Bima Journal of Science and Technology, Vol. 7 (2) June, 2023 ISSN: 2536-6041

DOI: 10.56892/bima.v7i2.446

MECHANICAL CHARACTERIZATION OF WASTE POLYETHYLENE SYNTHESIZED VIA Ni NANO COMPOSITE

[1]*RIFKATU, K.D., [2]BORYO, D.E. A.,[2]CHINDO, I.Y., and[2]SHIBDAWA, M.A.

[1]Deparment of Chemistry, Gombe State University (GSU), Nigeria

[2]Deparment of Chemistry, Abubakar Tafawa Balewa University (ATBU), Bauchi State of Nigeria

ABSTRACT

The mechanical properties of polymer are one of the important factors to be considered in determining the capability of using the material for electrical, construction and biomedical applications. In this study we assessed the effect of Nickel (Ni)nanoparticles on mechanical properties of waste polyethylene. Waste polyethylene/green synthesized Ni nanocomposite was prepared using solution method of polymerization. The nanoparticle of Ni was synthesis from garlic bark aqueous solutions. The mechanical properties were investigated using a shore 'A' durometer and Instron universal testing machine. The percentage elongation at break increases from 78.0 % to 86 %, the hardness of nanocomposite increases from 94.2 N/mm² to 94.40 N/mm², as well as increase in flexural strength from 13.62 Mpa to 14.35 Mpa. Themodulus of elasticity of the waste polyethelene/green Ni nanocomposite decreases drastically from 1.76 Mpa to 1.08 Mpa, and tensile strength of the nanocomposite decreases from1.13 Mpa to 0.6 Mpa. These mechanical properties are important to the field of nanotechnology to certify and facilitate the fabrication of high performing polymer for complex application in the field of electrical and biomedical nanotechnology.

Keyword: Green, Mechanical, Nanocomposite, Nanoparticles, Nickel, Polyethylene, Properties, Synthesis, Waste.

INTRODUCTION

Dealing with recycling of polymer waste and there mechanical properties is one of the important factors to be considered in determining the capability of material electrical, construction and biomedical applications. Waste polyethylene is one of the commonest wastes found in the municipal parts of the world due to lightweight, availability and easy to maintain when compared to metal and glass (Andrady and Neal, 2009). The studies of polymer composites are gaining much attention in the field of engineering because of their improved chemical and mechanical properties which gives birth to super materials such as carbon fiber reinforce plastic (CFRP) with superior properties use by aviation (Ramesh *et al*., 2017). Polyethylene is commercial polymer which is considered to have high performance and unique properties like biocompatibility, chemical inertness, excellent impact strength and highest abrasion resistance compares to other thermoplastics (Chang *et al*., 2013).

Waste polyethylene/green synthesized metal nanocomposite may be expected to possess advance mechanical properties such as high strength, high elasticity and toughness to be able to function as commercial polymers. Recently, polymer nanocomposites have drawn much attention in material sciences which are now used to create a new type of polymer composite that has interesting chemical and physical features due to present of reduce nano size materials such as metal, carbon tubes and gaphite (Kiaei *et al*., 2017).

The introduction of nanoparticles into a polymer enhances the mechanical, electrical and thermal properties compared to the neat polymer matrix depending upon the nanofillers used (Nisar *et al*., 2020). Studies showed that low contents of nanoscale fillers changes the thermal, electrical, and mechanical properties of polymers and their composites properties such as the crystallinity, strength, conductivity, and thermal stability (Alshammari *et al*., 2022). Therefore the most important advantages of nanoparticles over microparticles are the opportunity of multifunctional properties and the decrease of the quantity of filler required to give desirable properties (Alshammari *et al*., 2022).

Mechanical properties are associated with the ability of materials to resist mechanical forces and load and these are measured in terms of the behavior of the material when subjected to a force (Murugan, 2020). The effect of carbon-based magnetic fillers on the thermal, mechanical, morphological and magnetic properties of polyethylene nanocomposites was investigated; the result indicated that the mechanical property of the polymers was changed by the addition of filler ranging from 0 to 8.5 wt % (Nisar*et al*., 2018). The increase depended upon various factors such as the dispersion of the filler, filler matrix adhesion, and the aspect ratio of the filler (Nisar*et al*., 2018). The synthesis and Characterization of low density polyethylene (LDPE)/$NiFe_2O_4$ nanocomposites films for mechanical properties and fourier transform infrared (FTIR)for structural analysis was reported, it was revealed that The addition of Fe_2O_4 nanoparticles on the low density polyethylene showed very good mechanical properties by showing a higher tensile strength (Nayeemuddin*et al*., 2022).

The effect of nickel oxide (micro) addition on thermo-physical and mechanical properties of low density polyethylene (LDPE) has been studied. The report indicated that the mechanical properties of LDPE/NiO composites show an improvement with NiO addition and are explained in the light of various models and correlations (Tripathi and Dey, 2019). Additionally the evaluation of Polypropylene PP nanocomposites containing montmorillonite (OMMT) with or without iron nanoparticles modification was studied for food packaging applications and parameters such thermal, mechanical, morphological and gas barrier analyses were investigated. Polyethylene nanocomposite were prepared via melt interaction of clay in a twin screw extruder, the it was revealed that the addition of the clay nanoparticles showed no significant change in the ultimate tensile strength and elongation properties of nanocomposites (Khalaj *et al*., 2016).

Furthermore Polypropylene (PP) and graphene nanoplatelet (GNPs) composites were also produce using twin screw mixing and injection moulding. Two types of GNPs were blended with PP at loading rates of 1, 2, 3, 4, and 5 wt%. Mechanical properties such as tensile, flexural, impact strengths and Young's modulus (E) were determined. It was discovered that the mechanical strength improved with the loading of GNP for both grades mostly (Sutar *et al*., 2021). However limited studies were reported on the mechanical properties of waste polyethylene/green synthesized Ni nanocomposite. Current studies showed that recycling of waste through transformation into polymer composite by using green metal nanocomposites may not only open way for new composite raw materials but also improve the safety of our environment. These polymer composites may be useful in terms of electrical conductivity, thermal and biomedical applications. Hence, this research explored the mechanical properties of waste

DOI: 10.56892/bima.v7i2.446

polyethylene/green synthesized Ni nanocomposite such as hardness, flexural strength, ultimate tensile strength Young's modulus and elongation.

MATERIALS AND METHODS

Sample Collection and Preparation

Waste polyethylene (Sachet water leather) was collected from domestic waste bin, behind Labour Housing Estate Tunfure, Gombe State, Nigeria to ensure that one brand of the waste polyethylene was used (Atlantis sachet water leather). The waste polyethylene was prepared following the method of Streit *et al*. (2022) with slight modification. The waste polyethylene was washed using 20 mL of 0.1 M sulfonic acid then transfer into a 100 cm^3 beaker containing 50 mL of 0.1 M sodium lauryl sulfate, rinsed with distilled water and it was air dried in a laboratory. This was done to remove any impurities and contaminants. The waste polyethylene was shredded into small particles using knife and blade.

Dissolution of Polymer Waste

Achilias *et al.* (2007) method was adopted with a slight temperature modification as follows; the resized polyethylene waste was crushed and stored in a bottle container. 4 g of the crushed polyethylene and polypropylene waste was placed into a round bottom flask equipped with a vertical condenser and 20 mL of xylene solvent was added into the flask. The system was heated from 350 – 400 °C with constant stirring for 30 minutes.

Green Synthesis of Metal Nanoparticles Ni

Preparation of garlic bark extract

Garlic was purchased at Gombe main market. The skin was removed with hand and the garlic bark was washed with tap water several times followed by distilled water as reported by Modiand Fulekar (2020) with slight modification. The garlic bark was dried at 40 °C in the oven for 7 days and then the powder was prepared. 10 gram of garlic skin powder was soaked in a 250 cm^3 flask containing 100 cm^3 (80% water and 20% ethanol). The solution was heated at 60 °C for 20 min and stirred using magnetic stirrer for 24 hours. The extract was filtered using whatman membrane filter 0.45 µm at room temperature. 50 $cm^3$of filtrate was taken for the synthesis of nanoparticles while the rest of the filtrate was stored at 4 °C.

