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Effects of Particle Size and Loading on Tensile and Flexural Properties of Polypropylene Reinforced Doum Palm Shell Particles Composites

Samuel Audu Seth[a*], Isuwa Suleiman Aji[b], Aje Tokan[c]

[a,c]*Department of Mechanical /Production Engineering, Abubakar Tafawa Balewa University Bauchi, Nigeria*
[b]*Department of Mechanical Engineering, University of Maiduguri Borno, Nigeria*
[a]*Email: seth2audu@gmail.com*
[b]*Email: suleimanaji@yahoo.com*
[c]*Email: ajetokan@atbu.com*

Abstract

Natural Particulates (fillers) are reinforcement in composite materials. They are used in matrix for cost reduction, improved processing, density control, thermal conductivity, control of thermal expansion, flame retardancy and improved mechanical properties. Doum palm shell particles reinforced composite was prepared by compounding polypropylene matrix with 10 - 40 wt. % Doum palm shell particles at 5 wt. % intervals for 150 µm and 300 µm particles sizes using compression moulding techniques. The effect of the particles size and particles loading on tensile and flexural properties of the composite produced were investigated. The results showed that the tensile strength increased from 34.12 MPa for neat polypropylene to a maximum of 44.88 MPa at 10 wt. % Doum palm shell addition for 150 µm particle size; while it increased to a maximum of 39.62 MPa at 10 wt. % Doum palm shell addition for 300 µm particle size. Flexural strength increased from 37.91 MPa for neat polypropylene to a maximum of 57.68 MPa at 10 wt. % Doum palm shell addition for 150 µm particle sizes; however, it increased to a maximum of 49.63 MPa at 10 wt. % Doum palm shell addition for the 300 µm particle size. 150 µm particle size composite yield a better result compared to 300 µm particles size which is in agreement with the literature, the smaller the particle size the better the properties of the composite because it has better compaction, reduced porosity which give effective stress transfer between the matrix and the particles. The use of doum palm shell as fillers in composite will not only provide a renewable source of filler in polymer composite but also generate a non – food source of economic development for the famers in the rural areas.

Keywords: Doum palm shell particles; Polypropylene; Particle loading; Tensile and Flexural properties.

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* Corresponding author.

1. Introduction

Particles fillers are used in polymer matrices for various purposes such as to reduce cost, to improve the stiffness and other properties of matrix. Most commonly used filler materials in polymer matrix composites are calcium carbonate [1] alumina [2] and silicon carbide [3]. However, in the recent years, the use of natural filler material has been the subject of intensive research and it is experiencing significant development. Composites reinforced with natural filler materials are in considerable demand because of their low cost, renewable and biodegradable nature. This has reduced the use of high cost, non-biodegradable traditional reinforcement materials like ceramic fillers and synthetic fibers in applications. Natural fillers such as groundnut shell particle, wood flour, rice husk, coconut husk, wheat husk, sisal particles etc. are agricultural resources and are available in many countries. Attempts have been made by several researchers to develop and characterize composites using natural fillers as reinforcement in particle or powder form [4, 5, 6].

1.1Particulate composite

As the name itself indicates, the reinforcement is of particulate nature. It may be spherical, cubic, tetragonal, a Figurelet, or of other regular or irregular shape. Particle fillers are widely used to improve the properties of matrix materials such as to modify the thermal and electrical conductivities, improve performance at elevated temperatures, reduce friction, increase wear and abrasion resistance, improve machinability, increase surface hardness and reduce shrinkage. Particles are more commonly used as extenders to lower the polymer use with simultaneous improvement in properties [7]. *Doum palm (Hyphaene thebaica) is a desert palm tree with edible oval fruit, originally native to the Nile valley. It grows very well in the northern part of Nigeria. It is known as "Goruba" in Hausa language. Doum palm is a member of the palm family, Arecaceae and tends to grow in places where groundwater is present. It is listed as one of the most useful plants of the world [7]. Its fibre and leaflets are used by people among the Nile to wave baskets. Doum palm is edible and the foliage is used to make mats, ropes, baskets, and hats while the stem with the leaves are used for construction purpose [8]. Doum palm has similar morphology with coconut except for the fact that it is not as big as coconut. However, the husk of this fruit is mostly eaten while the fleshy part of coconut is the nutty part that is edible. The nut of this fruit is very hard, and closely similar to palm kernel nut [8].*

Figure 1: Doum palm fruits

Doum palm shell is considered as agricultural waste which can be utilized in composite production. The use of natural filler in thermoplastic composites serves to improve the toughness and strength of the plastic. natural filler cellulosic materials are considered to be of relatively higher strength, lower density, cheaper, more abundant and renewable [9] The present study is channeled towards producing a composite using polypropylene (as matrix) and doum palm shell particle (as reinforcement) and to investigate the effect of doum palm shell particles size and loading on the tensile and flexural properties of the composites.

