International Journal of Information, Engineering & Technology
Volume 12, Issue 7, PP 40-50, ISSN: 2360-9194, July, 2024
DOI: 4272-1454-381-1276
Double Blind Peer Reviewed International Research Journal
Journal Series: Global Academic Research Consortium (garc)
arcnjournals@gmail.com
https://arcnjournals.org

Determination of the Tensile Strength and Flexural Strength of Polypropylene Filled Doum Palm Shell Particles and Sugarcane Bagasse Composite

Ruqaiy A. Kyari[1]* Isuwa S. Aji[2] and Mohammed Dauda[3]
[123]Department of Mechanical Engineering, University of Maiduguri, P M B 1069 Borno, Nigeria

***Abstract**: To make polymers more suited for use in engineering applications, particulate fillers are added to them to enhance their mechanical and physical characteristics. Particles from Doum Palm Shell Sugarcane Bagasse reinforced composite was created by compressing a polypropylene matrix at 10-50 wt %. Doum palm shell particles and sugarcane bagasse at 5-wt% intervals for 150 µm. particle sizes. The study focused on the effect of particle loading on the composite's tensile and flexural properties. The results revealed that Tensile strength of pure polypropylene increased from 23.29 MPa to a maximum of 28.89 MPa at 20 wt %. The flexural strength of a pure polypropylene increased to 41.41 MPa to a maximum 35.55 MPa at 30% wt %. The Doum Palm Shell particles and the matrix exhibit strong interfacial bonding, as seen by the composites' SEM pictures. Doum palm shell particles and sugarcane bagasse are worthy reinforcements for polypropylene in order to create stronger, lighter, and more affordable composites that may be used in automotive applications.*

***Keywords:** Doum palm shell particles, sugarcane bagasse, polypropylene; particle loading; tensile and flexural properties.*

1. Introduction

The biodegradable and environmentally friendly properties of natural fiber/filler composites, together with their high strength and stiffness, make them a promising option for reinforcing materials in polymer matrix composites (Seth et al., 2018). The increased interest in composites has been prompted by growing demand for environmentally friendly resources, mounting Prices for petroleum-based polymers, and imposing environmental limitations (Audu et al., 2019a). Polymer composites are made up of polymers as the matrix and one or more fillers or fibers added to fulfill certain requirements, such mechanical and physical qualities, enhanced thermal qualities, reduced weight, and resistance to wear. Composites used in vehicle and aircraft applications, for example, must have strong for both thermal and mechanical qualities. Historically, glass or carbon-based synthetic fibers were utilized as composites' reinforcement and have the ability to create superior qualities. Nevertheless, with rising globally environmental concerns, its delayed biodegradability is a drawback. As a result, researchers are discovering more workable methods to improve polymeric composites' biodegradability. Natural fibers and fillers have good potential as polymer reinforcements because of this. The main benefits of utilizing natural fibers or composite fillers are used because of their low cost, low weight, non-abrasive, and non-hazardous properties., and above all their capacity to hasten the polymeric composites' biodegradability. It has been determined that, in comparison to the use of metals, composite materials have the potential to greatly lower the weight and cost of car vehicles. Reducing vehicle weight to conserve fuel is the primary goal for developing novel materials for automotive applications (Getu et al., 2020)

Particulate reinforcement of polymers is crucial for enhancing their both physical and mechanical characteristics, attributes including hardness, impact strength, resistance to abrasive wear, etc., making them more suitable for use in applications in engineering. Particles incorporated into the polymer matrix can regulate a polymer's mechanical properties. Fillers have an impact on many other aspects of composite materials, including solidity, density, and cost reduction. The mechanical behavior of composites made of polymers is significantly impacted by the effects of particle/filler loading, fiber length, fiber orientation, and fiber (Audu et al., 2019b).

Doum palms (Hyphaene thebaica) are desert palm trees that is mostly found in the Nile Valley. It bears edible, egg-shaped fruit. In Nigeria's north, it produces exceptionally well. As "Goruba" in Hausa, it is widely recognized. Members of the Arecaceae family of palms, including the doum palm, typically grow in regions with groundwater. Reportedly, it is among the world's most advantageous plants. The doum palm's leaves can be eaten, and their stem can be used to build structures. The leaves is also used to make mats, ropes, baskets, and hats (Hossam et.al.,2018).