Green synthesis of metal nanoparticle using Garlic bark

Method described by Amutha and Sridhar (2018) with some modification was adopted. Green synthesized Ni nanoparticles was synthesized by taking 1g of Ni $(NO_3)_2 .6H_2O$ in 250 ml beaker and dissolved in 100 ml distilled water then heated to 80 °C with mild stirring using magnetic stirrer under atmospheric pressure. After 10 minutes, 20 ml of the aqueous solutions of garlic bark extract was added to the mixture. After 10 minutes, 20 ml 0.1 M aqueous solution of sodium hydroxide was added to the mixtures at the rate of 3 ml per minutes it was subjected to an ultrasonicator (Qsonica model Q700) at 30 impulse for 30 minutes and the nanoparticle was precipitated uniformly. The colour of the solution changes Ni to gray green. The mixture was allowed to cool down to room temperature and the metal nanoparticles were obtained by centrifuging (Heraeus Labofuge 300) at 1000 rpm for 20 minutes and then decanting. The nanoparticles formed were washed 3 times with distilled water and 3 times with ethanol and air dried at 70 °C in an oven overnight.

Solution Formulation of Waste Polyethylene/ green synthesized Ni Nanoparticles

DOI: 10.56892/bima.v7i2.446

Method described by Alsharaeh (2016) with slight modification was used. From the method described, 2.0 g Ni green synthesized metal nanoparticles, and 1 g benzoyl peroxide (BP) was added to 80 g of the waste polyethylene, the mixture was stirred for 1 hour in a sonicator. The temperature of the mixture was maintained at 60 ˚C for 20 hours to promote solution free radical bulk polymerization. After the polymerization was completed, the product was poured into 50 ml methanol and was stirred for 15 minutes and washed with methanol. Hot water was used to wash the product and was repeated seven times. It was then filtered and dried in an oven at 30 ˚C overnight. The procedure was repeated for 0.5, 1.0 and 1.5 g respectively.

Characterization of Green synthesized Nanoparticles

The prepared green synthesized Ni nanoparticle was characterized using UV-visible spectrophotometer (Jenway 640). The morphology and average particle size of the metal nanoparticle size was investigated using scanning electron microscope (SEM with EDX, Sirion) and X-ray diffraction pattern was recorded using an X-ray diffractometer operated at 0 kV and 0 mA (Rigaku-binary). The samples were scanned at 2θ angles using the Cu Ka radiation source (kɑ 1.54060A°) in the Goniometer Radius [mm] 240.0 and Distance Focus-Diverg. Slit [mm] 0f 91.00. The crystalline size of the sample was calculated from the full width at half maximum (FWHM) of the intense X-ray diffraction peaks using Scherrer’s equation (Pudukudy *et al*., 2015)

Mechanical properties of waste polyethylene/ green synthesized Ni nanocomposite

Method reported by Fahim *et al*. (2015) was adopted with some modifications. The samples of waste polyethylene/green synthesized Ni nanocomposite was added into a mold of 3 mLthickness at 100 × 100 mm size and preheated at 150 ˚C. The sample was allowed to cold for 10 minutes; the molded material gave the shape of the molding cavity. A pressure of 2.5 pa was applied on the mold using the heated plates of the hydraulic press. The compressed sample was allowed to cool for further analysis.

Hardness testof waste polyethylene nanocomposite

Hardness tests was performed at Nigerian Institute of Leather and Science Technology Samaru-Zaria using Shore ‘A’ Durometer (Din 53505, En Iso 868, D 2240, Iso 7619) by adhering to ASTM D2240 standard testing procedures. The waste polyethylene/metal nanocomposite was label by name and indentation location. Moving along the longitudinal axis, the first location was 0.50 inch (12.7 mm) toward the center, on the longitudinal center axis. Subsequent points followed at 0.50 inch (12.7 mm) intervals from the first point toward the opposite end. Each sample had five test locations on one side and the average hardness was calculated as reported by Wei and Denton (2018). The result was represented in form of graph.

$$\text{Average hardness} = \frac{Total hardness}{Number\ of\ sample} \quad (1)$$

Flexural strength test of waste polyethylene nanocomposite

Flexural tests was performed the using Instron Universal Testing Machine, model TM2101-T7 Department of Polymer and Textile Engineering , Ahmadu Bello University, Zaria, Kaduna state of Nigeria. It was tested in accordance with ASTM 638(2014). The instrong with a load cell of 5 KN as reported by Mirjalili *et al*. (2014) with a slight modification. The test process used was three-point loading system utilizing center loading. The crosshead speed and span length was set

DOI: 10.56892/bima.v7i2.446

to 5 mm/minute and 70 mm, respectively. The polymer/metal nanocomposite was cut into rectangular sizes with 2.5 mm thickness, 31.7 mm width and 40 mm length for each sample. Three replicates per each sample were tested from each sample and the average values were determined **(**Nwapa *et al*., 2020).

Flexural strength = $\frac{3PL}{2bd2}$

Where P = load

L = span
b = breadth (width) of the sample
d = depth (thickness) of the sample.

Tensile strength test of polyethylene nanocomposite

The tensile strength of the samples were determined by cutting them with a dumb bell cutter into dumbel shape using a tensile testing machine TM2101-T7 according to ASTM D 638(2014) standard as shown in Figure 1 B. The dumb bell shape sample was placed in the grips of movable and fixures in an Instron machine taking care to align the long axis of the sample, the grips were tightened evenly and firmly to prevent slippage of the sample during the test. The speed of the test was set at 50 mm/min. and the machine was started and the tensile strength values were read **(**Nwapa *et al*., 2020). The tensile strength was calculated based on the formula reported by Sabo *et al*. (2021).

$$T= F/A \qquad (1)$$

Where T is the tensile strength, F is the Failure load in (Newton) and A is the area in (mm^2)

$$A=\pi D^2/4 \qquad (2)$$

where A is the area in mm^2 and D is the diameter in mm. $\pi = \frac{22}{7}$

Young Modulus of polyethylene nanocomposite

This test was done with an Instron Testing Machine at the Department of Polymer and Textile Engineering, Ahmadu Bello University, Zaria, Kaduna State of Nigeria. It was tested in accordance with ASTM 638(2014). The samples were cut into dumb-bell shape using a tensile testing machine TM2101-T7 according to ASTM D 638(2014) standard and the modulus of elasticity (Young's modulus) was determined from the slope of the linear portion of the load (Nwapa *et al*., 2020).

Percentage elongation at break testof waste polyethylene nanocomposite

The testing of the sample was done Department of Polymer and Textile Engeneering, Ahmadu Bello University, Zaria, Kaduna state of Nigeria. It was tested in accordance with ASTM 638(2014). The samples were cut into dumbel shape using a tensile testing machine TM2101-T7 according to ASTM D 638(2014) standard as shown in Figure 1 B. Method of Mohammed. (2009) was used to calculate the percentage Elongation at break as describe by Boryo *et al*., 2010; Boryo *et al*., 2014).

$$\text{Elongation (\%)} = \frac{L-L0}{L0} \times 100 \qquad (3)$$

where: L = extensional at breaking point. Lo = original length

RESULTS AND DISCUSSION

Characterization of green synthesized Ni nanoparticles

UV-Visible analysis of green synthesized Ni nanoparticles

The UV-Visible absorbance spectrum of the green synthesized Ni nanoparticles was observed from 200 to 700nm, and the

DOI: 10.56892/bima.v7i2.446

maximum wavelength of absorption was observed at 300 nm (Fig. 1).

