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Development and Characterizations of Mechanical Properties of Sisal Fiber Reinforced Recycled Polypropylene Composites (SFRRPPC)

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Abstract: *This study evaluated the mechanical properties of a composite developed from recycled polypropylene reinforced with a blend of sisal fibre at different proportions. Five samples of the composite with different compositions were produced using the compression moulding technique with a consolidation pressure of 2.5 MPa. The homogeneous blend of the sisal fibre and polypropylene was achieved by introducing the recycled polypropylene (PP) while the rolls of the two mill machine were in counter clockwise motion and soften for a period of 5 minutes at a temperature of 190^{o}C. Upon achieving a band and bank formation of the PP on the front roll, the prepared sisal fibre was introduced gradually to the bank, cross mixed and allowed to mix for 3 minutes. The composite was casted and labeled accordingly. The following results were obtained; optimal flexural and tensile strengths at a fibre loading of 10%; optimal impact strength at 30 % fibre loading and optimal average hardness at fibre loading 40%.*

Key words: *Keywords: Composite, Fibre, Mechanical properties, and Strength*

1. Introduction

A composite is an engineered material made from two or more constituent materials with significantly different physical or chemical properties combined together to form a resultant material with features that are different from the individual components. For a long time, fibres such as carbon, glass and aramid have dominated the composite manufacturing sector. This is predominantly because of their relatively superior mechanical and thermal properties. However, with increasing environmental concerns, researchers have investigated the possibility of replacing them with natural fibres in the manufacture of composites. Research has been done using natural fibres such as coir, sisal, banana, jute and investigating the possibility of using them as reinforcements in composites for non-structural applications. Natural fibre-reinforced composites (1) uses renewable raw materials, (2) are combustible, (3) have low density, (4) possess good thermal properties, (5) are bio-degradable, (6) are non-toxic, (7) low cost and (8) have great performance. Therefore, natural fibre reinforced composites form a new class of materials with desired properties which can substitute scarce wood in many non-structural applications such as ceiling boards, walls, room partitioning, door panels, electronic and food packaging (Asdrubali et al., 2015; Bajwa et al., 2015; Ramanaiah et al., 2011).

Sisal fibres on the other hand are extracted from sisal (*Agave sisalana)* leaves. The fibres are hard and are among the widely used natural fibres because of their availability. Each sisal plant produces 200-250 leaves and each leaf contains 1000-1200 fibre bundles (Mukherjee & Satyanarayana, 1984). Sisal fibres can easily be extracted from sisal leaves by retting and decortication. Additionally, the fibres are readily available, cheap, easily biodegraded and are of great performance. Sisal has competitive mechanical properties as compared to some other natural fibres Figure 1.1, shows the composition of a composite material: matrix, reinforcement and the interface between the two.

2. Materials and Methods

2.1. Materials

The materials used in this work include the Fibre material, Matrix material and the Mould material.

2.1.1. Fibre

The Sisal fibre used in the present investigation was sourced from local market. Sisal fiber possessed higher ultimate tensile strength compared to other natural fibers, such as sisal Fibre (polymers).

2.1.2. Polypropylene

In preparation for recycling, the waste PP bottles collected were cleaned with water to remove impurities and subsequently sun dried to ensure no moisture remains. After which, they were shredded into small sizes. This was done for easier melting.

2.1.3. Equipment

The equipment used in this project are given in Table 3.1.

Table 1 Equipment used in PP-Sisal fibre composite fabrication.

S/N	Equipment	Manufacturer/Model No.	Location accessed
1	Two Roll Mill	North Bergen, U.S.A (Model: 5183)	NILEST- Zaria*
2	Compression Moulding Machine	Wenzhouzhiguang Ltd, China (Model: 0557)	NILEST- Zaria
3	Universal Material Testing Machine	Norwood Instruments Ltd, (Cat. Nr. 261)	ABU, Zaria**
4	Digital Weighing Balance	Mettler Instruments Ltd (Model no: AE200)	NILEST- Zaria
5	Microhardness Tester	Vicker Hardness Tester (Model no MV 1-PC)	ABU, Zaria
6	Resil Impact Tester	CEAST Resil Family (6957.0000)	NILEST- Zaria

***NILEST-** Nigerian Institute of Leather and Science Technology, Zaria, ****ABU-** Ahmadu Bello University, Zaria

2.2. Methods

2.2.1. Manufacture of Mold

The mold was constructed according to the shape of the composite to be fabricated. For this work, a square mold of 150 mm x 150 mm x 3 mm dimension was adopted. The mold was produced with the use of a 3 mm heavy gauge iron sheet so that it is not affected by the high temperature during composite manufacture. Hence, the effect of mold bending was eliminated which results in perfect-shaped composite.

