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Agro Based Material (Rice Husk Powder and Carbon Nanotubes) as Reinforcement in the Development of a New Polymer Bio-composite

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Abstract

Attempts to remedy the problem of cost since most agro wastes are relatively available at low cost, these agro based materials have successfully found significant application in improving the performance of polymeric materials, In this research, a PP with rice husk and carbon nanotubes as composite material with useful application in construction and structural design were been developed. Alkali treatment is significant in enhancing the mechanical properties of the fiber through the removal amorphous portion, increases the crystallinity and strength of the natural fiber reinforced polymer composites, tensile test results shows that the ultimate tensile strength at 5% for rice husk, as shown in the results, a decline in tensile and flexural strength from 5% filled composite were attributed to agglomeration as filler concentration increased. Hence the better the dispersion of the filler in the macromolecular chains of the matrix, the better enhanced the mechanical property will be.

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Keywords and phrases: rice husk powder; carbon nanotubes; polymer.

Introduction

Polymer composites consist of a polymer resin as the matrix and one or more fillers are added to serve specific objectives or requirements, traditionally synthetic fibers such as carbon or glass fibers have been used to reinforce composites and are able to produce such properties. However, with the growing global environmental concerns, their slow biodegradability is at disadvantage. Therefore, there is need to find a viable approaches to enhance or accelerate the biodegradability of polymeric composites. For this reason, natural fibers provide good prospective as reinforcements fillers in thermosets, thermoplastics, and elastomers.

Some main advantages of using natural fibers in composites are low cost, sustainability, lightweight, and being nonabrasive and nonhazardous and more importantly they can accelerate biodegradability of the polymeric composites [1]. The new and rapidly developing biocomposites materials are high technology products, which have unique advantage since waste products that traditionally cost money for proper disposal have now become beneficial resources in construction and automobile industries [2]. Rice husk (RH) is an inexpensive byproduct of rice processing and is separated from rice grain during the rice milling process. It is reported that, for every ton of rice produced, about 0.23 tons of RH is formed [2].

Carbon nanotubes (CNTs) are allotropes of carbon with a cylindrical nanostructure. These cylindrical carbon molecules have unusual properties, which are valuable for nanotechnology, electronics, optics and other fields of materials science and technology [3].

Materials

Poly propylene (BAGCO Super Sacks Company, Kano), Carbon Nanotubes (South Africa), Rice Shell (at Sabontasha market, Kaduna), Sodium Hydroxide (sigma Aldrich),

Method

Alkali treatment of Rice Husk

600g of the rice husk were weighed and soaked into 500ml beakers containing 5% NaOH solution. The mixture were stirred with a glass rod and soaked for 2 hours. The mixture were filtered so as to remove the alkali, distilled water were used to rinse the mixture repeatedly. The pH was also monitored on rinsing to ensure that all absorbed alkali were completely neutralized. The treated rice husk were collected into large crucibles and then oven dried at 105^{o}C for 24 hours to ensure complete removal of moisture. The treated rice husk were collected from the oven and then the dried sample were pulverized using a motar and pistol so as to achieve a reduced sieve size of 75microns (μm).

Compounding and processing of composite

The composite is composed of treated rice husk powder as filler with density of 0.97g/cm^3 and Poly propylene (PP) as matrix with a density of 0.94g/cm^3. The PP matrix was obtained from BAGCO Super Sacks Company, Sharada Industrial Estate Kano Nigeria. The size screened and treated rice husk powder were mixed with poly propylene by compounding using two-roll mill. The two-roll mill machine was heated to a temperature of 215^{o}C for 20 minutes, which is the melting temperature of poly propylene. At the end of this period, 95 wt% of PP were poured into the preheated two-roll mill to melt the PP for about 5 minutes, followed by gradual pouring of 5 wt% into the melted PP until a complete mixing of the filler with the matrix were achieved, the compounded rice husk powder/PP were scraped from the mill to form a sheet. The compounded sheet were pressed using hydraulic compression molding machine. At the start, the machine was heated for 30 minutes at the set temperature of 210^{o}C. After which the compounded sample is placed inside a rectangular mold with uniform thickness of 3mmcoveredwith aluminum foil. The mold was rubbed with processing oil (release agent) to aid removal of the composite after processing. The arranged mold were taken into the preheated compression molding machine and held under a set pressure of 4MPa for a period of 5 minutes. Thereafter, the samples were removed from the machine and allowed to cool before removing the composite sample from the mold. The procedure were repeated for 5wt 10 wt% and 15wt% of carbon nanotubes with the corresponding 95wt% 90 wt% and 85 wt% matrices of poly propylene, for 5wt% 10 wt% and 15wt% of rice husk powder with the corresponding 95wt% 90 wt% and 85 wt% matrices of poly propylene and for 2.5wt 5wt% and 7.5wt% of carbon nanotubes,2.5wt 5 wt% and 7.5 wt% of rice husk with the corresponding 95wt% 90 wt% and 85 wt% matrices of poly propylene.

