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THE EFFECTS OF CASSAVA PEEL CONTENT ON MECHANICAL PROPERTIES OF LOW-DENSITY POLYETHYLENE (LDPE) COMPOSITES

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ABSTRACT
Polymer matrix composites (PMCs) have garnered significant attention in both academic and industrial research due to the growing demand for environmentally friendly and biodegradable materials. This study focuses on exploring alternative options to synthetic materials by investigating composites of polymers with natural fibers. Specifically, the influence of varying cassava peel powder concentrations as a filler on the tensile, flexural, and hardness properties of pure low-density polyethylene (LDPE) samples was examined. The natural fiber, cassava peel, underwent treatment with a 2% NaOH solution before being compounded with LDPE on a two-roll mill to create a biocomposites. The compounded samples were moulded into uniform thickness (3mm) rectangular shapes using a compression moulding machine at a pressure of 4MPa for 5 minutes. This process was repeated for different filler concentrations. The mechanical properties of the produced composites, including tensile strength, flexural strength, and hardness, were then tested. The results showed that the tensile strength initially increased from 17.83 MPa to 20.20 MPa and subsequently decreased at filler concentrations of 20%, 30%, 40%, and 50% to 14.7 MPa, 8.58 MPa, 6.12 MPa, and 5.26 MPa, respectively. Flexural strength decreased with increasing cassava peel powder loading, ranging from 22.22 MPa (0% loading) to 6.22 MPa (50% loading). Hardness also exhibited an increasing trend with fiber loading, starting at 10.9 HV (0% loading) and reaching 32.62 HV at 50% loading.

Keywords: Polymer matrix composites, Natural fibers, Cassava peel powder, LDPE (Low-Density Polyethylene), biocomposites, Filler concentration.

1. INTRODUCTION

Composite materials have gained significant attention due to their ability to combine the strengths of different components, resulting in materials with enhanced properties that meet specific engineering requirements. Because of this, they are now widely used in a variety of industries, including construction, automotive, aerospace and more (Smith *et al.,* 2015*).*

In an effort to develop bio-based composites, researchers are investigating the incorporation of natural fillers into polymer matrices as a means of achieving sustainability and environmental friendliness. Researchers are coming up with workable methods to improve or hasten polymeric composites' biodegradability. Natural fibers therefore provide promising opportunities as fillers and reinforcements in thermosets, thermoplastics, and elastomers. Natural fibers provide several benefits when used in composites, including affordability, sustainability, lightweight design, nonabrasive and nonhazardous properties and above all the capacity to hasten the polymeric composites biodegradability (Amash *et al*., 2000).

Cassava peels, a common agriculture residue in many locations, are one example of natural filler. Cassava peels are a good fit for integration into polymer matrices due to their potential, mechanical and chemical qualities. Using them as filler in composites has the dual benefit of decreasing waste by making use of agricultural byproducts and perhaps improving the characteristics of polymer composites. One typical thermoplastic polymer with a variety of uses is low density polyethylene (LDPE) (John and Jane, 2023). Because of its adaptable qualities, which include mechanical strength, flexibility and transparency, it is a desirable option for a number of sectors. Cassava peels have the ability to improve the characteristics of LDPE and make it more appropriate for particular uses when included into LDPE to create composite materials (John and Jane, 2023). A broad hypothesis has been proposed on the possibility of enhancing the mechanical characteristics of polymeric materials through the use of bio fillers as reinforcements (Martin, 2013). Its chemical composition includes cellulose (9.7%), hemicellulose (32-36%), protein (3.7%), lignin (16.89%), and ash (11.38%), though these values may fluctuate due to factors like climatic conditions, harvesting time, soil quality, and type (Nanssou *et al*., 2016).

The purpose of this study is to examine how different cassava peel contents affect the resulting materials' tensile, hardness and flexural properties in LDPE composites. By systematically altering the cassava peel content, we intend to assess how this natural filler influences the mechanical behavior and internal structure of the composites. This knowledge may help determine whether it is feasible to modify the characteristics of LDPE composites for certain uses by utilizing cassava peels. The application of sustainable fillers, such as cassava peels, could lead to economically and environmentally sustainable material science solutions as composite materials continue to progress. This work broadens our understanding of the impact of natural fillers on mechanical properties and contributes to the expanding body of research on fillers in polymer composites (Ezekiel *et al*., 2021).
Composite materials are created by fusing together two separate constituents, each possessing unique features. Biocomposites are defined as materials containing one or more biologically generated components (Johnson *et al.,* 2012). Together, these elements often referred to as reinforcement and the matrix produce a material with better properties than either of its constituent parts alone.

Composites are made to maximize the positive aspects of each component and minimize their negative aspects. Their strength, durability and light weight makes the popular in a wide range of industries, including construction, sports equipment, automotive and aerospace.