2. Methodology

2.1 Materials

The raw materials used in this work were:

(i) Doum palm shell.

(ii) Polypropylene with Density 0.905 g/cm^3, Melt flow 12 g/10 min, and melting temperature of 135 – 171 ^{o}C.

2.2 Equipment

Table 1: Equipment and Specifications.

Equipment	Specification
Tensile Testing Machine	Hounsfield (Monsanto) tensometer (Universal Testing Machine) (model No. S/N8889) Load capacity of 250 kN.
Flexural Strength Machine	Universal Material Testing Machine CAT. NV. 261.
Two roll mill	Two roll mill, Allen-Bradley with model 802T-WS1P.
Electronic hydraulic press	Carver hydraulic press with model No. 3851-0.

2.3 Doum Palm Shell Particles Preparation

The doum palm use for this study was collected from Ashaka Gari, Gombe state. The edible part of the part of the fruit and the seed was removed, and shell was dried in an oven to remove residual moisture for 24hrs. The shell was crushed to smaller pieces, grind to powder and sieved using set of standard sieves 150 and 300µm sizes. Figure 2 shows the doum palm fruits, shell and particles prepared.

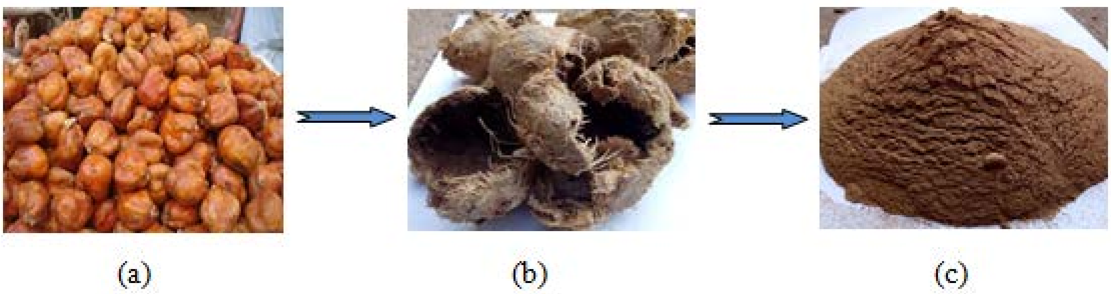

Figure 2: From doum palm fruit to doum palm particles. (a) Fruit (b) Shell and (c) Particles

2.4 Composite preparation

2.4.1 Mould Preparation

Mould with dimensions 100 x 100 x 10 mm and 150 x 120 x 5 mm mould cavity was prepared. The mould was used for moulding the composite to the desired size for test sample preparation.

2.4.2 Composite Preparation

(i) Compounding

The doum palm shell particles and polypropylene were blended together in a two-roll mill at a temperature of 180^0C and rotational speed 45rpm. First, polypropylene was melted to allow for adequate flow of the molten polymer before pouring the doum palm shell particles (DPSP) used as filler for the composite. Cross mixing of the molten polypropylene and the doum palm shell particles was done properly until uniformity was obtained. Fifteen samples were produced according to the formulation shown in Table 2.

Table 2: Compositions of the composites

Designation	Particle size	Composition
B0		PP (100 %)
B1	150 μm	PP (90 wt. %) + Doum palm particle (10 wt. %)
B2		PP (85 wt. %) + Doum palm particle (15 wt. %)
B3		PP (80 wt. %) + Doum palm particle (20 wt. %)
B4		PP (75 wt. %) + Doum palm particle (25 wt. %)
B5		PP (70 wt. %) + Doum palm particle (30 wt. %)
B6		PP (65 wt. %) + Doum palm particle (35 wt. %)
B7		PP (60 wt. %) + Doum palm particle (40 wt. %)
B8	300 μm	PP (90 wt. %) + Doum palm particle (10 wt. %)
B9		PP (85 wt. %) + Doum palm particle (15 wt. %)
B10		PP (80 wt. %) + Doum palm particle (20 wt. %)
B11		PP (75 wt. %) + Doum palm particle (25 wt. %)
B12		PP (70 wt. %) + Doum palm particle (30 wt. %)
B13		PP (65 wt. %) + Doum palm particle (35 wt. %)
B14		PP (60 wt. %) + Doum palm particle (40 wt. %)

(ii) Compression moulding

The band of the composites formed round the front roll of the mill was removed after compounding using heat resisting hand gloves, placed in metallic mould and compressed by an electrically heated hydraulic press and allowed to cool to room temperature under pressure of 8 MPa before the sample was removed from the press. Figure 3 shows the composite formulation.