Bagasse is the excess of 30 % that remains after the crushing of the sweet cane stalk in sugar or alcohol mills. The bagasse is obtained from several parts of the cane stalk, such as the outer rind and the crushed inner pith (Abedom et al., 2021). Bagasse is composed of pith and fiber, with the fiber having thick walls and a length of 1.4 mm. Polypropylene (PP) is a polymer synthesized catalytically from propylene. PP has the lowest density among commodity plastics. PP has a high resistance to chemicals and may be changed using a number of techniques, such as extrusion and injection molding. PP is utilized for several elements of the automobile. Dashboards, batteries, air conditioning ducts, doors, and quarter panels are some of the locations that are used in cars (Adediran et al., 2022).

The present research aims to produce a composite using Doum palm shell particles, Sugarcane Bagasse as reinforcement, and polypropylene as the matrix. It also aims to examine the effects of Sugarcane Bagasse and Doum palm shell particle loading on the composites' tensile and flexural properties in order to utilize agricultural waste.

2. Methodology

2.1 Materials.

The following raw materials were used in carrying out this work:

i. Doum palm shell (i).
ii. Sugarcane Bagasse
iii. Distilled water
iv. Sodium Hydro-Oxide (NaOH)
v. PH paper
vi. Polypropylene with Melt flow: 12 g/10 min, density: 0.905 g/cm3, and melting temperature: 135–171^{0}C

2.2 Equipment; Various equipment with their specification were used in carrying out this work as shown in table 1.

Table 1: Equipment and Specifications

Equipment	Specification
Tensile Testing Machine	Hounsfield (Monsanto) Tensiometer (Universal Testing Machine) (model No. D-100KN (SN:190536)
Flexural Strength Machine	Universal Material Testing Machine CAT. NV. 261.
Two-roll mill	Two-roll mill, North Bergen, U.S.A(Model: 5183)
Electronic Hydraulic Press	Carver hydraulic press with model No. 3851-0.
Standard sieve	Standard set of Sieves 150 µm size

2.3. Doum Palm Shell Particle Preparation

2.3.1 Doum Palm Shell Particle Extraction and Preparation

The Doum palm was collected from Gamboru (Custom) market Maiduguri. The edible sections of the fruit and seed were removed, then the shell was weighed and sun-dried for 24 hours to minimize any residual moisture. The dried Doum palm shell was shredded into smaller components and milled into particle form using a laboratory milling machine (Mekins Agro Products Ltd Model No 150). The powdered Doum palm shell were sieved separately using ASTM sieve size 150 µm because smaller particles perform better when it comes to bonding (Audu et al., 2019). Figure 1 depicts the Doum palm fruits, shell, and particles prepared.

Figure 1: (a) Doum palm fruit (b) Doum palm shell (c) Doum Palm Particles

2.3.2 Extraction, Treatment and Preparation of Fiber

The bagasse fibers were collected from Baga Road market in Maiduguri, weighed to 500.50grms and chemically treated by immersing it in a 10% NaOH alkaline solution for three hours to remove celluloses and hemicelluloses (Putra & Anggono, 2020).Then, it was filtered, washed with distilled water severally until the colour of the filtrate become clear and the pH of the filtrate is approximately 7.0 so that it will be free from alkali. Then followed by drying up under the sun for 48hrs (Abedom et al., 2021). The dried fibre was pulverized into particulate form using laboratory milling machine (Mekins Agro Products Ltd Model No 150) and then sieved separately using ASTM sieve size 150 µm because smaller particle size provides higher compaction and lower porosity, which allows for efficient stress transmission between the particles and the matrix (Samuel et al., 2018).

2.4 Composite preparation

Sugarcane Bagasse, Doum palm shell particles and polypropylene were combined in a two-roll mill. To ensure that the molten polymer could flow properly, polypropylene was melted before Sugarcane Bagasse and Doum palm shell particles was added, which served as reinforcing components for the composite. The composites samples were developed using a melt mixing procedure that involved the injection of a polymer (PP) pellet while the rollers of the two rolls mill machine were in counter clockwise motion and softened for 5 minutes at 190 °C and 45 rpm rotation. The composite obtained from the mixing procedure was inserted into a metal mould with dimensions of 140 mm × 120 mm x 3.2 mm and placed on the hydraulic hot press (Compression Moulding Machine) for shaping at 160 °C and 2.5 MPa for 5 minutes. It was allowed to cooled at room temperature, removed from the mould and labelled accordingly. The Bagasse were utilized with Doum palm shell at a 50:50 percent weight ratio ranging from 10-50% of the total weight while PP were varied in the composite till a suitable mixture is obtained. The composites formulation is shown in Table 3.2. Five specimens for each sample (DPS/SCB A, DPS/SCB B, DPS/SCB C, DPS/SCB D and DPS/SCB E) were tested and average properties were calculated. Figure 2 depicts the formulation of composites.