These composites qualities are usually determined by a number of variables, such as the amount of filler used, the features of the material and the bonding at interfaces (Liang., 2006 and Osman *et al*., 2004). Among many polymers used in many applications, low density polyethylene (LDPE) is particularly useful and indispensable. Because they may combine the qualities of different constituents, composite materials have attracted a lot of interest. This has led to materials with enhanced properties that meet exact technical requirements.

The aim of the study is to investigate the influence of cassava peels content on the mechanical properties specifically tensile, flexural and hardness of Low-Density Polyethylene and to produce a viable composite material made of LDPE and cassava peels for use in structural and commercial design e.g. composites used to make furniture with improved strength and flexibility.

There has been a significant increase in the use of natural fibers like wood and agricultural waste as fillers in composite materials, compared to synthetic fibers like glass. When compared to manufactured fibers like glass, the usage of natural fibers as fillers in composite materials has increased significantly, such as wood and agricultural waste (Eichhorn *et al*., 2010; Peng *et al*., 2014; Ifuku and Yano, 2015; Zulkifli *et al*., 2015; Boran, 2016). These materials' renewable nature, affordability, reduced density, good heat conductivity and remarkable mechanical qualities are what are driving this transition.

However, despite the potential advantages, a significant research gap persists concerning the effects of varying cassava peel content on the fundamental mechanical attributes, most notably mechanical properties of LDPE composites. This research endeavors to address these gaps by embarking on a systematic investigation aimed at comprehending how altering cassava peel content influences mechanical properties. By unraveling these intricate relationships, this study seeks to shed light on the feasibility of harnessing cassava peels as a means to meticulously engineer the properties of LDPE composites in alignment with specialized application requirements. Also, environmental concern on pollution as a result of dumping agricultural waste such as cassava peels, wood dust, can be regulated to the beeriest minimum (Oladunjoye *et al*,.2021)

Several research works have reported on the production of composites with a variety of properties through the use of agricultural waste materials such as rice husk (Yap *et al.,* 2020), palm kernel shell fiber (Oladele *et al.,* 2020), corn husk fiber (Ibrahim *et al.,* 2019), coconut husk (Ipilakyaa *et al*., 2019), and cassava cortex (Omah *et al*., 2018).
Ahmed *et al*. (2017) examined the tensile properties of cassava starch (CS) bio-composite films by altering the content of treated cassava bagasse (CB) and cassava peel (CP). They employed a casting technique and utilized cassava starch as the matrix and fructose as the plasticizer, bio-composite films were systematically developed with deliberate additions of CB and CP to optimize their properties. The integration of both fibers resulted in a significant increase in tensile strength and young modulus, and a reduction in the elongation at break of the bio-composite films. Notably, the addition of 6% bagasse led to a significant augmentation in modulus and maximum tensile stress, reaching 581.68 and 10.78 MPa. This study further establishes the value of cassava bagasse and peel as reinforcement agents, contributing to the transformation of these waste by-products into environmentally friendly food packaging materials.

Adeleke *et al.* (2023) explored the potential of cassava back peel as a reinforcement material in epoxy resin-based composites through a hand lay-up technique, altering the carbonized cassava back peel (CCBP) content from 0% to 10%, while maintaining iron fillings (IF) at a constant 5%. The combination of IF and CCBP notably improved the epoxy resin's density, with the 5%CCBP epoxy composite achieving a maximum density of 1270 kg/cm³. Water absorption properties were enhanced, particularly in the 5%IF10CCBP epoxy hybrid composite, which recorded 30% water absorption. Mechanical testing highlighted changes in ultimate tensile strength (UTS) and breaking strength (BS) based on the filler materials, with the 5%CCBP epoxy composite displaying 41.26 MPa for both UTS and BS. However, a decrease in percentage elongation suggested reduced ductility. The incorporation of fillers also increased the hardness number of the epoxy.

Ofem *et al.* (2020) prepared Cassava Peels Powder (CaPP) of size less than 750µm which was incorporated with high-density polyethylene (HDPE). The tensile test findings indicate that yield strain, yield strength, strain at break and strength at break decrease with increasing cassava peel powder content. An appreciable rise in the elastic modulus was attained as the amount of cassava peels increased. The yield strength of pure HDPE is 22.15 MPa; at 6% weight, it rises to 24.05 MPa; at 12% wt of CaPP, it decreases to 22.02 MPa. At yield, HDPE elongation is 22.98%, while at break, it is 54.81%. The elongation was reduced by the addition of CaPP to 7.19 and 12.78% at the yield point and break respectively, at 12% loading. The greatest percentage drop is 68. 71 % for elongation at yield point and 76.68 % at point. Tensile strength at break for pure HDPE was found to be 19.50 MPa, but at 12% weight, this value decreased to 17.53 MPa. The high hydrophilic character of cassava peels is responsible for the loss in tensile strength when CaPP increases.