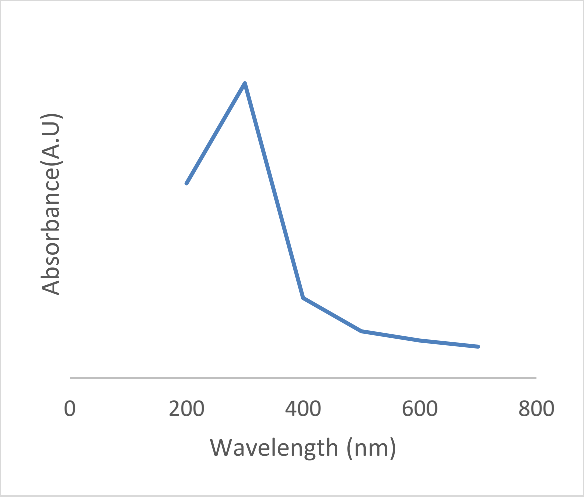

Figure 1: UV-visible analysis of green synthesized Ni nanoparticles

The maximum absorption peak at 300 nm was due to the size distribution condition which the particles were distance from each other with different sizes larger and smaller. Each nanoparticle absorbs at different wavelength due to different energy bandgap resulting in the absorption at 300nm. The surrounding of the nanoparticles also influence the absorption due to the dielectric interactions between the metallic particles and the environment called surface plasmon resonance. A similar observation was reported by Lobotka *et al*. (2013) where it was revealed that Ni nanoparticles obtained a maximum absorption at 300 nm due to localized surface plasmon resonance. The absorptions depend on the size, shapes and the environment of the nanoparticles as observed by the present study. Another reported by Huang *et al*. (2021) showed that Ni nanoparticles gave maximum absorption at 341 nm which was higher than the result obtained from this work due to the difference in the nature of the plant extract used. Further report by Hemalatha *et al*. (2014) indicates absorption of the Ni nanoparticle at 320nm which was close to findings of the present research. However, Hong *et al*. (2021) stated that absorption tends to increase towards the shorter wavelength region 290 nm due to the formation of NiO nanoparticle.

X- ray diffraction pattern of green synthesized Ni nanoparticles

Figure 2 shows the x-ray diffraction pattern of green synthesized Ni nanoparticle from the powder samples.

DOI: 10.56892/bima.v7i2.446

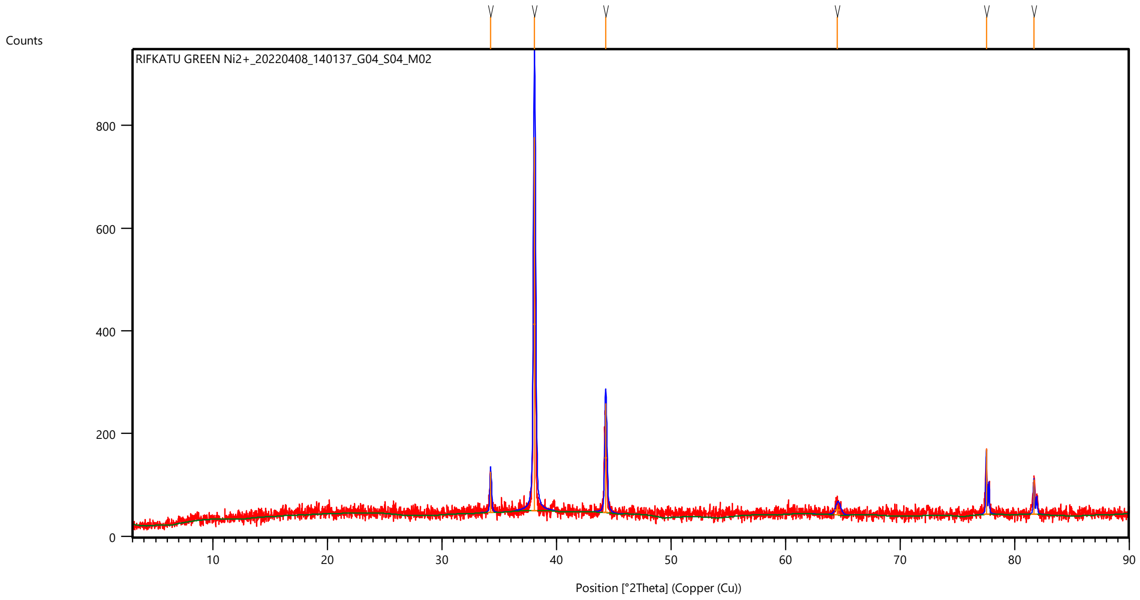

Figure 2: X-ray Diffractions (XRD) pattern of green synthesized Ni nanoparticle

The result showed a peaks at 2θ value of 34.23°, 38.04°, 44.27 °, 64.52°, 77.51 ° and 81.67°. The values indexed as plane of (101), (111), (200), (220), (311) and (222) and the average crystalline size was calculated as 35.73 nm. The plane was in accordance with JCPDS data: PDF number 78-0643. Zhang *et al*. (2021) reported biosynthesized NiO nanoparticles of similar plane with a crystalline size of 33.17 nm. Huang *et al*. (2021) revealed that synthesis of NiO nanoparticles under low temperature resulted in peaks with a similar indexed plane and a crystalline size from 10.1 to 33.6 nm. El-kemary *et al*. (2013) reported synthesis and spectral NiO interaction with glucose with a crystalline size of 37.5 nm. Another report revealed that Kumar *et al*. (2019) synthesized NiO nanoparticles using *Gymnema sylvestere* plant extract with the average crystallite from 23 nm to 32 nm close to the result obtained from this study. Taghizadeh (2016) reported a study of structural of NiO nanoparticles with a plane of 111, 200, and 222 and similar with plane obtained from the current research.

Scanning electron microscopy and electron dispersive x-ray analysis (SEM/EDX) of green synthesized Ni nanoparticles

Figure 3 A present the SEM image micrograph of the Ni nanoparticles, while B and C are the EDX profile and particle size distributions.

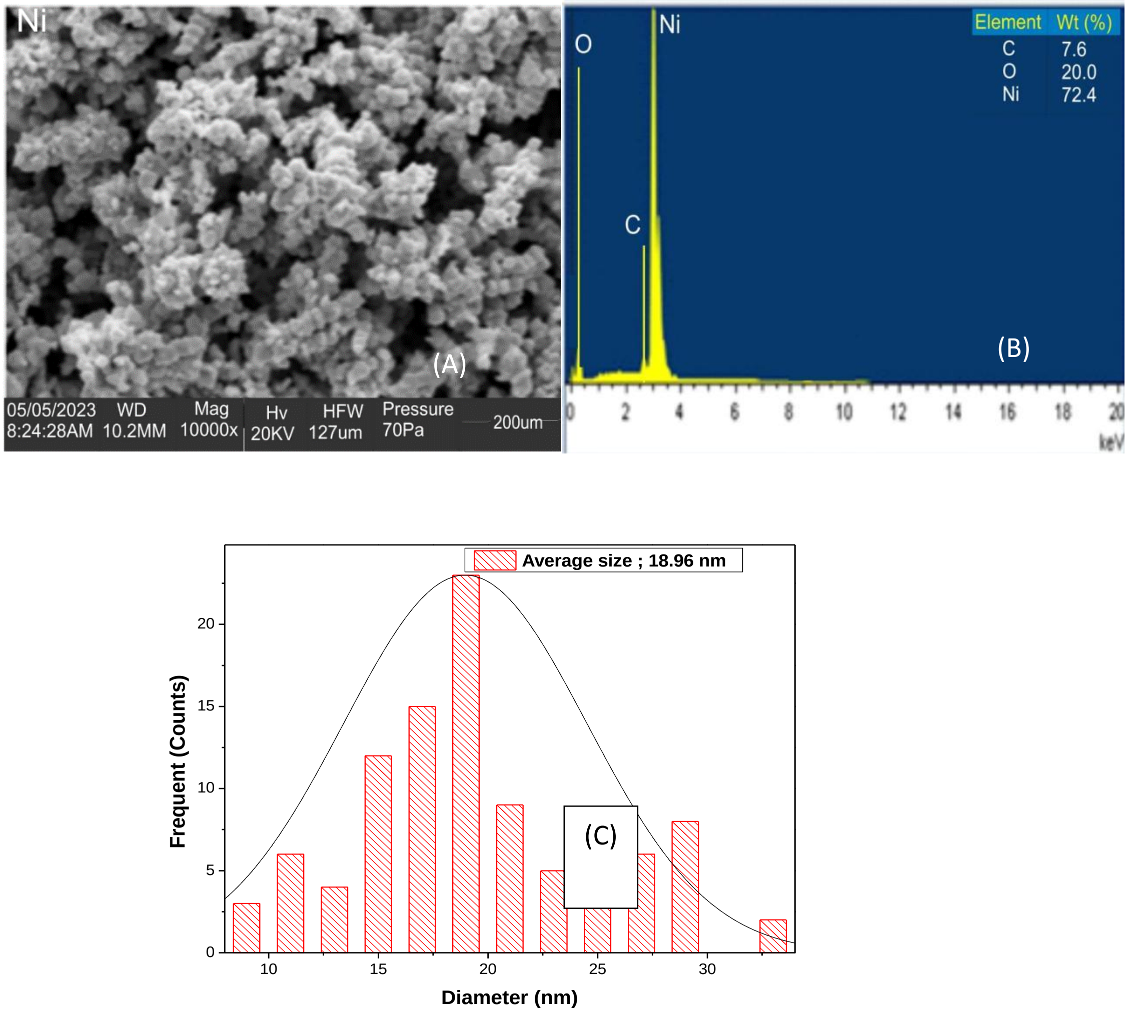

Figure 3: A, B and C: The SEM image, EDX analysis and size distribution of the green synthesized Ni nanoparticles.

