-rugs.com.

Jayaraman K. (2003). Manufacturing sisal–polypropylene composites with minimum fibre degradation. *Composites Science Technology 63*, 367–374.

Jia, B. B., Li, T. S., Liu X. J., Cong, P. H. (2007). Tribological behaviors of several polymerpolymers sliding combination under dry friction and oil lubricated conditions. *Wear 262*(1112):135-139.

Kim, W., Yun, I., Lee, J., & Jung, H. (2010). Evaluation of mechanical interlock on adhesion strength of polymer metal interfaces using micro patterned surface topography. *International Journal of Adhesion and Adhesives, 30*(6), 408-417.

Malcenji, k., Goodship, V., Christmass, P., Smith, G. F., & Pearce, B. (2010). *A mixed plastic waste and de-inked residue composites from recycled paper waste products. Progress in Rubber Plastics and Recycling Technology, 26*(2), 93-106.

Nishino, T. K., Kotera, M., Nakamae, K., & Inagaki, H. (2003). Research on kenaf reinforced biodegradable composites. *Science and Technology, 63*, 1281.

Rahimi, A., & Garcia, M. J. (2017). Chemical recycling of waste plastics for new materials production. *Nature Review Chemistry 1*, 0046.

Tingting, W., Jianxiu, S., Yongfeng, L., Hongyuan, Z., Yaqi, Z., Mingming, Z., & Bolin, W. (2018). Wear Resistance Mechanism of Alumina Ceramics Containing Gd_2O_3.

Venkatachalam, N., Navavneethakrishnan, P., Rajsekar, R., & Shankar, S. (2015). Research on Alkaline chemical treatment on the surface of natural fibre. *International Journal of Innovative Science, Engineering and Science, 4*, 172-178.