Oladele *et al.* (2020) carried out an investigation on the influence of chemically treatment palm kernel shell fiber (PKSF) and particulate cassava peel (PCP) as hybrid reinforcements on some selected mechanical properties and wear behavior of PKSF/PCP hybrid reinforced epoxy composite. Open mould technique was used to develop the composites by intermingling fixed amount of PKSF in both treated and untreated conditions into varied amount of epoxy and PCP, respectively. The cured samples after 28 days were tested for tensile, flexural and wear properties. From the results, it was discovered that, chemically treated PKSF/PCP hybrid reinforced samples notably performed better than the untreated PKSF/PCP hybrid reinforced counterparts in tensile and hardness properties. The addition of chemically treated PKSF/PCP hybrid reinforcement into the epoxy matrix brought about some significant improvement in the stiffness of the composites which made them have better resistance to deformation under different

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loading conditions for the estimation of young's modulus of elasticity and flexural strength at peak and wear.

In a study by Joe *et al.* (2022) the composites were prepared from cassava peel, eggshell and high- density polyethylene (HDPE) using an injection moulding machine. The study looked at how the mechanical, water absorption and biodegradable qualities of HDPE composites were affected by loadings of 30% for eggshell powder (ESP) and 10, 20, 30 wt.% for the cassava peel powder (CPP). The tensile strength, tensile modulus, elongation-at-break, flexural strength, flexural modulus and impact strength all significantly decreased as the amount of cassava peel powder increased, according to the results of the mechanical characteristics analysis. According to the findings, the polymer matrix significantly improves the retarded mechanical characteristics when CPP and ESP are included.

2. MATERIALS AND METHODS

2.1 Materials

Cassava Peel, Weighing Balance, Sodium Hydroxide (NaOH), Universal Indicator Paper, Distilled Water, Stirring Rod, Beakers (500ml), Bakers (500ml), Volumetric Flask (1000ml), Pure Low-density Polyethylene (LDPE).

2.2 Sampling

Pure Low-density Polyethylene (LDPE) was acquired from A.A.M. PLASTICS LTD, Bh 8/9 Kurmin Mashi off Nnamdi Azikiwe Bye Pass Kaduna, Nigeria, Industrial Area in the city Kaduna, state Kaduna. Cassava peels, were obtained from Sabon Tasha Kaduna state, washed, dried and pre-sized to *70 μm* in a local milling machine shop.

2.3 Alkaline Treatment of Cassava Peels

Exactly 20g of NaOH pellets was transferred into a 1000ml volumetric flask and dissolved in distilled water to fill up the mark so as to prepare a 2% NaOH solution. Then 300g of the cassava peels was weighed and soaked into different 500ml beakers containing the already prepared 2% NaOH solution. After 2 hours of stirring with a stirring rod, the mixture was soaked. Following its removal from the beakers, the treated fiber was rinsed with tap water and distilled water until an indicator paper test revealed a pH of 7.0, indicating a neutral state. To guarantee total moisture removal, the treated fiber was gathered on aluminum foil and oven dried for 12 hours at 105^{o}C. After removing the dried sample from the oven and treating the cassava peels, a crushing machine was used to reduce the sieve size to 75 μm (Kambai *et al*., 2024).

2.4 *Functional group analysis*

To analyze the structural modifications in Cassava Peels, infrared (IR) spectra for both alkaline treated samples were obtained using an Agilent ATR-FTIR spectroscopy instrument. The procedure involved first powering on the Agilent ATR-FTIR instrument and allowing it adequate time to warm up before calibration. Calibration settings were adjusted to a sample scan of 30, a background scan of 16, with a scanning range from 4000 cm^{-1} to 650 cm^{-1} and a resolution set at 8, under a system status classified as Good. Upon opening the sample compartment, a small quantity of the sample was carefully placed on the ATR crystal surface. The compartment was then securely closed, ensuring direct contact between the sample and the ATR crystal, by tightening the knob. The measurement process was then initiated, allowing the instrument to record and produce the infrared spectrum of the sample. This spectrum illustrates the absorption patterns of infrared light by the functional groups present within both the treated Kenaf fiber and the rice husk filler transitioning from untreated to treated states, as documented in the studies by Nathan *et al*. (2023).

2.5 *Compounding and Processing of Composite*

The low-density polyethylene matrix in the composite has a density of 0.91-0.94g/cm^3, whereas the treated cassava peel powder filler has a density of 0.9g/cm^3.
The table below shows the various formulations for the six samples that were developed

Table 1. Composite Composition for Low Density Polyethylene (LDPE) with Cassava Peels Preparation.