2.2.2. Preparation of Composite Moulds

The composites samples were produced by a mixing process involving the introduction of the Recycled Polypropylene (PP) while the rolls of the two rolls mill machine were in counter clockwise motion and soften for a period of 5 minutes at a temperature of 190°C. Upon achieving a band and bank formation of the PP on the front roll, the prepared Sisal fibre was introduced gradually to the bank; cross mixed and allowed to mix for 3 minutes. The composite was sheeted out and labeled accordingly.

The composite obtained from the mixing process was then placed into a metal mould of dimensions 150 mm x 150 mm x 3 mm and was placed in the hydraulic hot press (Compression Moulding Machine) for shaping at temperature of 160^{o}C and pressure of 2.5 MPa for 5mins. The resulting composite was then cooled in a cool compression moulding machine platen under 2.5 MPa pressure at room temperature for 3mins and labeled accordingly.

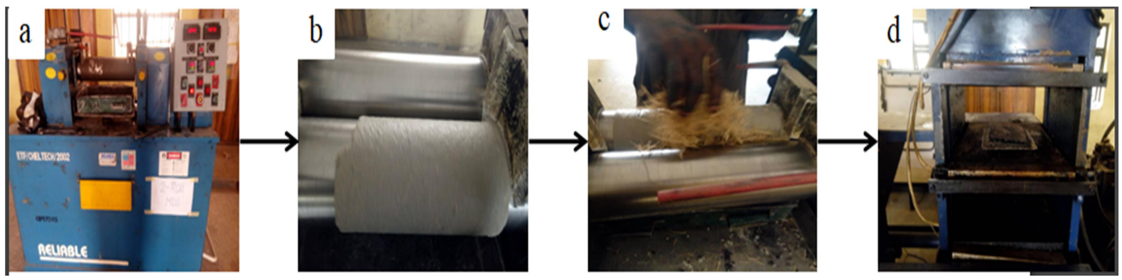


Plate 2 Composite production process; a) Two roll mill machine b) PP compounding c) Mixing PP with Sisal fiber d) Compression Moulding Machine

2.2.3. Characterization Process

The PP-Sisal fibre composite was prepared using randomly oriented fibre and is characterized into samples SF1, SF2, SF3 and SF4 using 10, 20, 30 and 40 % weight fraction of Sisal fiber, respectively. The experimental characterization of PP-Sisal composite was performed by testing the tensile, flexural, impact and hardness properties of the developed composite. These tests were carried on the samples cut from the developed composite as per the relevant ISO and ASTM standards for composite laminates as shown in Table 2. Three specimens from each sample (SF1, SF2, SF3 and SF4) were tested and the average properties were calculated.

Table 2 Test standards adopted

Type of test	**Test Standard**
Tensile test	BS EN ISO 527-2:1996
Flexural test	EN ISO 14125:1998
Impact test	ASTM D256
Hardness test	ASTM D785