The SEM image depict the Ni nanoparticles as having spherical shape with some partial agglomeration. The elemental compositions show that, the nanoparticles consist of Ni = 72.40%, O = 20.00% and C = 7.600% respectively. The size distribution reveal that the Ni nanoparticle was having an average size of 18.96 nm as determine by image J software. The images was similar with a report of Abdulhadi *et al.* (2021) which revealed that Ni nanoparticles were spherical in shape and homogenously distributed with the average particle size of 25nm close to the size obtained in this study. Another report by Rehman *et al.* (2023) indicated that the trend of the Ni nanoparticles are uniformly distributed with a spherical shape that is densely agglomerated similar to the present findings. Further findings of Hemalatha *et al.* (2014) reported that, typical morphology of

DOI: 10.56892/bima.v7i2.446

Ni nanoparticles showed a spherical shape with homogeneous size distribution similar to the result obtained in the present study.

Mechanical Properties of Polyethylene/ Green Synthesized Metal Nanocomposite

Effect of green synthesized Ni nanoparticles on the hardness on waste polyethylene

The hardness test of waste polyethylene (sachet water leather)/ green synthesized Ni nanoparticles is shown in Figure 4.

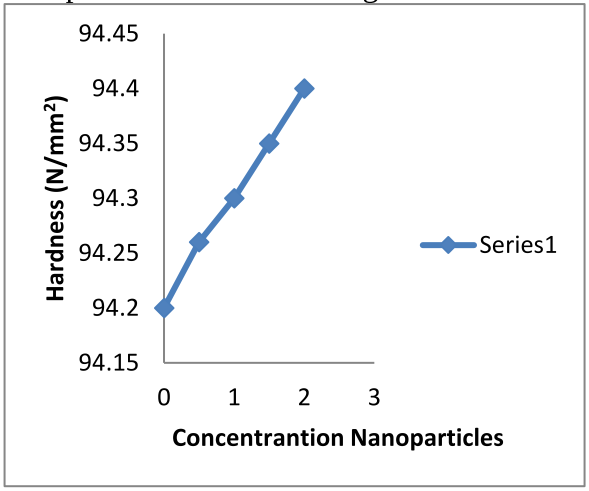

Figure 4: Effect of green synthesized Ni nanoparticles on the hardness on waste polyethylene

From the result, it can be observed that the control waste polyethylene 0.0 g recorded a hardness value of 94.2 N/mm². The incorporation of green synthesized Ninanoparticles into the waste polyethylene improved the hardness of the composites. The hardness increases with increase in the concentration of the green synthesized Ni nanoparticles from 0.5 to 2.0 g the value increases from 94.26 to 94.4 N/mm². This was because the hardness of waste polyethylene/green synthesized Ni nanocomposites, increases based on the physical and chemical nature of the metal nanoparticles added.

Physically, the shape and the size of the nanoparticle influence the hardness by increasing the hardness of the product based on nanoparticles shapes and sizes Ni. The shape of the nanoparticle is one of the important factors that affect the nanoparticle because shape of the particle determines the nature of the distribution and interaction that occur between the matrix of the waste polyethylene and the nanoparticles. A nanoparticle with spherical shape increase the hardness of polymer because this shape promote homogeneously distribution of the particles within the polymer matrix than an anisotropic shaped particles which are poorly distributed during mixing due to the irregularity of shapes. The larger the size of the particle the more it increase in hardness of polymer because larger particles present a larger surface area for interaction between the nanoparticles and the polymer matrix or chain which eventually aid stress transfer and impart strong reinforcement. The size of the particles also allowed the formation a protective barrier within the polymer surface gave rise to difficult deform of polymer hence, enhancing the hardness of the polymer just as observed by the waste polyethylene/ green synthesized Ni nanoparticles.

Chemically, the increase in hardness was due to the nature of nanoparticle, this Ni is hard and ductile transition metal due to the presence of 2 electron in 4s orbital and 8 electrons in 3d orbital a valance electron in outer energy level. The present of valance electron in the outer shell makes them more difficult to lose electron resulting into strong metallic bond. The oxidation of the Ni to Ni^{2+} nanoparticles during composites formulation may lead to a crosslinking reaction which induced crystallization by orderly rearrangement of the polymer chain thereby increasing the harness of the nanocomposites.

Comparing of this studies with other result, it can be seen the result obtained indicate that addition of nanoparticles gave higher hardness than the control waste polyethylene. The result obtained from the current research is higher that the result reported by Wawan *et al*. (2019 which show that addition of addition of sawdust particles on recycled high density polyethylene (HDPE) increases the hardness from 86.8 to 131.3 N/mm². AL-Maatoq *et al*. (2022) also revealed that addition of multiwall carbon nanotubes (MWCNTs) to high-density polyethylene (HDPE), increase 54:92 to 63 N/mm² and increase in his result which was lower than the result obtained from this study. Another literature reported by (Fattahi and Najipour, 2017) addition of carbon nanotubes to polyethylene significantly increase the hardness of the polyethylene/ carbon nanotubes nanocomposites from 40.8 to 59.9 N/mm² which also lower than the result from this studies. Furthermore, Jacob *et al*. (2018) reported that recycled low density (RLDPE) polyethylene treated fibre reinforcement shows an increase in hardness value from 70 85.6 N/mm² of the polyethylene control to 85.6 N/mm² of nanocomposites. This was because there were better interfacial adhesion between the fibre and the recycle low density polyethylene (RLDPE) matrix as well as good particle distribution in the matrix (Jacob *et al*., 2018). However, Hashim *et al*. (2020) reveal that addition of graphene (Gr) nanoparticle to a neat polylactic acid (PLA) via melt blending and solution mixing reduces from 77.6 to 69.0 .6 N/mm² which oppose the result obtained from this research. The decreases the hardness polylactic acid/graphene composite was due to the interaction of molecular chain which was weakened by the insertion of the plasticizer (grapheme) (Hashim *et al*., 2020).

Effect of Ni nanoparticles on the flexural strength waste polyethylene

Figure 5, shows the flexural strength of waste polyethylene (sachet water leather)/green synthesized Ninanocomposite.

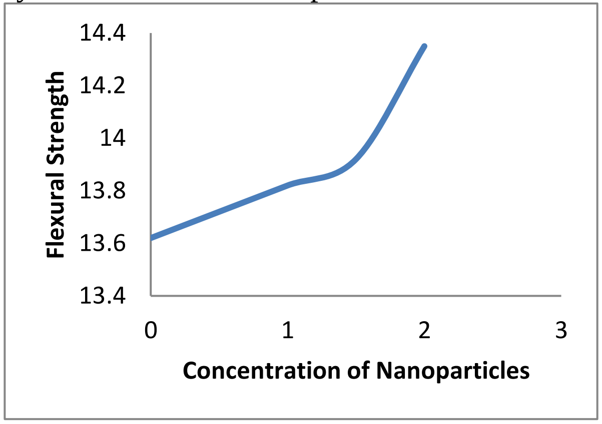

Figure 5: The Effect of Ni nanoparticles on the flexural strength waste polyethylene

The flexural strength of control waste polyethylene was recorded at 13.62 Mpa. The polyethylene/green synthesized Ni nanocomposite indicated a flexural strength value From 13.72 to 14.35 Mpa as the concentration of nanoparticles increases. From the result obtained, it is clear that the loading of Ni nanoparticles increases the flexural strength of the waste polyethylene nanocomposite.