Sample ID	Mass of LDPE matrix in grams	Mass of cassava peel powder in grams	Weight percentage of filler/ matrix
1	100	0	0%/100%
2	90	10	10%/90%
3	80	20	20%/80%
4	70	30	30%/70%
5	60	40	40%/60%
6	50	50	50%/50%

Figure 1. Two-roll Mill used for mixing filler and the polymer pellet

A two-roll mill was used to compound the size screened and processed cassava peel powder with low density polyethylene. For ten minutes, the two-roll mill was heated to 180 ^{o}C, which is the processing temperature for low density polyethylene. After this time, 90% of the LDPE was added to the heated two roll mill, which melted approximately five minutes. Next, 10% of the powdered cassava peel was gradually added to the melted LDPE until the filler and matrix were completely mixed. Ultimately, a sheet was formed by scraping the combined LDPE and cassava peel powder

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from the mill. The hydraulic compression molding machine was heated to 150 for 30 minutes. The compounded sample is then put into a rectangular mold that has been wrapped in aluminum foil and has a uniform thickness of 3mm. To facilitate the removal of the composite after processing, processing oil also known as release agent was rubbed on the mold. The prepared mold was placed inside a heated compression molding machine and given time to cool before the composite sample was taken out of the mold. The process was carried out once more for 20 wt%/80 wt %, 30wt %/70 wt %, 40wt%/60wt% and 50wt %/50wt% of cassava peel and matrices of LDPE (Kambai *et al*., 2024).

Figure 2. Press board samples of control (white) and LDPE/CP composites (brown)

2.6 Mechanical analysis

Tensile, flexural and hardness properties of the formulated samples were examined. The average specimen dimensions met the ASTM requirements for polymers' tensile qualities. Test specimen for tensile strength: 3mm in thickness, 40mm in gauge length, 30mm in grip length, 15mm in width, 10mm in reduced width.

2.6.1 Tensile strength

The tensile strength was carried out in accordance with ASTM D-638 (Kambai *et al*., 2024).

The actual procedure is to apply the stretching (tensile) load to the sample starting from a low value to ultimately a value when the sample fractures by breaking into two pieces. The dimension of the samples was 120mm x 150mm and 3mmthick.

At break: this is the maximum tensile stress obtained at the failure of the sample.

Percentage Elongation: is the elongation of a test specimen (at yield or break) expressed as a percentage of the original gauge length.

$$\text{Tensile Stress} = \frac{\text{Force (N)}}{\text{Area (m}^2\text{)}}$$

$$\text{Tensile Strain} = \frac{\text{Extended Length}}{\text{Original Length}}$$

$$E = \frac{\Delta L}{L}$$

Percentage elongation: is the ratio of extension of original length multiplied by 100

$$\%\text{Elongation} = \frac{\Delta L}{L} \times 100$$

Young Modulus: is the measure of the ability of a material to withstand changes in length when under length wise tension or compression. It is also equal to the longitudinal stress divided by the strain.

$$\text{Young Modulus= (MPa)} \frac{\text{Tensile Stress}}{\text{Tensile Strain}}$$

2.6.2 Flexural strength

The flexural strength test on the blends was carried out in accordance with ASTM D-790. The specimen measuring 100 mm × 25 mm × 3.2 mm was placed on a support span horizontally at 80 mm gauge length and a steady load was applied to the centre by the loading nose, producing three-point bending until the sample specimen failed. The maximum load (N) and the corresponding deflection (mm) were recorded accordingly as the sample specimen failed (Kambai *et al*., 2024). The flexural strength and modulus were calculated using equations 1 and 2, respectively.

Flexural Strength =$3FL/2bd^2$ (MPa)… …….. (Eq 1)
Flexural Modulus = $FL^3/4bd^3D$ (MPa)…….. (Eq 2)
Were,
F = Maximum Load at break
L = distance between the support spans at both edge of the specimen = 80mm
b = Sample width = 25mm
d = Sample thickness = 3.2 mm.