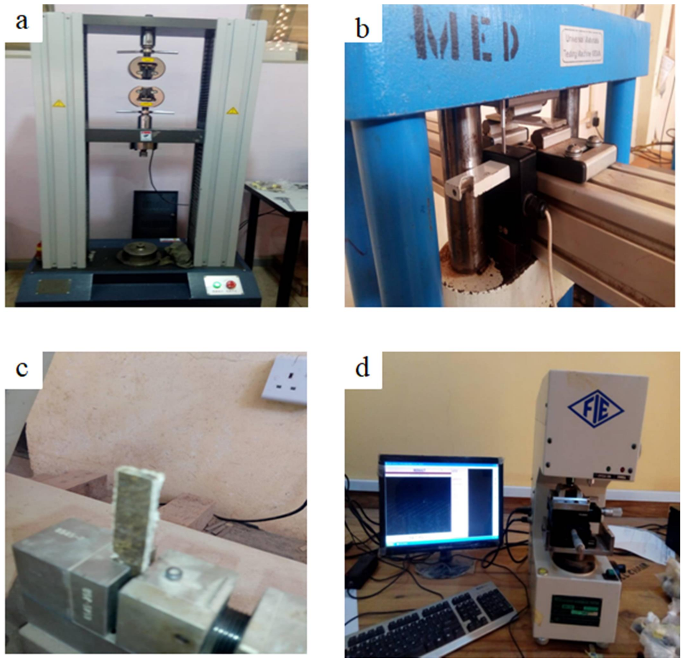


Plate 3 Testing Set-up; a) Tensile test b) Flexural test c) Impact test d) Hardness test

2.2.3.1. Tensile Strength Test

The tensile strength test was carried out using Universal Testing Machine according to ASTM D-638. A dumbbell shaped samples with gauge dimensions 50 mm x 10 mm x 3 mm were subjected to a tensile force and tensile properties such as the tensile strength, % elongation, and modulus for each sample was determined. These were automatically generated by the machine.

2.2.3.2. Flexural Strength Test

The flexural strength test on the blends was carried out in accordance with ASTM D-790. The specimen measuring 100 mm x 25 mm x 3 mm was placed on a support span horizontally at 80 mm gauge length and a steady load was applied to the center 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. The flexural strength and flexural modulus were calculated using the equations;

Flexural Strength = $3FL/2bd^2$ (MPa) …………………………………………… (Eq. 1)

Flexural Modulus = $FL^3/4bd^2D$ (MPa) …………………………………………… (Eq. 2)

Where,

F = Maximum Load at break

L = distance between the support spans at both edge of the specimen = 80 mm

b = Sample width = 25 mm

d = Sample thickness = 3.2 mm

2.2.3.3. Impact Strength

The impact test was carried out according to the ASTM D-156 standard; the specimen was cut to specimen dimension 64 mm x 12.7 mm x 3.2 mm and 45° notched was inserted at the middle of the test specimens from all the produced blend samples. The impact energy test was carried out using Izod Impact Tester (Resil impactor testing machine). The specimen was clamped vertically (IZOD) on the jaw of the machine and hammer of weight 1500 N was released from an inclined angle 150°. The impact energy for corresponding tested specimen was taken and recorded. Impact strength was also calculated and recorded accordingly. The Impact strength was determined using equation;

Impact Strength = $\frac{Average\ Impact\ Energy}{Sample\ Thickness}$ (J/m) .... (Eq. 3)

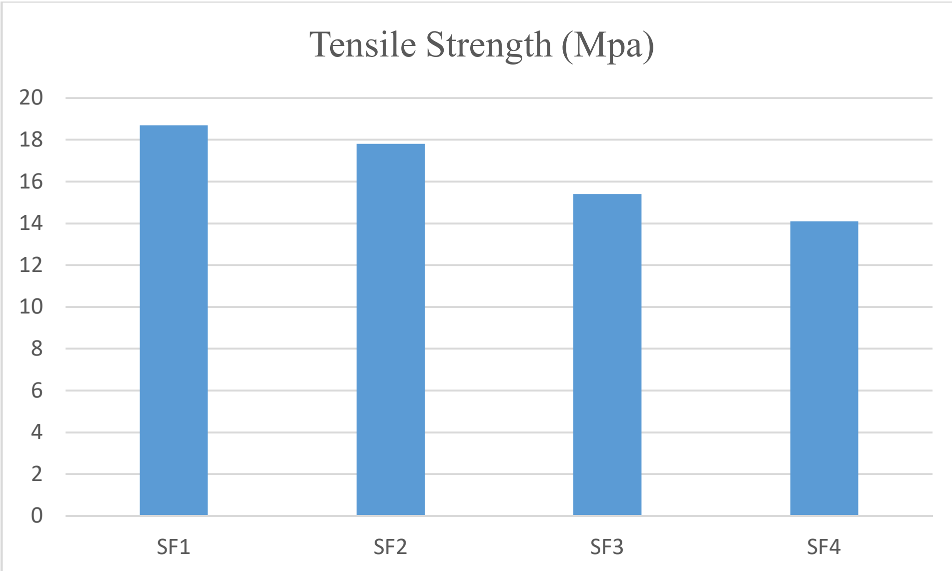
2.2.3.4. Hardness

The hardness test was carried out in accordance with ASTM D2240 standard using Micro Vicker Hardness Tester. The sample measuring 30 mm x 30 mm x 3 mm was placed on the mounting stage and the stage was raised such that the sample come in contact with the dial point and exacts pressure/force on the sample and the reading was taken directly from the system screen. This was repeated three (3) times at different positions on the sample and average hardness was calculated.