Figure 3: Doum palm shell particles and polypropylene Composite

2.5 Characterization of the Composites

2.5.1 Determination of Tensile Properties

A tensile strength test was used to measure how much stress can be applied to a material until failure. The tensile test was performed in accordance with standard procedure specified in ASTM D638 [10], using the Hounsfield (Monsanto) Tensometer (universal testing machine) with maximum load of 250 kN. The specimen geometry was in a dumb-bell shape and the dimensions were ascertained using vernier callipers. The standard specimen was mounted at its ends into the holding grips of the testing machine and Uni-axial load was applied to each ends of the respective samples until it fails. Stress-strain curves were plotted from the force extension data obtained on a special graph paper during the tests and tensile strength and modulus were determined. The procedure was repeated three times for each spacemen and the average value was recorded.

2.5.2 Determination of Flexural Strength properties

The flexural strength of a composite is the maximum tensile stress a composite can withstand during bending before reaching the breaking point. The three-point bend test was conducted on all the composite samples according to ASTM D790 [11] using the universal testing machine CAT. NV. 261. Sample spacemen with dimension 60 x 30 x 10 mm was prepared in triplicate and used for the analysis. The flexural properties of the composite specimen were determined using equation 1 and 2.

$$Flexural\ strength = \frac{3FL}{2bd^2} \quad (1)$$

$$Flexural\ modulus = \frac{FL^3}{4bd^3y} \quad (2)$$

Where, **L** is the span length of the sample (mm)

F is maximum load (N)

b the width of specimen (mm)

d the thickness of specimen (mm)

y deflection of the beam

3. Results and Discussion

3.1 Effect of Doum Palm Shell Particles Loading and Size on Tensile Properties

Figure 1 illustrates the effect of doum palm shell particles loading on tensile strengths of doum palm shell particle composite. The tensile strength increases to a maximum values at 10 wt. % reinforcement for the two particles sizes considered, after which decreases with increase in particles loading. This may be because of the particle agglomeration that that limits the load transfer from the matrix to the particles, causing cracks to initiate and propagate easily. The cracks produced reduced the strength of the composite. The 150 µm size doum palm shell particles reinforced composite shows higher tensile strength of 44.88 MPa at 10 wt. %. Compared to 300 µm particles size with 39.62 MPa at 10 wt. %. These result shows that 150 µm sizes composite have better tensile properties when compared to 300 µm this is because 150 µm sizes composite has better compaction, reduced porosity which give effective stress transfer between the matrix and the particles. Similar trend of decrease in tensile strength of composites with increase in particles loading has been reported by Durowaye and his colleagues Hassan and his colleagues [12, 13]

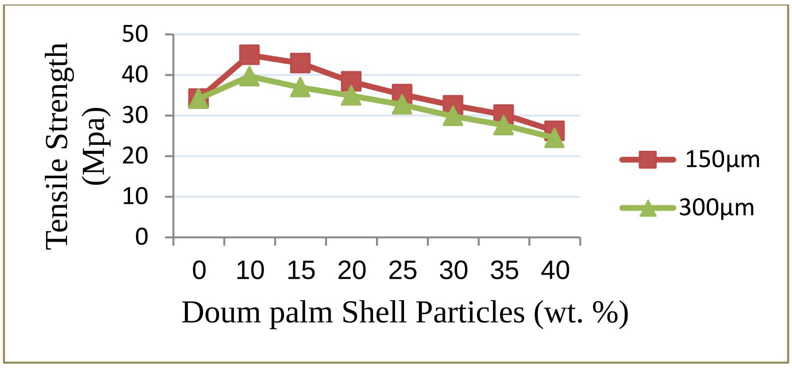

Figure 1: Variation of tensile strength with doum palm shell particle loading.

Tensile modulus of the composite increases with the introduction of the particles in the matrix. Figure 2 shows the effect of doum palm shell particles loading on tensile modulus of the composites. The tensile modulus of the reinforced composite is higher than that of the unreinforced composite. At 10 wt. %, the composite has the highest modulus, after which started decreasing with the increase in the particle loading. This experimental observation could be attributed to the fact that stiffness of the composite is improved on addition of doum palm shell particles. This result conforms to the findings of Onuegbu and his colleagues [14] who reported that the tensile modulus of polypropylene and Egg shell powder composite was improved with introduction of the Egg shell particles in the polypropylene.