2.6.3 Hardness

The hardness test was carried out in accordance with ASTM D2240 on a Mico Vicker Hardness Tester. The test
was carried out at different positions on each sample, and the average hardness was calculated using equation 3

$$\text{Average Hardness} = \frac{1st + 2nd + 3rd}{3} \text{ (Hv)}\ldots\ldots\ldots\ldots \text{ (Eq 3)}$$

(Kambai *et al*., 2024)

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3. RESULTS AND DISCUSSION

3.1 ATR-FTIR spectrum of treated Cassava peel

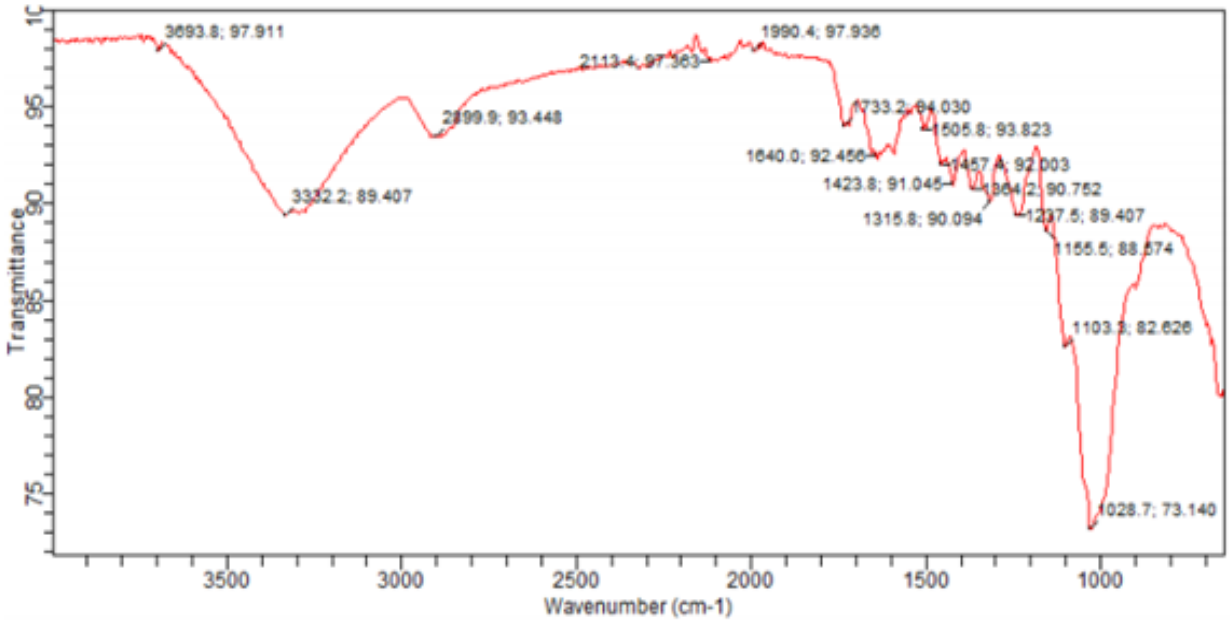

Figure 3: ATR- Fourier transform infrared spectroscopy of treated cassava peel.

Analyzing the ATR-FTIR spectra of various samples, including cassava peel, revealed distinct vibrational bands characteristic of cellulose, hemicellulose, and lignin. The observed vibrational bands across a spectral range from 3500 to 3100 cm^{-1}, demonstrating O-H stretching vibrations, indicate the presence of hydroxyl groups engaging in hydrogen bonding in all specimens. The variety in peak width within this range points to a complex interplay of both intermolecular and intramolecular hydrogen bonds, shedding light on aspects like cellulose crystallinity and the intricacies of its hydrogen bonding network. The presence of a subtle peak around 2900 cm^{-1} across the samples hints at the stability of cellulose's chemical structure post-treatment, suggesting negligible alterations to its alkyl or methylene groups. Significantly, peaks at 1730 cm^{-1} are indicative of C=O stretching vibrations within carbonyl groups, underscoring the presence of hemicellulose through potential C-O stretching vibrations. Similarly, the detection of peaks between 1620 and 1550 cm^{-1}, attributed to C=C stretching vibrations in aromatic rings, validates the presence of lignin within the samples. Peaks observed within the 1245 to 1265 cm^{-1} range are likely linked to C-O stretching vibrations, potentially associated with glycosidic linkages in cellulose. Furthermore, peaks observed in the 902 to 870 cm^{-1} range, denoting alpha glycosidic linkages within cellulose glucose units, were consistent across all samples, indicating minimal effects on the cellulose structure due to treatments. This comprehensive analysis echoes the findings of prior studies (Inuwa *et al*., 2014; Nur *et al*., 2014; Wang *et al*., 2020; Basri *et al*., 2021; Majid *et al*., 2016), which related the specified wavenumber ranges to O–H stretching and bending, in addition to bands linked to C–H stretching, C=O stretching, the benzene skeleton, and C–O stretching vibrations. This correlation enhances the understanding of the vibrational behavior exhibited by the samples under investigation (Kambai *et al*., 2024).

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3.3 Mechanical analysis test results.