Figure 2:(a) Doum Palm particles (b) pulverized Bagasse (c) Polypropylene

(d) Composites

Control sample was first prepared thereby taken different ratios at equal intervals as prepared in this formulation of this composites material as depicted in table 2.

Table 1: Formulation Table

Sample	Bagasse (SCB) and Doum Palm Shell (DPS) (50:50% weight)	Polypropylene (% weight)
Control	0	100(500.50 grms)
DPS/SCB A	10	90
DPS/SCB B	20	80
DPS/SCB C	30	70
DPS/SCB D	40	60
DPS/SCB E	50	50

2.5 Characterization of the Composites

2.5.1 Determination Tensile Properties

Tensile Strength refers to the maximum stress a material can endure before breaking when stretched or pushed. The tensile characteristics of randomly oriented fibre composites were investigated utilizing a Universal Testing Machine with a constant rate of traverse of the moving grip. Tensile force was applied to the specimen until failure was seen. The tensile strength was determined using ASTM D-638 standards. Tensile tests were conducted on dumbbell-shaped samples with gauge measurements of 50mm x 10mm x 3.2 mm. Five samples was carried out for the test. The equipment directly determined the Tensile strength, modulus, and elongation at break using a computer display coupled to the universal testing machine.

2.5.2 Determination Flexural Strength Properties

A composite's flexural strength is the maximum tensile stress it can withstand when bending before breaking. Flexural characteristics were evaluated with a Universal Testing Machine. Flexural strength was measured in line by ASTM D-790. Five samples measuring 100 mm x 25 mm x 3.2 mm were placed horizontally on a support span with an 80 mm gauge length, and the loading nose applied a steady force to the center, resulting in three-point bending, which caused the specimen to collapse. When the sample specimen failed, the machine quickly determined the maximum load (N) and corresponding deflection (mm) using a computer display connected to the universal testing machine. Furthermore, to confirm the flexural strength and flexural modulus were computed using the equation below Karaoui et al., (2023)

Flexural Strength = $3FL/2bd^2$ (MPa) ……………………………………………………….(3.1)

Flexural Modulus = $FL^3/4bd^3D$ (MPa) …………………………………………………. (3.2)

Where;

F = Maximum Load at break

L = the distance between the specimen's two edges' support spans. = 80mm

b = the sample width 25mm

d = sample thickness 3.2 mm

2.5.3 Analysis of Microstructure

Scanning electron microscopy (SEM) with the Phenom pro X model was used to investigate the interior microstructure of the composites under a microscope. Using magnifications ranging from 20 to 100,000 times, surface electron microscopy (SEM) produces larger topographical images of a material's surface. In this investigation, 1000 times magnification was used for the captures.

3.0 Results and Discussion

3.1 The Effects of Doum Palm Shell Particle Loading and Sugarcane Bagasse Tensile Properties

Figure 3.1 depicts the loading of Sugarcane Bagasse and Doum palm shell particles affects the tensile strength of the Sugarcane Bagasse and Doum Palm shell particles. Tensile strength was maximum at 20wt%. It was shown that when fiber loading was increased from 0% to 20% resulted in an initial 80% improvement in tensile strength, which thereafter decreased as particle loading rose. At 30wt% and 50wt% fiber loading, strength was reduced by 27.07MPa compared to pure PP. This might be due to particle agglomeration, which inhibits load transmission from the particles to the matrix, allowing fractures to easily develop and disseminate. Breaks weakened the strength of the composite. Audu et al.,(2018) and Usman,(2020)