Generally, increase in flexural strength of the Nano composite arises from the nature of the nanoparticles such as its shapes and sizes. The shape and particle size permit the formation of an intragranular or an intergranular structure to reinforce the polymer matrix so as to prevent the stress. Smaller nanoparticles exhibits more curvy shapes which concentrate stress more than a flat shape material improving the flexural strength of the polymer. Addition of the nanoparticles in the polymer matrix effectively transfers the stress from the polymer matrix to its self who helps in distributing and dissipating the applied load as a result enhancing the flexural strength.

DOI: 10.56892/bima.v7i2.446

Incorporation of nanoparticles also reinforces the polymer by reducing the crack growth within the waste polyethylene material this occurs by acting as fence within the polymer matrix from which the cracks are impeded from propagation. This delay in the crack propagation led to an increase in the flexural strength of the polymer.

The current result obtained from this study was lower than the report from Mahendra *et al*. (2019) which reveal that addition of calcium carbonate ($CaCO_3$) nanoparticles to polypropylene increases the flexural strength from 40 to 50 Mpa than when compared to the control. Onuoha *et al*. (2017) indicated that addition of periwinkle shell filler to recycled polypropylene flexural strength from 20 to 30 Mpa recycled polypropylene/ periwinkle shell powder composites. The result observed by his studies was slightly higher than the result recorded by this study. Oyar *et al*. (2018) also reported that addition of Au nanoparticles in to polymethyl methacrylate matrix improved the flexural strength from 120 to 140 Mpa much higher than the result obtained from this research. Furthermore, Mirjili *et al*. (2014) stated that addition of nano α-Al_2O_3 to polypropylene resulted in to increase in the of the composites flexural strength from 47 to 55.88 MPa of polypropylene/nano α-Al_2O_3 composites. The result obtained from his researched was higher than the result obtained from the present study. Compare the result with some of the literature obtained, it was reveal that the result from this study indicated a lower improved in the flexural strength due to the nature of the polymer matrix and the type of the nanoparticle involved.

However, Ashori, (2012) reported a result which recorded that incorporation of nanosilica in the matrix of polypropylene cause the flexural strength of the composites to increases higher than polypropylene from 1.11 to 2.9 Mpa. Comparison of his result with the result of this study, the present result indicates a better improvement in the flexural strength 13.62 to 14.43 Mpa waste polyethylene Ni nanocomposites. Bajuri *et al*. (2016) reported that incorporation of silica nanoparticles in epoxy polymer decreased the flexural strength from 43.8 to 3.05 MPa epoxy polymer composites at different concentration. His result opposed the result observed in the current study in which flexural strength increase with incorporation of the nanoparticles. Another report by Chee *et al*. (2012) showed that introduction of alumina particles into low density polyethylene (LDPE) significant reduce the flexural strength from 7.4 Mpa neat low density polyethylene to 6.9 Mpa which totally disagree with the result obtained from this study.

Effect of green synthesized Ni nanoparticles on the tensile strength waste polyethylene

The effect of the green synthesized nanoparticles on the tensile strength of waste polyethylene (sachet water leather) was observed in Figure 6.

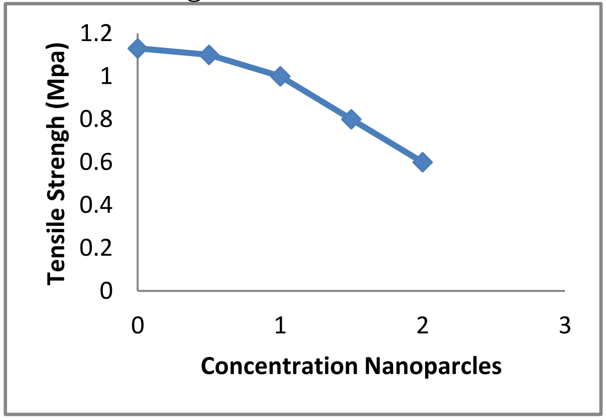

Figure 6: Effect of Ni nanoparticles on the tensile strength waste polyethylene

It can be seen that control waste polyethylene gave a value at 1.13 Mpa. Incorporation of

DOI: 10.56892/bima.v7i2.446

the green synthesized nanoparticles decreases tensile strength of the nanocomposite. At 0.5 and 2.0 g, a clear decrease is obtained from 1.1 to 0.6 Mpa as the concentration of the nanoparticles increases.

Generally, the decrease in tensile strength of nanocomposites arises from the different sizes of nanoparticles formed during formulation and also the non-uniformed distribution of the particles within the polymer matrix. The decrease can also be due to some factors such as molecular weight and crosslinking effect of the nanoparticles during formulation. The larger sizes of the Ni nanoparticles courses complex viscosity which more chain entanglement occur. The chain entanglement usually reduce the interfacial interaction between the nanoparticle and the polymer matrix leading to low load distribution which result into poor stress transfer within the matrix hence reducing the tensile strength of the polymer. The smaller sizes of the nanoparticles agglomerated forcing the area of agglomeration to be highly reinforced by increasing it strength thereby decreases the tensile strength. During formulation, the Ni nanoparticles disrupt the polymer chain entanglement which prevents the crosslinking reaction within the polymer matrix causing degradation and reduction in the molecular weight of the polymer which resulted into a decrease in the tensile strength.

The result of this study agrees with the report from Tripathi and Dey (2019) which indicated that incorporation of NiO nanoparticles in to low density polyethylene (LDPE) decrease the tensile strengthfrom 9.5 of to 8.3 Mpa LDPE/NiO nanocomposites. Parmjit *et al*. (2016) revealed that addition of talc and $MgCO_3$ to polypropylene/linear low density polyethylene (PP/LLDPE) blend decreased the tensile strengths from 68.07 Kgf/cm^2 to 32.75 Kgf/cm^2. Another report by Chee*et al*. (2012) indicated that that addition of nano α-Al_2O_3 to low density polyethylene decrease the tensile strength of the nanocomposite from 7.8 neat low density polyethylene to 6.5 Mpa nanocomposite. Further report by Mosalman *et al*. (2017) revealed that polymethyl methacrylate containing nanoparticles showed reduction in tensile strength from 79.16 to 38.17 MPa composites. The nanoparticle acts as impurities and the tensile strength decreases as a result of the extra additive (Mosalman *et al*., 2017).

The values of the tensile strength reported from some of the literature mention were higher than the value observed by this studies this is because of the polymer involved in the present research is a waste product. The waste has undergo some other mechanical processes like stretching by secondary manufacturers and consumers. However Kaleel *et al*. (2011) showed incorporation of TiO_2 nanoparticles polyethylene raises the tensile of polyethylene/doped-titania nanocomposites from 17 neat polyethylenes to 33 Mpa. His result opposes the result obtained from this study in which the tensile strength decreases from 1.13 to 0.6 Mpa. Another report by Titone *et al*. (2021) indicated that addition of silica nanoparticles to polypropylene increases the tensile strength of the polymer composite higher than of the neat polypropylene 24.3 MPa to 30 Mpa which opposed the result obtained in this research. Also, (Lin *et al*., 2009) reported that addition of nanoZnO filler into polypropylene matrix has enhanced the tensile strength from 31 to 37 Mpa composites. Further research by Mirjalili *et al*. (2014) indicated that, addition of nano α-Al_2O_3particles to polypropylene and enhanced tensile strength nanocomposite 31.15 to 36.45 compared with in the neat polypropylene. It can be seen that the current of this study also disagree with his report which stated that tensile strength of composite were enhanced by addition of nano α-Al_2O_3particles.

Effect of green synthesized Ni nanoparticles on the Young modulus of waste polyethylene

The Figure 7 represents effect of green synthesized Ni nanoparticles on the modulus of elasticity (Young's modulus) of waste polyethylene.

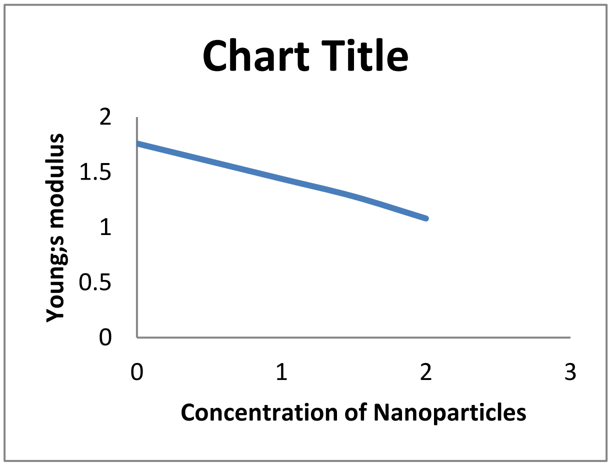

Figure 7: Effect of green synthesized Ni nanoparticles on the Young modulus of waste polyethylene

It can be observed that Young's modulus of control waste polyethylene was observed at 1.76 Mpa. The Young's modulus waste polyethylene/green synthesized Ni nanocomposite decreases from 1.6 to 1.08 Mpa with increase concentration of the nanoparticles.