Table 2: Shows the UTS, Modulus of Elasticity, % Elongation, Flexural Strength, Flexural Modulus and Hardness Test Results

Sample (wt %)	Ultimate Tensile Strength (UTS) (N/mm)	Modulus of Elasticity (N/mm)	% Elongation	Flexural Strength	Flexural Modulus	Hardness
100% LDPE	17.83	0.0172	1037.22	22.22	823.90	10.9
10% C.P/90% LDPE	20.20	0.0178	1132.27	17.660	622.92	16.47
20% C.P/ 80% LDPE	14.17	0.0173	820.673	8.889	442.646	21.43
30% C.P/ 70% LDPE	8.58	0.030	280.986	8.830	313.956	25.67
40% C.P/ 60% LDPE	6.12	0.018	160.628	7.01	263.956	29.47
50% C.P/ 50% LDPE	5.26	0.011	105.213	6.22	184.724	32.67

Composites with LDPE matrix were obtained in different proportions with cassava peel as reinforcement in the proportions of 10,20,30,40 and 50% respectively.

Figure 4a-c shows the pressed board samples of LDPE/CP. *Figure 5a-e* shows the various curve of the LDPE/CP samples. *Table 2* shows the results of the ultimate tensile strength, elongation, young modulus, strain, flexural strength, and flexural modulus and hardness tests of the LDPE/CP samples.

3.3.1 Tensile strength test

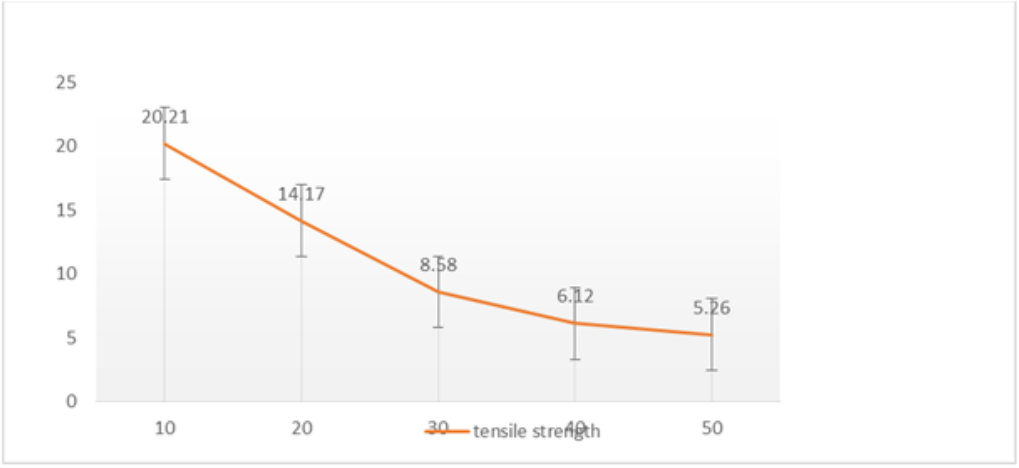

Figure 4a: A graph of tensile strength against concentration

The ASTM D638-02 standard is used to determine the tensile strength of the composite materials. The results obtained exhibit a notable variation based on the quantity of cassava peel filler applied. With the exception of the 10% filler concentration, figure 4 shows that the tensile strength of the bio composite samples was lower than that of the control sample, which was 17.66n/mm². Tensile strength was found to decrease as filler content increased due to an increase in filler-filler interactions. Furthermore, Odetoye *et al.,* (2022) deduced that the sample with the highest filler composition has the lowest average stress at peak, whereas the biocomposite with the lowest filler % weight has the highest average at peak at the very least. This also applies to elongation at peak since increasing loading results in a fall in the matrix's percentage humidity, which lowers elongation and stress at peak. In contrast to filler-matrix interactions, Odetoye *et al.,* (2022) pointed out that this decrease might be the consequence of

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growing filler-filllers interactions. Furthermore, it's linked to inadequate adhesion because of the filler and matrix's different polarities, which can encourage failure.