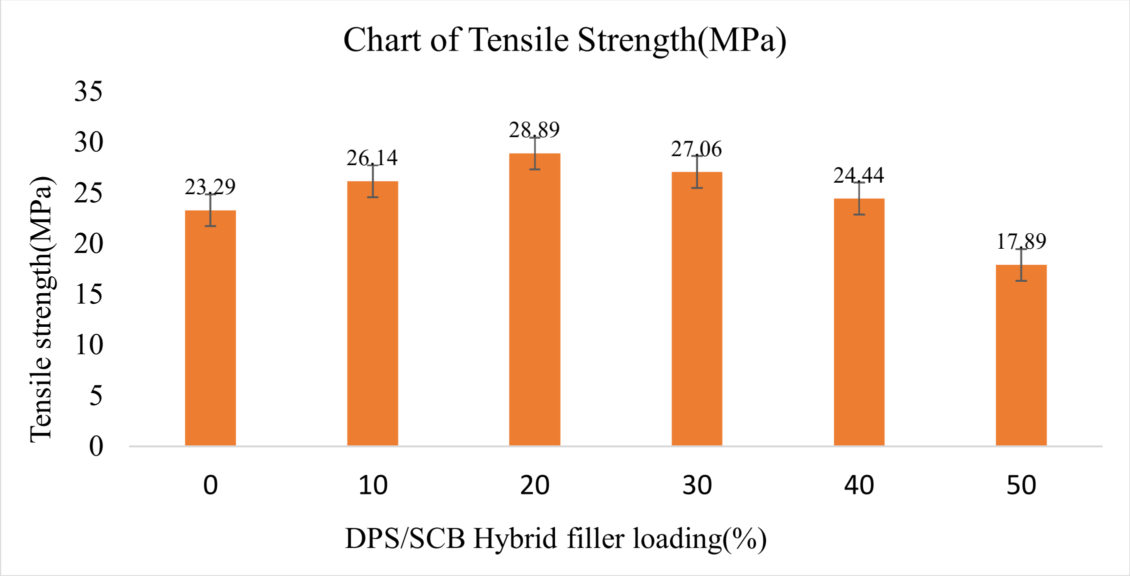
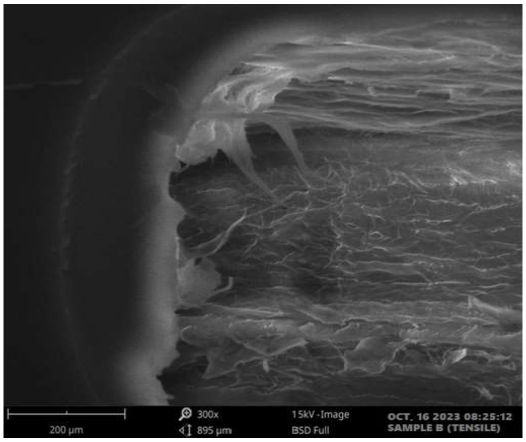
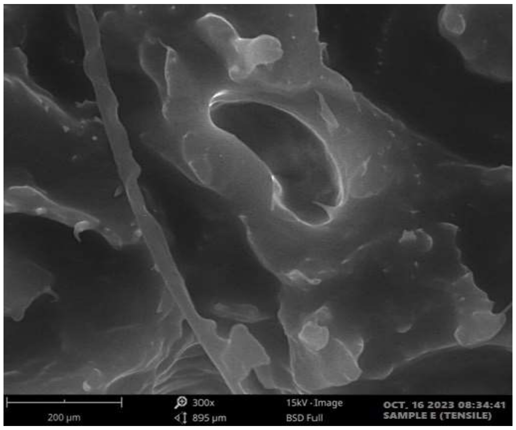


Figure 3. 1: The effect of fiber loading on the tensile strength of DPS/SCB PP composite

The scanning electron microscopy test result in Figure 3.1.1 was obtained when the test was carried out after the failure during the tensile strength test Figure 3.1.1a demonstrates strong interfacial adhesion between Sugarcane Bagasse, Doum palm shell particles and the matrix. These accounts for the excellent mechanical properties. Figure 3.1.1b demonstrates inadequate blending of the composite materials. Weak interfacial bonding results from the particles removing themselves from the Polypropylene surface of the matrix Balogun et al., (2023).



(a) 20wt% for Tensile Strength



(b) 50wt% for Tensile Strength

The composite's Tensile Modulus increases when particles are introduced into the matrix. Figure 3.1.2 shows how DPS/SCB particle loading affects the tensile modulus of the composite. The reinforced composite has a greater tensile modulus than the plain composite, with a 61% rise when the fiber loading is raised from 0 to 40wt%. The composite exhibits the maximum modulus at 40 wt.%, which gradually decreases as Particle loading increases. This experimental results might be associated with the fact that the stiffness of the composite increases with the addition of Sugarcane Bagasse and Doum Palm shell particles. This outcome confirms the results of Onuegbu et al.,(2017) and Adebisi et al.,(2021) who observed that introducing egg shell particles with polypropylene improved tensile modulus composite material.