This is because absorption of nanoparticles by the polymer alters the polymer chain arrangement by influencing the changing in the direction of the chain orientation. This activity alter the chain confirmation and reducing the crystalline structure. The Ni nanoparticles are rigid and stiffed in nature addition into polymer matrix restrict the movement of the chain creating much concentration of stress and local deformation which lead to reduction in the Young's modulus. Also chemical interactions occur which strong bonding are formed preventing the polymer chain from debonding or agglomeration during deformation hence reducing Young's modulus.

This work finding agree with the work of Nayeemuddin*et al*. (2022) where pure low density polyethylene (LDPE) recorded a higher Young's modulus than LDPE/$NiFe_2O_4$ nanocomposites from 8.20 Mpa neat LDPE to 6.20 Mpa. The result observed from this study also agree with reported by Maurice *et al*. (2013) which revealed that addition of SiO_2 nanoparticles into polymethylmethacrylate (PMMA) decreases the Young's modulus of PMMA/SiO_2 composite from 4.28 control PMMA to 4.22 Mpa composites. Another report by Cho *et al*. (2006) Showed Addition of alumina particles nanoparticles to Vinyl ester resin decreases the Young's modulus with 3.5 to 1.15 Mpa nanocomposites which was higher than that obtained from this study. This is because elastic modulus depend of degree of polymerization and crystalline structure of the polymer. High concentration of nanoparticles causes agglomeration hence decrease in the elastic modulus of the composites. However, the elastic modulus on the present study was lower due to the reduction in the crystalline structure arrangement of the polymer composites by addition of the nanoparticles. This imply that the polymer composites can easily undergo larger stress and return to shape with more impact resistance than coomposites with higher Young modulus. Further research by Zdiri *et al*. (2018) reported that addition of graphene nanoparticles to recycled polypropylene (rPP) decreases the Young's modulus recycled polypropylene/Graphene (rPP/GN) nanocomposites from 1.9 to 1.45 Mpa which was slightly above the result obtained from the current work. The decrease in the Young's modulus of Vinyl ester resin composites was due to increase in particles size as stated by Cho *et al*. (2006) and also The decrease was attributed to the agglomeration of the grahene induced local stress concentration in the nanocomposites and reduction in the graphene aspect ratio, thereby reducing the contact surface area between the nanoparticles and the polymer matrix (Zdiri *et al*., 2018).

However, the finding of this work opposes the work reported by Nisar *et al*. (2018) which revealed that elastic module of polyethylene/Ni-C (PE/Ni-C) nanocomposites increases from 386 to 456 MPa by the incorporation Ni-C nanoparticles compared to polyethylene (control). It was stated that the enhancement was due excellent interface between polymer matrix and filler; the filler tends to have greater surface area per unit volume ratio, which enables good load transfer to the polymer (Nisar *et al*., 2018). Fu *et al*. (2008) indicated that incorporation of nano-SiO_2 into a low density polyethylene improved the Young's modulus from 6.9 to 3.8 Mpa LDPE/ SiO_2 composites which also opposes the result obtained from this research by implying that addition of nanoparticle increase the Young's modulus of the low density polyethylene. Further studies from Kaleel *et al*. (2011) stated that the elastic modulus of polyethylene/doped-titania nanocomposites increaseses from 325 neat polyethylene to 342 Mpa with the addition of TiO_2 nanofiller.

Effect of green synthesized Ni nanoparticles on % elongation a break waste polyethylene

Figure 8 present the effect Ni nanoparticles on the percentage elongation at break of waste polyethylene.From the result, the control waste polyethylene showed % elongation at break of 78.0 %. It can be observed that the percentage elongation increase with the addition of the nanoparticles from 79 to 86.0 % nanocomposites.

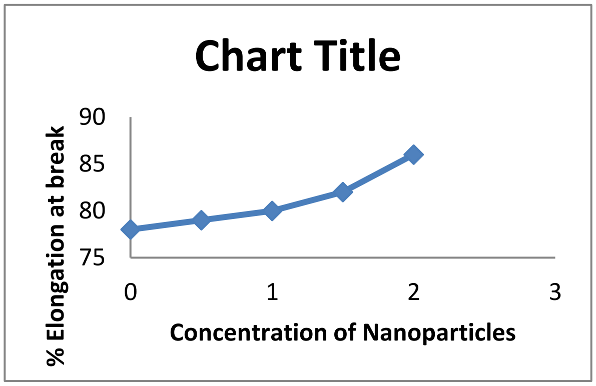

Figure 8: Effect of green synthesized Ni nanoparticles on % elongation a break waste polyethylene

This is because of the Ni nanoparticles promotes the formation of long and flexible chain during polymerization and also form an interface that prevent the polymer from premature debonding which influencing the percentage elongation of the composites. The nanoparticles also reinforce the polymer matrix thereby distributing the stress by improving load transfer within the composites which prevent crack hence improving the percentage elongation. The polymer matrix interacts with the surface of Ni nanoparticles with an electrostatic force which enhance the interfacial adhesion increasing the percentage elongation of the composites.

The findings percentage elongation at break obtained from the present studies agrees with the literature reported Li (2020) where that incorporation of graphene nanoparticles to polypropylene increase the value of the % elongation at break from 29 of the unfilled polypropylene (control PP) to 40 % polypropylene/grapheme (PP/GN) nanocomposites. However, the values reported were lower than the current value obtained. Another report from Ginting *et al*. (2016) indicated the distribution of maleic anhidride (MA) nanoparticles into polyethylene (PE) in improved the ultimate elongation of the polyethylene grafted maleic anhidride (PE-g-MA) nanocomposite from 10 of the polyethylene control to 17 % the nanocomposites. Further studies by Sabo *et al*. (2021) showed that incorporation of NiO nano particles into styrene shows that untreated polystyrene gave a percentage elongation of 46.67 % while tha of PS/NiO nanocomposite percentage elongation of increase to 50.00 % . The higher increase in the % elongation of this study was due to aging factor of the waste polyethylene from manufacturers to consumers in which some of the properties may be loss and also present of polymer additives which may cause site reaction such as crosslinking with nanoparticles thereby increasing the % elongation higher the most literature.

However, Tripathi and Dey (2019) reported that addition of NiO nanoparticles to low density polyethylene (LDPE) decreases the % elongation at break of LDPE/NiO from 90 % to 20%. Also Nayeemuddin*et al*. (2022) revealed that addition of $NiFe_2O_4$ nanoparticles to low density poly ethylene shift the % percentage elongation of % LDPE/NiFe2O4 nanocomposites higher that than pure LDPE 0.32 to 0.14 % which disagree with the present findings. Another result by Awang and Mohd (2018) showed that rice husk (RH) and TiO_2 particle loading into polypropylene resulted in an abrupt drop in elongation at break From 15.8 to 2.0 % PP/RH/TiO2 composites. Also Titone *et al*. (2021) reported that addition of SiO nanoparticles to neat polypropylene (PP) found to decrease the percentage elongation at break of polypropylene/SiO_2 nanocomposites from 30.2%, to 5%. Further report of Zaman and Khan (2022) stated that incorporation of organo muscovite clay (OM)into neat polypropylene courses the elongation at break (%) to decreases significantly from 96 % of Control polypropylene to 88 % PP/OM nanocomposites.

CONCLUSION

The nanocomposites were formulated through waste and green synthesized nanoparticles and also have a great impact on the nanocomposites. The incorporation of the green metal nanoparticle increases the mechanical properties such as hardness, flexural strength and percentage elongation at break. Decrease was also observed on the tensile strength and Young's modulus properties. The result indicated that a waste polyethylene can be transformed into a nanacomposite with advance nanotechnology properties for future applications.