4. Results and Discussion

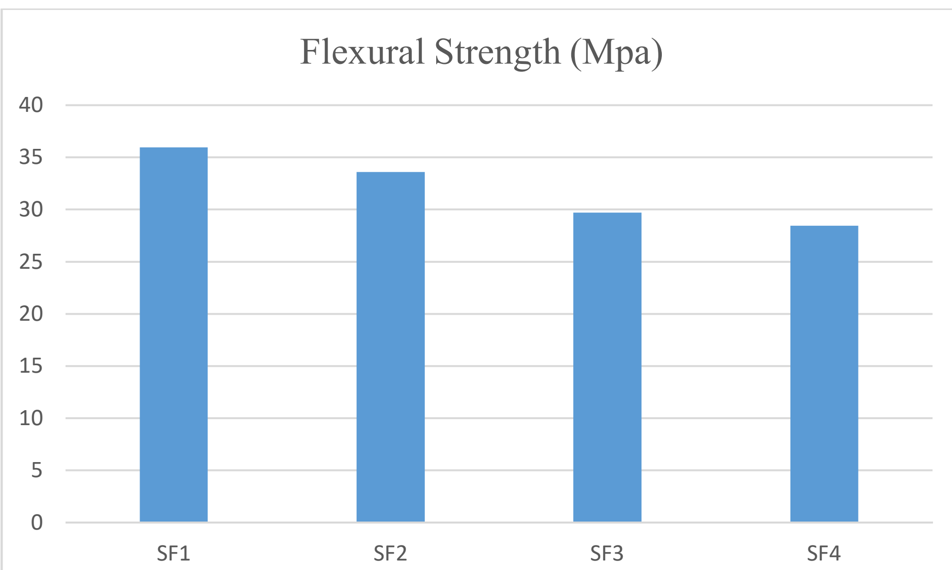
4.1 Tensile Strength of the Manufactured Composite

Figure 4.1 shows the tensile strength of Sisal fibre-PP composite at different fiber loading. It can be observed that the tensile strength decreases linearly with increasing fibre content. Therefore, the composite with 10 % fibre loading exhibits the highest tensile strength while the Sisal-PP composite with 40% fiber loading has lowest tensile strength. This indicate that the tensile strength largely depends on the matrix.



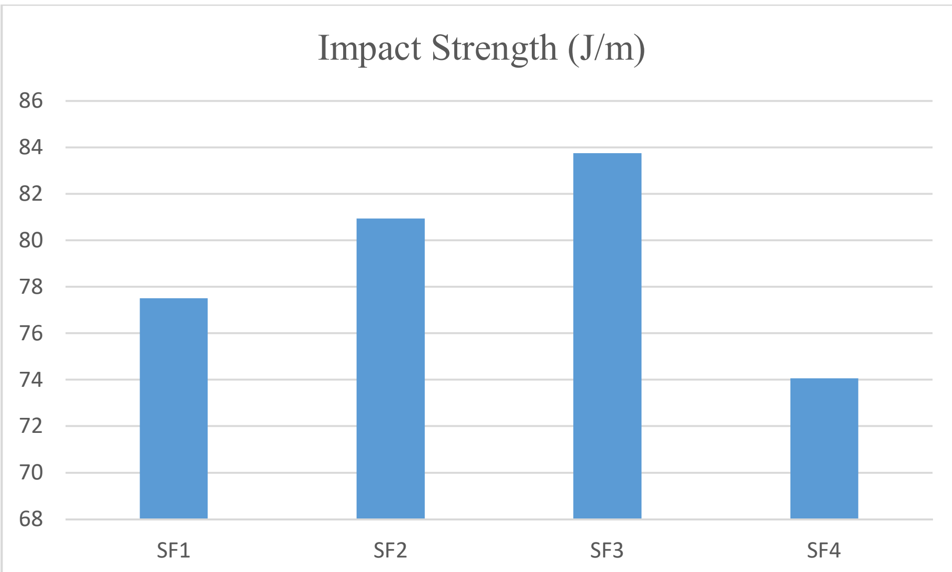
4.2 Flexural Strength of the Manufactured Composite