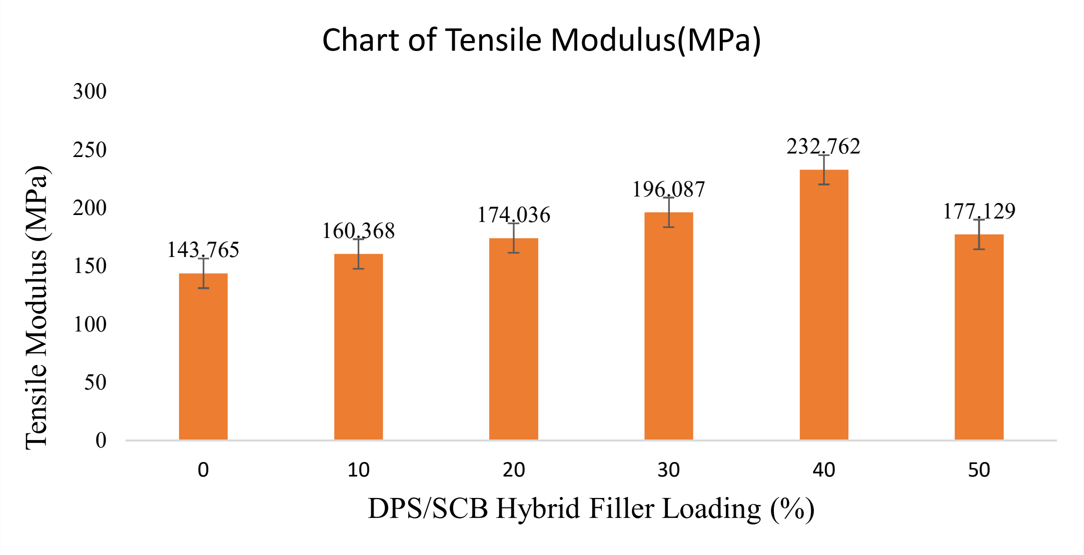


Figure 3.1.2 (a): Effect of fibre loading of the Tensile Modulus of DPS/SCB/ PP composite

Elongation at break decrease when the matrix's particle content was introduced. Figure 3.1.2b Elongation at break decreases with filler content, reflecting lower ductility of the material as filler quantity increases (Okeke et al., (2020); Achukwu, (2020). The elongation at break of the composite reinforced material exceeds that of the pure composite that is there was an increase of 97% at 20wt% recording the highest average elongation of 16.6% and a decrease at 50wt%.