3.3.2 Hardness Test

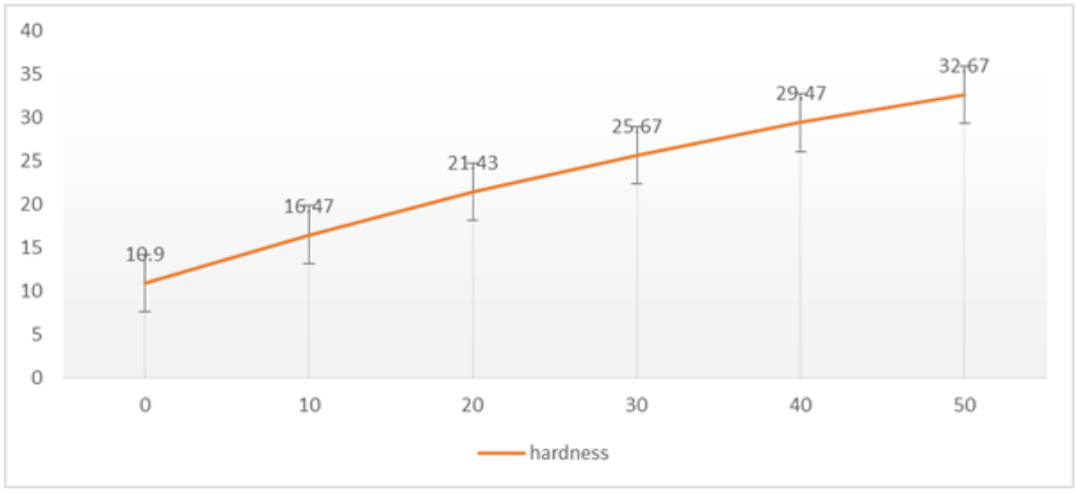

Figure 4b: A graph of hardness against concentration

As per the ASTM D2240-05 standard, the hardness property of composite materials is determined. With the control sample (0% filler content) having the lowest hardness property of 10.93 and the 50% filler content sample exhibiting hardness strength of 32.67, indicating a significant percentage of hardness as filler content rose. This demonstrates that a greater filler matrix interfacial bonding value is responsible for the higher hardness property value. This result is consistent with previous research which found that increased filler content causes increased filler agglomeration, which creates a zone of concentrated stress that needs more energy to propagate cracks.

3.3.3 Flexural Property

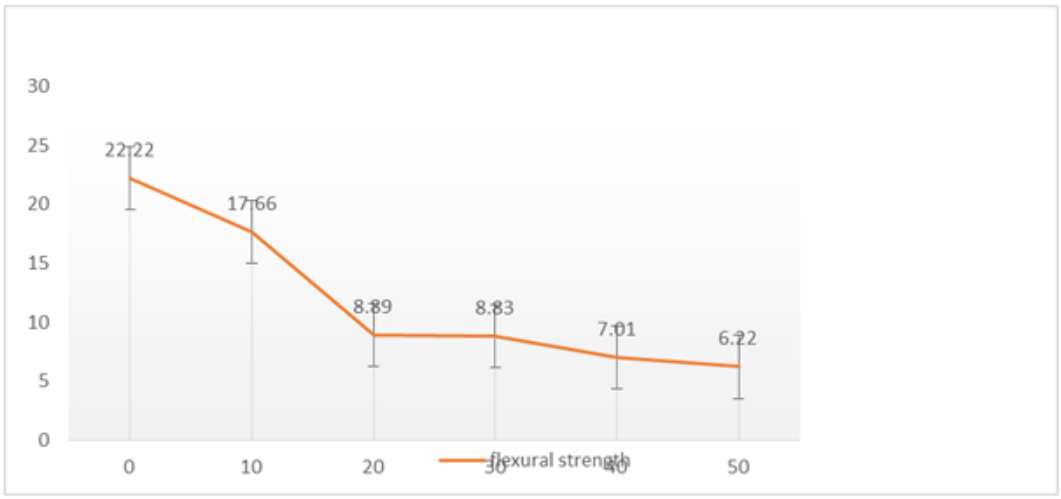

Figure 4c: A graph of flexural strength against concentration

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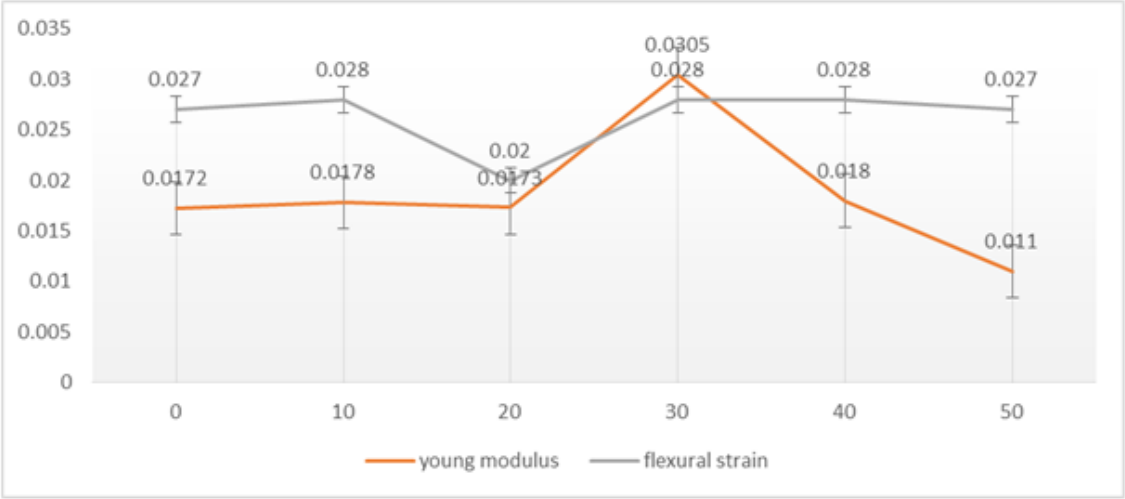