Acknowledgments
The Authors appreciate Dr. Andrew Kwaji, Department of Chemistry Gombe State University of Nigeria, all the laboratory staff of Abubakar Tafawa Balewa University, Bauchi State of Nigeria, Mr. Bitrus Habila Nigerian Institute of Leather and Science Technology Samaru-Zaria for the kind support. And also grateful to TETFUND for funding of the first Author.

REFERENCES

Abdulhadi, O. O., Ibrahim A. AA. Rahmmanc, A. S. Obaida (2021) Synthesis and Characterization of Nickel Nanoparticles Formed by Solution Cold Plasma Jet. *Journal of Physics: Conference Series*, 2114: 012083

Achilias. D. S., Kanellopoulou, I. and Megalokonomos, P., Antonakkou, E. Lappas, A. A. (2007). Chemical Recycling of Polystyrene by Pyrolysis:

DOI: 10.56892/bima.v7i2.446

Potential use of Liquid Product for the Reproduction of Polymer. *Macromolecular Material and Engineering* 292:923-924.

AL-Maatoq., M., Fuentealba, P., Fachet, M., Glüge, R. Ali, S. H. R. and Hoeschen, C. (2022). Carbon Nanotube-Based Reinforced Polymers for Medical Applications: Improving Impact Strength of Polymer-Polymer Composites. *Journal of Nanomaterials*, 2022(1760198):1-15

Alshammari, B.A., Hossain, M., Alenad, A.M., Alharbi, A.G., AlOtaibi, B.M., (2022). Experimental and Theoretical Analysis of Mechanical Properties of Graphite/Polyethylene Terephthalate Nanocomposites. *Polymers* 14: 1718.

Alsharaeh, E. H. (2016) Polystyrene-poly(methyl methacrylate) Silver Nanocomposites: Significant Modification of the Thermal and Electrical Properties by Microwave Irradiation. *Materials,* 9(6): 458

Amutha S., Sridhar S. (2018). Green Synthesis of Magnetic Iron Oxide Nanoparticle using Leaves of *Glycosmis mauritiana* and their Antibacterial Activity against Human Pathogens. *Journal of Innovations in Pharmaceutical and Biological Sciences* 5 (2): 22-26,

Andrady, A.L. and Neal M. A. (2009). Application and Social benefits of Plastic. *Transaction Royal Society London B Biological Science,* 64(1526):1977-1984

ASTM D638-14(2014) Standard Test Method for Tensile Properties of Plastics.

Ashori, A. (2012). Effects of Nanoparticles on the Mechanical Properties of Rice Straw/polypropylene Composites. *Journal of Composite Materials,* 47(2):149–154

Awang, M. and Mohd, W. R. W. (2018). Materials Comparative studies of Titanium Dioxide and Zinc Oxide as a Potential Filler in Polypropylene Reinforced Rice Rusk Composite.*Science and Engineering,* 342:1-8

Bajuri, F., Norkhairunnisa, M., Mohamad, R. I., and Junichiro, I. (2016). Flexural and Compressive Properties of Hybrid Kenaf/Silica Nanoparticles in Epoxy Composite. *Procedia Chemistry* 19:955 – 960

Boryo DEA; Bello, KA; Ibrahim, AQ; Gin, NS; Ezeribe, AI; Wasiu, KA (2014). Effects of Alternative Mercerizing Agents on Mechanical Properties of Cotton/Polyester Blend Fabric. *Academic Journal of Interdisciplinary Studies,* 3(5):91-103

Boryo, D. E.A., Ezeribe, A. I., Mustapha A.O., and Aliyu, J. (2010). Effects of Urea, Borax and Ammonium Phosphate on Fire Retardant and Mechanical Properties of Plastic Obtained from Polyvinyl Chloride. *Journal of Chemical Society of Nigeria,* 32(2): 11-16

Chang, B. P., Akil1, H. M., Nasir, R. B. M., Bandara, I. M. C. C. D. and Rajapakse, S. (2013). The Effect of ZnO Nanoparticles on the Mechanical, Tribological and Antibacterial Properties of Ultra-high Molecular Weight Polyethylene. *Journal of Reinforced Plastics and Composites,* 33(7):1–13

Chee, C. Y., Song, N. L., Luqman, C. A., Thomas, S. Y. C., Azowa, I., and Chantara, T. R. (2012). Characterization of Mechanical Properties: Low-Density Polyethylene Nanocomposite Using Nanoalumina Particle as Filler. *Journal of Nanomaterials,* 2012:1-6

Cho, J. Joshi, M.S. and Sun, C.T. (2006). Effect of Inclusion Size on Mechanical Properties of Polymeric Composites with

Micro and Nano Particles. *Composites Science and Technology* 66:1941–1952

El-kemary, M., Nagy, N and El-mehassaeb, L. (2013) Nickel Oxide Nanoparticles: Synthesis and Spectral of Interaction with Glucose. *Materials Science in Semiconductor Processing* 16: 1747–1752.

Fahim, I. S., Mamdouh, W. and Salem, H. G. (2015). Effect of Processing Technique on LDPE Thin Films and Sheets. *International Journal of Engineering,* 4(12): 01-05

Fattahi, A.M. and Najipour, A. (2017). Experimental Study on Mechanical Properties of PE/CNT Composites. *Journal of Theoretical and Applied Mechanics*, 55(2):719-726

Fu, S. Y, Feng, X. Q., Lauke, B. and Mai, Y. W. (2008). Effects of Particle Size, Particle/Matrix Interface Adhesion and Particle Loading on Mechanical Properties of Particulate–Polymer Composites. *Composites*: Part B 39: 933–961

Ginting, E. M., Bukit, N., Frida, E. and Gea, H. A. (2016). Characterization of Nanoparticles Fe_3O_4 Nanocomposite Blend with Thermoplastic HDPE. *Chemistry and Materials Research* ,8(8):44-52

Hashim, N. Amin, N.R.B. Abdullah, S., Abdullah, A.H., Abdullah, N., Mohamed, R.M. Yahya, N.A.M. and Yusoh, K. (2020). The Effect of Blending Methods on the Properties of PLA/Gr Nanocomposites. *Journal of Physics: Conference Serie,* 1532 (012012):1-7

Hemalatha, M., Suryanarayanan, N. and Prabahar, S. (2014). Synthesis and Characterization of Nickel Nanoparticles by Chemical Reduction Method. Optoelectronics and *Advanced Materials – Rapid,* 8(3-4):288 – 291

Hong, S.J., Mun, H.J., Kim, B.J. and Kim, Y.S. (2021).Characterization of Nickel Oxide Nanoparticles Synthesized under Low Temperature. *Micromachines*, 12(1168):1-10

Huang, Y., Zhu, C., Xie, R. and N, M. (2021). Green Synthesis of Nickel Nanoparticles using *Fumaria officinalis* as a Novel Chemotherapeutic Drug for The Treatment of Ovarian Cancer, *Journal of Experimental Nanoscience*, 16(1): 368–381

Jacob, J., Mamza, P.A.P., Ahmed, v. and Yaro, S.A. (2018).Effect of Benzoyl Chloride Treatment on the Mechanical and Viscoelastic Properties of Plantain Peel Powder - Reinforced Polyethylene Composites. *Science World Journal*, 13(4):25-29

Kaleel, S. H. A., Bahuleyan, B. K., Masihullah, J. and Al-Harthi, M. (2011). Thermal and Mechanical Properties of Polyethylene/Doped-TiO2 Nanocomposites Synthesized Using In Situ Polymerization. *Journal of Nanomaterials*, 2011(964353): 1-6

Khalaj, M., Ahmadi, H., Lesankhosh, R. and Khalaj, G. (2016). Study of Physical and Mechanical Properties of Polypropylene Nanocomposites for Food Packaging Application: Nano-clay Modified with Iron Nanoparticles. *Trends in Food Science & Technology,* 51: 41-48

Kiaei, M., Kord, B., Samariha, A., Moghdam,Y. R. and Farsi, M. (2017). Mechanical, Flammability, and Morphological Properties of Nano-composite Plastic based on Hardwood Floor High-density Polyethylene Embedding by Nano-Zinc Oxide. *BioResources*, 12(3):6518-6528

Kumar, P. V., Ahamed, A. J. Karthikeyan, M. (2019). Synthesis and Characterization of NiO Nanoparticles by Chemical as well

As Green Routes and Their Comparisons with Respect to Cytotoxic Effect and Toxicity Studies in Microbial and MCF-7 Cancer Cell Models. *Springer Nuture Journal of Applied Sciences,* 1(9): 1-15

Li, J. (2020). Simultaneous Improvement in the Tensile and Impact Strength of Polypropylene Reinforced by Graphene. *Journal of Nanomaterials*, 2020(7840802):1-5

Lin,O. H., Hazizan, M. A., and Shahrom, M. (2009). Effect of Particle Morphology on the Properties of Polypropylene/Nanometric Zinc Oxide (Pp/Nanozno) Composites. *Journal of Composite and Advance Letters,* 18(3): 77-83

Lobotka, P., Radnoczi, G., Czigany, Z, Vavra. I., Drzik, M., Micusik, M., Dobrocka E. and Kunzo P. (2013) Preparation of Nickel, Nickel-Iron, and Silver-Copper Nanoparticles in Ionic Liquids .*Confrence On Solid State Sensor*, 2021-2024

Mahendra, S. B., Vasu, D. B. Gurubasavaraj, G. K., and Abhishek, V. (2019). Mechanical Responses of Polypropylene and Calcium Carbonate Nanoparticles *International Journal of Engineering Research & Technology*, 7(07):1-3.