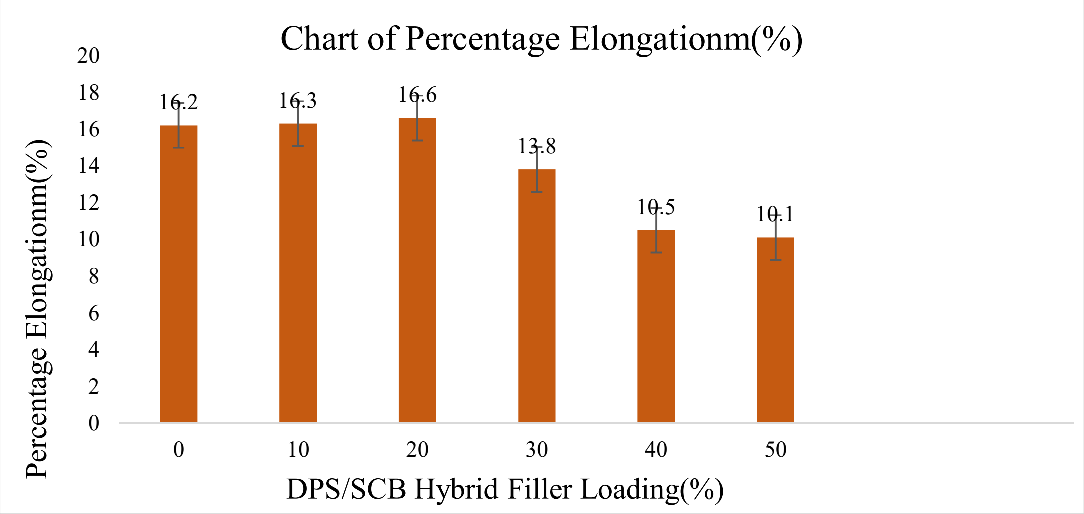


Figure 3.1.2 (b): Variation of elongation with fibre loading

3.2 Effect of Doum Palm Shell Particle and Sugarcane Bagasse and Loading on Flexural Properties.

Figure 3.2 demonstrates Flexural Strength of a Sugarcane Bagasse and Doum Palm Shell particle composite with different loadings of particles. Flexural Strength of Sugar Cane Bagasse and Doum Palm shell reinforced polypropylene composite increased from 37.98 MPa at 10wt% to an average of 41.41 MPa at 30wt% compared to neat PP, indicating an 86% increase when fiber loading was increased from 0 to 30wt% and then decreased to 36.19 MPa at 50wt% particle reinforcement. The decrease in strength is due to void content or fracture formation at the composite the interface, the particle's inability to bear stresses transfer from the matrix, and weak bonding at the interface between particle and matrix materials, all of which contribute to a weak structure. The introduction of particles increased the composites' flexural modulus. The introduction of sugarcane bagasse and Doum Palm shell particle in matrix restricted polymeric chain mobility due to the increased stiffness of the composites Ali et al., (2020).

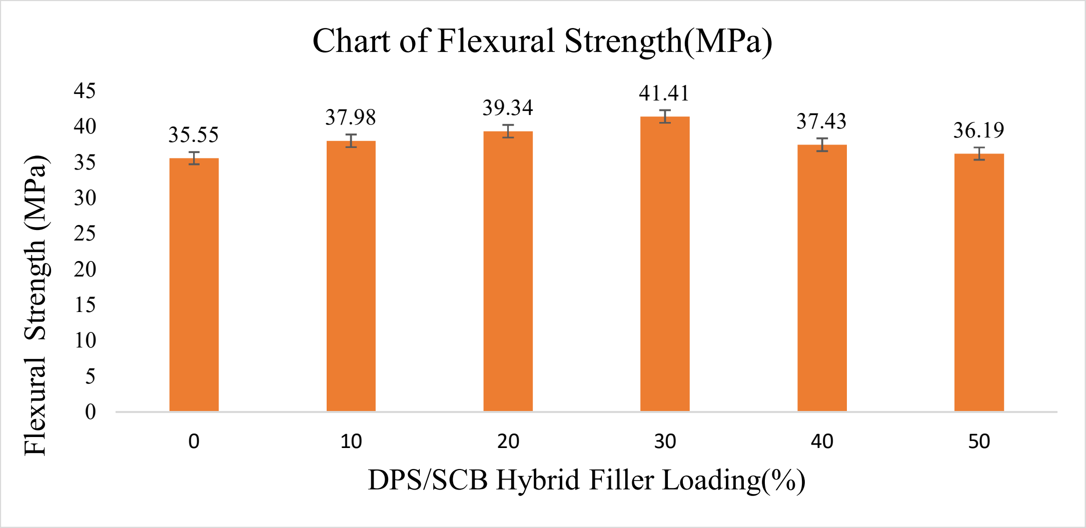
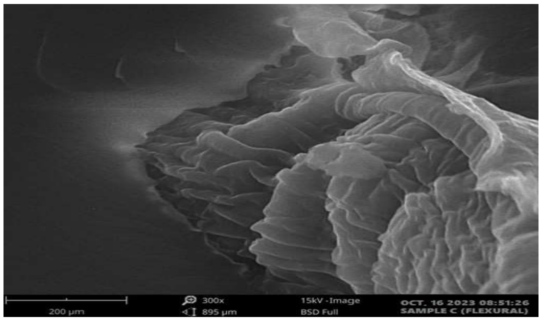
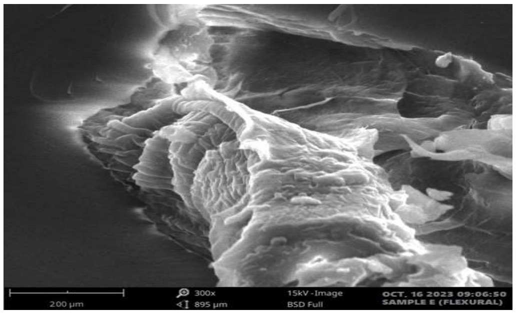


Figure 3.2: Variation in flexural strength fibre loading

The SEM result with optimum value for flexural strength at 30% and 50% reinforcement loading Figure 3.2.1. Figure3.2.1a demonstrates a poorly connection between matrix and particles. Particle accumulation occurs at some point as a result of inadequate composite mixing. Figure 3.2.1bd exhibits particles and matrix are not well mixed. Certain groups of particles are distributed throughout the matrix, resulting in poor interfacial connection Obidiegwu et al.,(2022).