Figure 4d: A graph of young modulus/flexural strength against concentration

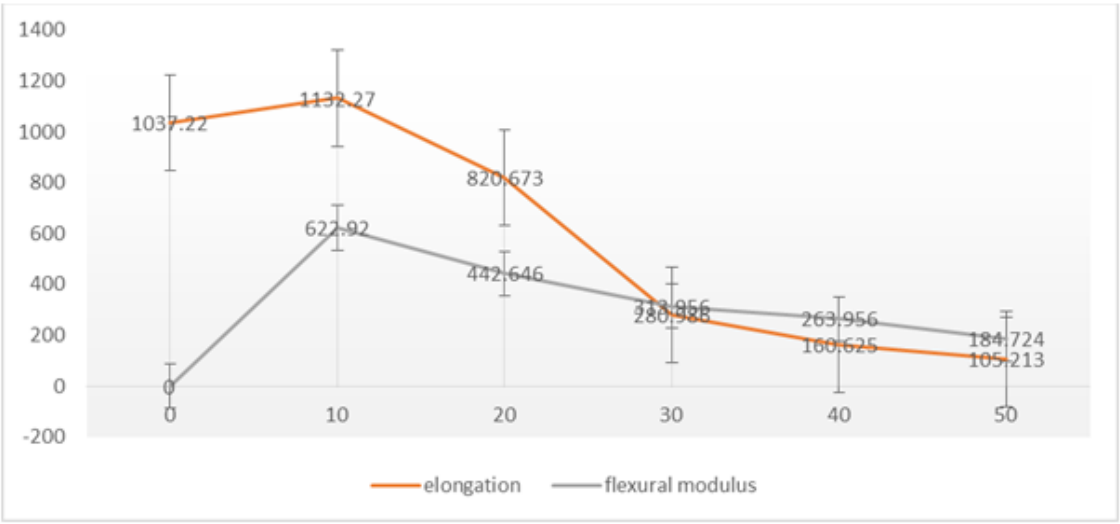

Figure 4e: A graph of elongation/flexural modulus against concentration

The ISO-178 standard is used to determine the flexural property for composite materials. Bio-composites that are intended for use as structural materials must have a specific level of flexural strength. Figure 8 illustrates how the bending modulus declined when additional filler was added; in the control sample, the value was 622.9N/mm^2, but in the 30% sample, it dropped to the lowest value of 313.9N/mm^2. According to Canigueral *et al.* (2009), this pattern is related to the filler particles' improved interfacial interaction with the LDPE matrix. They said that it has been discovered that the stiffness of composites is influenced by the properties if the filler material, filler content and uniformity of the filler dispersion. The low filler quality may be the cause of this reduction in flexural modulus as the filler concentration increases.

5. Conclusion

This study examined the practical effects of cassava peel filler on the tensile strength, hardness, and flexural characteristics of LDPE composites. The purpose of the study was to assess the mechanical characteristics of the composites and determine whether cassava peel could be used as a sustainable filler in LDPE. The findings from the flexural and tensile tests indicated a trend toward a decline in mechanical properties with increasing cassava peel filler content. This decrease can be attributed to the increased fiber content, which causes the materials to become harder, thereby reducing tensile strength and flexural performance. Additionally, the reduction in mechanical characteristics is linked to the degree of matrix and filler adherence. These composites, with their moderate tensile strength and flexural modulus, are well suited for specific applications in various industries where a balance between strength and flexibility is crucial, such as automotive, aerospace, consumer products, and medical devices. The hardness results showed a noticeable increase with higher filler content. This improvement is likely due to better interaction and bonding between the filler and the LDPE matrix, resulting in a tougher, more void-free composite material. These composite materials are ideal for applications requiring increased stiffness, longevity, and wear resistance, such as packaging materials used to protect goods from compression or impact forces. This study

advanced our understanding of LDPE's mechanical characteristics and the use of cassava peel as reinforcement to produce viable composite materials for structural and commercial design applications, such as furniture with improved strength and flexibility. By analyzing these mechanical characteristics, we have significantly expanded the current understanding of polymer composite materials and their potential uses.

Availability of data
Data availability is not applicable.

Funding
This research work is self-funded.

Conflicts of interest
No conflict of interest was associated with this work.

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