Figure 4.2 shows the Flexural Strength of Sisal fibre-PP composite at different fiber loading. It can be observed that the sample SF1 with 10% fiber loading exhibits the highest flexural strength, while the PP-Sisal composite SF4 with 40% fiber loading has lowest flexural strength. Similarly, the flexural strength largely depends on the matrix.



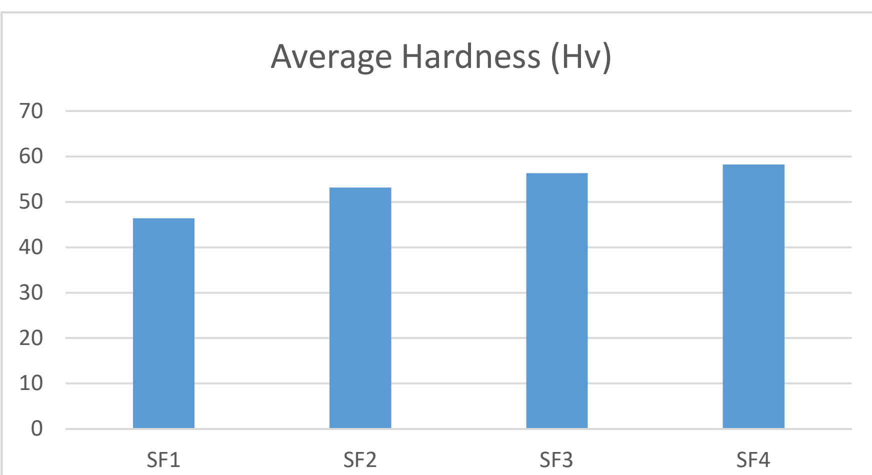
4.3 Impact Strength of the Manufactured Composite

Figure 4.3 shows the impact strength of PP-Sisal composite at different fiber loading. Overall, it can be observed that the sample SF3 with 30% fiber loading exhibits the highest tensile strength, while the sample SF4 with 40% fiber loading has the lowest impact strength. The impact strength of the composite increased gradually with fibre loading up to 30 %. However, steep decline was recorded at 40 % fibre loading. This indicate that the impact strength of the composite depends on the fiber.



4.4 Average Hardness of the Manufactured Composite

Figure 4.4 shows the average of PP-Sisal composite at different fiber loading. If the composite SF4 with 40% fiber loading exhibits the highest average hardness, while the PP-Sisal composite SF1 with 10% fiber loading lowest average. This indicate that the average hardness of the composite depends on the fiber.



5. Conclusion

This study evaluated the mechanical properties (i.e. flexural, tensile, hardness and impact) properties of a composite manufactured from recycle polypropylene reinforced with a blend of sisal fibre. Four sets of composites with different fibre loadings were produced using a consolidation pressure of 2.5 MPa.

The composites samples were produced by a mixing process involving the introduction of the Recycled Polypropylene (PP) while the rolls of the two rolls mill machine were in counter clockwise motion and soften for a period of 5 minutes at a temperature of 190°C. Upon achieving a band and bank formation of the PP on the front roll, the prepared sisal fibre was introduced gradually to the bank, cross mixed and allowed to mix for 3 minutes. The composite was sheeted out and labeled accordingly.

Then the composite were obtained from the mixing process was placed into a metal mould of dimensions 150mm x150mm x 0.3mm and was placed on the hydraulic hot press (Compression Moulding Machine) for shaping at temperature of 160^{o}C and pressure of 2.5 MPa for 5mins. It was cooled on a cool compression moulding machine platen under 2.5 MPa pressure at room temperature for 3mins and labeled accordingly.

- Optimal flexural and tensile strengths at a fibre loading of 10%.
- Optimal impact strength a fibre loading 30%.
- Optimal average hardness at fibre loading 40%

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