(a) 30wt% for Flexural Strength



(b) 50wt% for Flexural Strength

The flexural modulus of Sugarcane Bagasse and Doum Palm shell reinforced polypropylene composite follow a similar pattern with the composite's flexural strength, as demonstrated in figure 3.2.2a.

The Flexural Modulus was found to increase with increased fiber loading. It exhibited an increase in modulus value with fiber loading from 1477.75MPa for pure PP to 2025.42MPa at 40wt% fiber loading of PP composites. This might be ascribed to the contribution of fiber. When the fiber loading was increased from 0 to 10wt%, flexural modulus improved by around 63%. Flexural moduli improved much more when loaded above 10wt%. The highest flexural modulus of 2025.42MPa was attained at 40wt% fiber loading, with a gradual reduction at 50wt%. As a result, the improvements in modulus of these composites were caused by increased starting modulus of the fibers functioning as the basic building block of composites, as well as improved Interfacial bonding between fibers and matrix. Furthermore, this might be ascribed to the fibers' contribution of their mechanical qualities to the composites. It is evident that surface treatment significantly affects all composites' modulus strength. Audu et al., (2019).

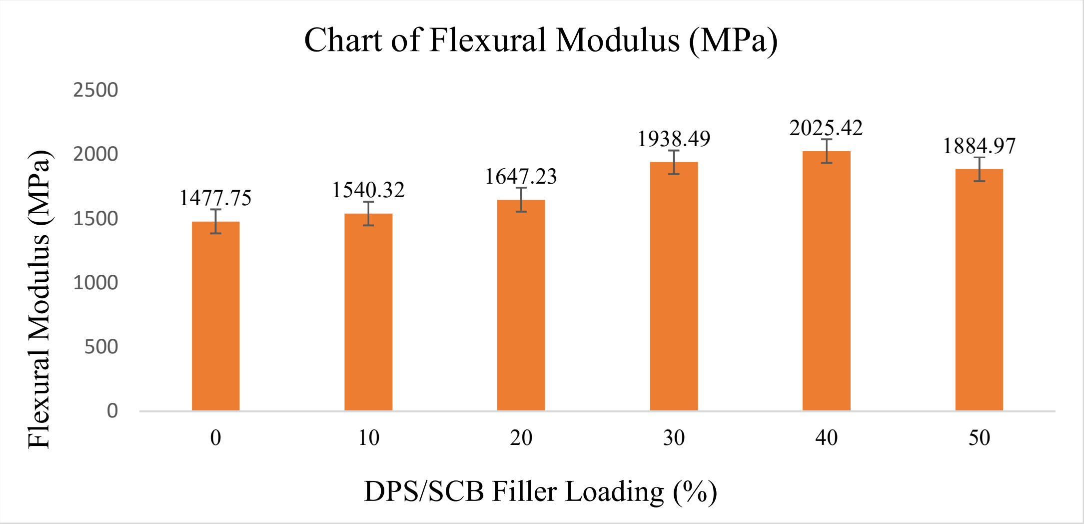


Figure 3.2.2 (a): Effect of fiber loadings on the flexural modulus of DPS/SCB/PP composite

3.3 Conclusion.

The study demonstrates a successful production of a composite from Doum palm shell particles, Sugarcane Bagasse, and polypropylene using a compressive moulding technique. The composite's tensile and flexural properties have been established, as well as the influence of particle loading on these properties. The results reveal that the addition of Doum palm shell particles and Sugarcane Bagasse increased the composite's tensile and flexural capabilities. SEM images of the composites demonstrated significant interfacial contact between Doum palm shell particles, sugarcane bagasse, and the matrix. To summarize, Doum palm shell particles and sugarcane bagasse are suitable reinforcements for polypropylene that may be utilized to make stronger and more inexpensive composites ideal for car applications.

Reference

Abedom, F., Sakthivel, S., Asfaw, D., Melese, B., Solomon, E., & Kumar, S. S. (2021). Developm-ent of Natural Fibre Hybrid Composites Using Sugarcane Bagasse and Bamboo Charcoal for Automotive Thermal Insulation Materials. 2021.