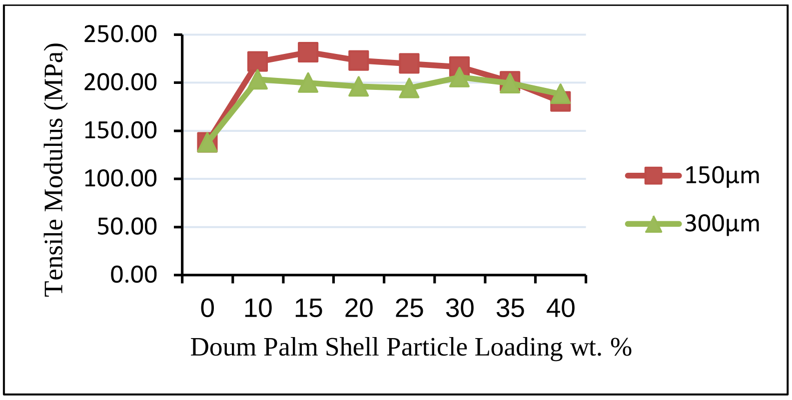

Figure 2: Variation of tensile modulus with doum palm shell particle loading.

3.2 Effect of Doum Palm Shell Particles Loading and size on Flexural Properties.

Figure 3 shows the flexural strength of doum palm shell particulate composite at different particle loading and size. Flexural strength of doum palm shell reinforced polypropylene composite is increased from 37.91 MPa at 0 % to maximum value of 57.68 MPa at 10 % for 150 µm and 49.63 MPa at 300 µm and then decreased to 38.97 MPa to 32.17 MPa at 40 % particles reinforcement. This decrease is attributed to the void content or crack formation at the interface of composite, inability of the particle to support stresses transferred from the matrix and poor interfacial bonding between particle and matrix materials which generates a weak structure. The flexural modulus of the composites improved with introduction of the particles. The presence of doum palm shell particle in matrix reduced polymeric chain mobility due to the increased stiffness of the composites.

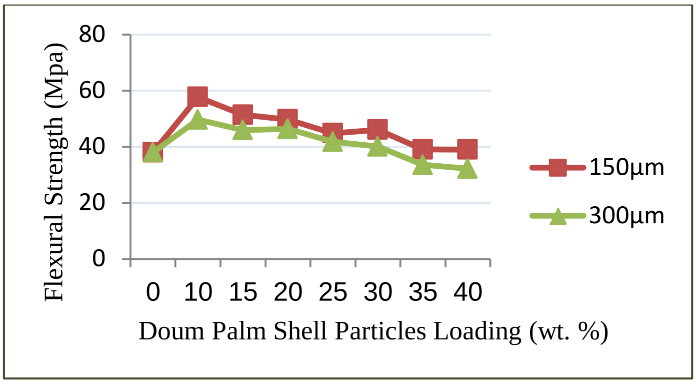

Figure 3: Variation of flexural strength with doum palm shell particle loading.

The Flexural modulus of doum palm shell reinforced polypropylene composite follow similar trend with the flexural strength of the composite as shown in figure 4. the flexural strength increased from 49.27 MPa at 0 % to maximum value of 72.07 MPa at 10 % for 150 µm and 64.77 MPa at 300 µm and then decreased to 49.66 MPa to 42.01 MPa at 40 % particles reinforcement

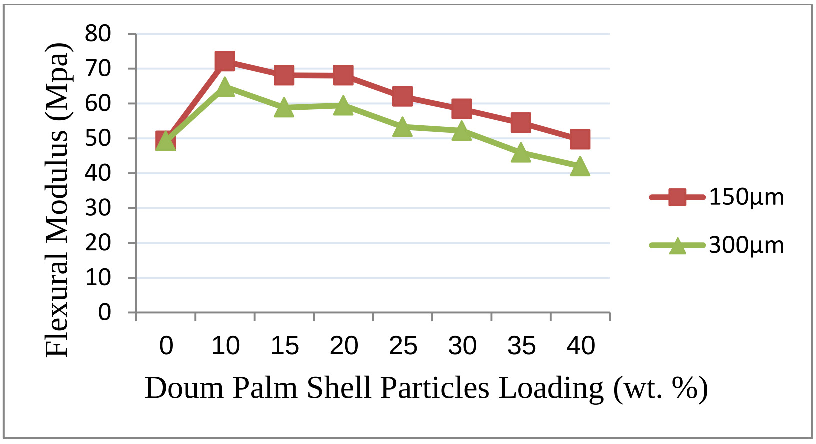

Figure 4: Variation of flexural modulus with doum palm shell particle loading

3.3 Conclusion

The work shows the successful development of composite from doum palm shell particles and polypropylene using compressive moulding technique. The tensile and flexural properties of the composite have been determined and the influence of the particle loading and size on the tensile and flexural properties of the composite has been established. The result shows that the tensile and flexural properties of the composite were improved with the introduction of doum palm shell particle. 150 µm size composite yield a better result compared to 300 µm particles size which is in agreement with literature, the smaller the particle size the better the properties of the composite because it has better compaction, reduced porosity which give effective stress transfer between the matrix and the particles. The use of doum palm shell as fillers in composite will not only provide a renewable source of filler in polymer composite but also generate a non – food source of economic development for the famers in the rural areas.

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