Maurice, G., Rouxel, D., Vincent, B., Hadji, R., Schmitt, J. Taghite, M. and Rahouadj, R. (2013). Investigation of Elastic Constants of Polymer/ Nanoparticles Composites Using the Brillouin Spectroscopy and the Mechanical Homogenization Modeling. *Polymer Engineering and Science*, 53(7): 1-11

Mirjalili,F., Chuah, L. and E. Salahi, E (2014).Mechanical and Morphological Properties of Polypropylene/Nano α-Al_2O_3 Composites. *The Scientific World Journal,* 2014:1- 12

Modi, S.and Fulekar, M. H. (2020).Green Synthesis of Zinc Oxide Nanoparticles Using Garlic Skin Extract and Its Characterization.*Journal of Nanostructures*, 10(1): 20-27

Mohammed N. A. M. (2009). Studing the Mechanical Properties and Morphology of Ternary Blends of Polyethylene. *Engineering and Technology Journal*, 27(6):1197-1205

Mosalman, S., Rashahmadi, S. and Hasanzadeh, R. (2017). The Effect of TiO2 Nanoparticles on Mechanical Properties of Poly Methyl Methacrylate Nanocomposites *International Journal of Engeneering Transactions B: Applications,* 30(5):807-81

Murugan S. S. (2020). Mechanical Properties of Materials: Definition, Testing and Application. *International Journal of Modern Studies in Mechanical Engineering* (IJMSME)6(2): 28-38

Nayeemuddin, Quadri, S.A.M. N., and Inamdar, H. K. (2022). Synthesis and Characterization of LDPE/$NIFe_2O_4$ Nanocomposites Films for Mechanical Properties and FTIR for Structural Analysis. *International Journal of Creative Research Thoughts*, 10(5):7-12

Nisar, M., Thue, P. S., Heck,C. A., Cuaila, J. L. S., Geshev, J., Lima, E. C., Jacobi, M. M. and Galland, G. B. (2018). Synthesis of Polyethylene/Nickel–Carbon Stimuli-Responsive Material under Magnetic Field at Room Temperature: Effect of the Filler on the Properties. *European Polymer Journal*, 99:378-383

Nisar, M., Thue, P. S., Maghous, M. B., Geshev, J., Lima, E. C. and Einloft, S. (2020). Metal Activated Carbon as an Efficient Filler for High-density Polyethylene Nanocomposites. *Polymer Composites*, 41:3184–3193

Nwapa, C., Okunwaye, O. J., Okonkwo, C. L. and Chimezie, O. W., (2020). Mechanical Properties of High Density Polyethylene and Linear Low Density Polyethylene Blend. *International Journal of Polymer and Textile Engineering*, 7(1):23-28

Onuoha, C., Onyemaobi, O.O., Anyakwo, C.N., and 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*, 6(4):72-79.

Oyar, P., Sana, F.A. Nasseri, B. Durkan, R. (2018). Effect of Green Gold Nanoparticles Synthesized with Plant on the Flexural Strength of Heat-polymerized Acrylic Resin. *Nigerian Journal of Clinical Practice*, 21(10): 1295

Parmjit, S., Vipan, K. S. and Rajesh, K. S.(2016). Study of Thermo-Mechanical Properties of Polypropylene and Low Density Polyethylene Composite Material. *Oriental Journal of Chemistry*, 32(1):455-461

Pudukudy, M. and Yaakob, Z. (2015). Facile Synthesis of Quasi Spherical ZnO Nanoparticles with Excellent Photocatalytic Activity. *Journal of Cluster Science*, 26: 118-1201

Ramesh, K. N., Kishore, K. M., and Bankim, C. R. (2017). Processing of Polymer-Based Nanocomposites. *Classification of Nanomaterials*, 4:55-75

Rehman, Z.U., Nawaz, M., Ullah, H., Uddin, I., Shad, S., Eldin, E., Alshgari, R.A., Bahajjaj, A.A.A., Arifeen, W.U. and Javed, M.S. (2023). Synthesis and Characterization of Ni Nanoparticles via the Microemulsion Technique and Its Applications for Energy Storage Devices. *Materials*, 16(325):1-11

Sabo, Y.T., Boryo, D.E., Chindo, I. Y., Habib, A.I. (2021). Nanocomposites Transformed from Polystyrene Waste/Antimony, Barium and Nickel Oxides Nanoparticles with Improved Mechanical Properties. *J. Appl. Sci. Environmental Management*, 25(11):1921-1925

Streit, A.F.M., de SantanaM. P. and Bertuol D.A. (2022). Development of a Pre-treatment Process of Polymeric Wastes (HDPE, LDPE/LLDPE, PP) for Application in the Qualification of Selectors of Recyclable Materials. *Environment, Development and Sustainability*, 24: 6349 -6371

Sutar, H., Mishra, B., Senapati, P., Murmu, R. and Sahu, D. (2021). Mechanical, Thermal, and Morphological Properties of Graphene Nanoplatelet-Reinforced Polypropylene Nanocomposites: Effects of Nanofiller Thickness. *Journal of Composite Science*, 5: 24.

Taghizadeh, F. (2016). The Study of Structural and Magnetic Properties of NiO Nanoparticles. Optics and Photonics Journal, 6:164-169

Titone, V., Maria, C. M., Luigi, B. and Francesco, P. L. M. (2021). Investigation on the Properties and on the Photo-Oxidation Behaviour of Polypropylene/Fumed Silica Nanocomposites. *Polymers,* 13(2673):1-14

Tripathi, D. And Dey, T. K. (2019). Effect of Particle Size Distribution on Thermo-Mechanical Properties of NiO filled LDPE Composites. *Bulleting Material Science*. 42(174):1-10

Wawan,T. P., *SaifulBahri*, B. M., Martini, B. M., and Muhammad, A. B. M. (2019). Effectiveness Teston Hardness Performance of Plastic Waste and Sawdust Composite. *International*

Journal of Recent Technology and Engineering, 8(2S7):275- 280

Wei, D. V. and Denton, N. L., (2018). "Hardness Comparison of Polymer Specimens Produced with Different Processes".*ASEE IL-IN Section Conference*. 3:1-14

Zaman, H. and Khan, R. A. (2022). Preparation and Characterization of Polypropylene/Organo-Muscovite Clay Nanocomposites by Melt Extrusion. *Advanced Journal of Science and Engineering*, 3(1):23-34.

Zdiri, K., Elamri, A., Hamdaoui, M., Harzallah, O., Khenoussi, N. and Brendléc, J. (2018) Reinforcement of Recycled PP Polymers by Nanoparticles Incorporation. *Green Chemistry Letters and Reviews*, 11(3):296–311

Zhang, Y., Mahdavi, B., Mohammadhosseini, M., Rezaei-Seresht, E., Paydarfard, S., Qorbani, M., Karimian, M., Abbasi, N., Ghaneialvar, H. and Karimi, E. Green synthesis of NiO Nanoparticles using *Calendula officinalis* Extract: Chemical Charactrization, Antioxidant, Cytotoxicity, and Anti-esophageal Carcinoma Properties. *Arabian Journal of Chemistry* 14:103105