Achukwu, E. O. (2020). Fabrication of palm kernel shell epoxy composites and study of fabrication of palm kernel shell epoxy. January 2015.

Adebisi, A. A., Mojisola, T., Shehu, U., & Adam, M. S. (2021). In-Situ Synthesis and Property Evaluation of High-Density Polyethylene Reinforced Groundnut Shell Particulate Composite. 6, 305–311. https://doi.org/https://doi.org/10.26776/ijemm.06.04.2021.06

Ali, J. B., Musa, A. B., Danladi, A., & Bukhari, M. M. (2020). Physico-mechanical Properties of Unsaturated Polyester Resin Reinforced Maize Cob and Jute Fibre Composite

Amenaghawon, N. A., & Okieimen, C. O. (2016). Production of particle boards from corn cobs and cassava stalks : Optimisation of mechanical properties using response surface methodology. Production of Particle Boards from Corn Cobs and Cassava Stalks : Optimisation of Mechanical Properties Using Response Surface Methodology, 7(4), 1236–1244.

Audu, S., Aje, S., Isuwa, T., & Aji, S. (2019a). Investigation of the Impact , Hardness , Density and Water absorption of Polypropylene Filled Doum Palm Shell Particles Composite. 9(1), 28–37. https://doi.org/10.7176/JIEA

Balogun, O. A., Daramola, O. O., Adediran, A. A., Akinwande, A. A., & Bello, O. S. (2023). Investigation of Jute / Tetracarpidium conophorum reinforced polypropylene composites for automobile application : Mechanical , wear and flow properties. Alexandria Engineering Journal, 65, 327–341. https://doi.org/10.1016/j.aej.2022.10.026

Getu, D., Babu, R., Masresha, M., & Kishan, S. (2020). Materials Today : Proceedings Production and characterization of bamboo and sisal fibre reinforced hybrid composite for interior automotive body application. Materials Today: Proceedings, xxxx. https://doi.org/10.1016/j.matpr.2020.08.780

Hossam S. El-Beltagi, Heba I. Mohamed, H. N. Y. and E. M. F. (2018). Biological Activities of the Doum Palm (Hyphaene thebaica L.) Extract and Its Bioactive Components. https://doi.org/http://dx.doi.org/10.5772/intechopen.74772

Karaoui, M., Hsissou, R., Alami, M., & Assouag, M. (2023). Materials Today : Proceedings Thermal , mechanical , morphological , and structural properties of composites based on polyolefin and biofiller produced from snail shell (PP / SSP). Materials Today: Proceedings, July. https://doi.org/10.1016/j.matpr.2023.07.350

Okeke, P. E., Atuanya, C. U., & Umembamalu, J. C. (2020). Optimization of processing parameters and its effect on the mechanical properties of recycled low density polyethylene composite reinforced with Tetracarpidium conophorum shell particulates Optimization of processing parameters and its effect on the mecha. 1–15.

Okeke, P. E., Atuanya, C. U., & Umembamalu, J. C. (2020). Optimization of processing parameters and its effect on the mechanical properties of recycled low density polyethylene composite reinforced with Tetracarpidium conophorum shell particulates Optimization of processing parameters and its effect on the mecha. 1–15.

Onuoha, C., Onyemaobi, O. O., Anyakwo, C. N., & Onuegbu, G. C. (2017). Open Access Effect Of Filler Loading And Particle Size On The Mechanical Properties Of Periwinkle Shell-Filled Recycled Polypropylene. 4, 72–79.

Putra, B., & Anggono, J. (2020). Reinforcement of polypropylene with alkali-treated sugarcane bagasse fibres : Mechanism and consequences ´ cz o. 200. https://doi.org/10.1016/j.compscitech.2020.108428

Samuel Audu Setha,, Isuwa Suleiman Aji, Aje Tokan (2018). Effects of Particle Size and Loading on Tensile and Flexural Properties of Polypropylene Reinforced Doum Palm Shell Particles Composites American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS) (2018) Volume 44, No 1, pp 231-239

Usman M.A, I. M. and A. O. U. (2020). Mechanical , physical and biodegradability performances of treated and untreated groundnut shell powder recycled polypropylene composites Mechanical , physical and biodegradability performances of treated and untreated groundnut shell powder recycled poly. 1–14. https://doi.org/https://doi.org/10.1088/2053-1591/ab750