The figures below show the various equipments used in composite processing.

Figure 1: Two roll mill. Figure 2: Compression molding machine 3.5.

Characterization of composite material

Three samples from each sample formulation were tested for tensile properties and also tested for flexural properties. The mean specimen dimensions were according to the ASTM specifications for tensile and flexural tests for plastics.

Tensile test specimen: Thickness = 3mm, Gauge Length = 40mm, Grip length = 30mm, width = 15mm, Reduced width = 10mm.

Flexural test specimen: Thickness = 3mm, Gauge length = 40mm, width = 30mm

Tensile test

The tensile test was conducted at the department of mechanical engineering in Amadu Bello University Zaria according to ASTM D638-03 using the Monsarto Tensometer machine. An average for three specimens in each formulation was conducted during the test. The dimensions, gauge length and cross-head speeds were chosen according to the ASTM specifications. The tensile strength was calculated by dividing the maximum load by cross sectional area of the sample. The modulus of elasticity were expressed as the ratio of the applied stress to the resulting strain while the percentage elongation at break were expressed as percentage of change of the original length for each specimen between grips at the break. This procedure was carried out for all other samples and the results were obtained and recorded.

Figure 3: Samples for tensile strength test.

Figure 4: Monsanto Tensometer.

Flexural test

Flexural strength were measured under a three-point bending approach using Monsanto Tensometer testing machine according to ASTM D790-03. An average for three specimens in each formulation was conducted during the test. The distance between the spans was 40mm, and the strain rate was 5 mm/min. The flexural properties (n/mm^2) were calculated by using the formula below.

Flexural strength = MOR=$3PL/2bd^2$

Flexural modulus = MOE= $PL^3/4bd^3D$

Figure 5: Universal material testing machine.

Figure 6: Samples for flexural test.

Result

Tensile and Flexural test results

Tables 1-3 show the results of the mean tensile properties for every composite sample of pp containing different Rice Husk and Carbon Nanotubes filler concentration.

Table 1: Poly propylene and rice husk.

Sample (wt%)	**Ultimate tensile strength (UTS) (N/mm^2)**	**Strain (mm)**	**%Elongation**	**Modulus of elasticity (N/mm^2)**
100%PP	28.89	0.44	44%	84.97
95%PP/5%R.H	32.5	0.44	44%	80.65.
90%PP/10%R.H	30.91	0.31	31%	99.71
85%PP/15%R.H	28.46	0.31	31%	93.26

Table 2: Poly propylene and carbon nanotube.

Sample(wt%)	**Ultimate tensile strength (UTS) (N/mm^2)**	**Strain (mm)**	**%Elongation**	**Modulus of elasticity (N/mm^2)**
95%PP/5%C.Nt	19.76	0.36	36%	94.30
90%PP/10%C.Nt	37.21	0.31	31%	119.1
85%PP/15%C.Nt	40.43	0.29	29%	124.4

Table 3: Poly propylene, carbon nanotubes and rice husk.

Sample(wt%)	**Ultimate tensile strength(UTS) (N/mm^2)**	**Strain (mm)**	**%Elongation**	**Modulus of elasticity (N/mm^2)**
95%PP/2.5%C.Nt/2.5%R.H	43.0	0.375	37.5%	114.67
90%PP/5%C.Nt/2.5%R.H	32.10	0.325	32.5%	98.77
85%PP/7.5%C.Nt/7.5R.H	35.7	0.38	38%	102.01

Tables 4-6 result of the mean flexural properties for identical composite sample of PP containing different Rice husk filler concentration.

Table 4: Poly propylene and rice husk.

Sample (wt%)	**Modulus of rapture (MOR) (N/mm^2)**	**Modulus of elasticity (MOE) (N/mm^2)**
100%PP	0.0523	0.2883
95%PP/5%R.H	0.0474	0.7638
90%PP/10%R.H	0.0467	0.9732
85%PP/15%R.H	0.0428	1.0995

Table 5: Poly propylene and carbon nanotube.

Sample (wt%)	**Modulus of rapture (MOR) (N/mm^2)**	**Modulus of elasticity (MOE) (N/mm^2)**
95%PP/5%C.Nt	0.0536	1.0638
90%PP/10%C.Nt	0.1508	1.0732
85%PP/15%C.Nt	0.0762	1.6614

Table 6: Poly propylene and rice husk/carbon nanotube.

Sample (wt%)	**Modulus of rapture (MOR) (N/mm^2)**	**Modulus of elasticity (MOE) (N/mm^2)**
95%PP/2.5%C.Nt/2.5%R.H	0.0742	1.0416
90%PP/5%C.Nt/2.5%R.H	0.0729	1.1759
85%PP/7.5%C.Nt/7.5R.H	0.0624	1.3294

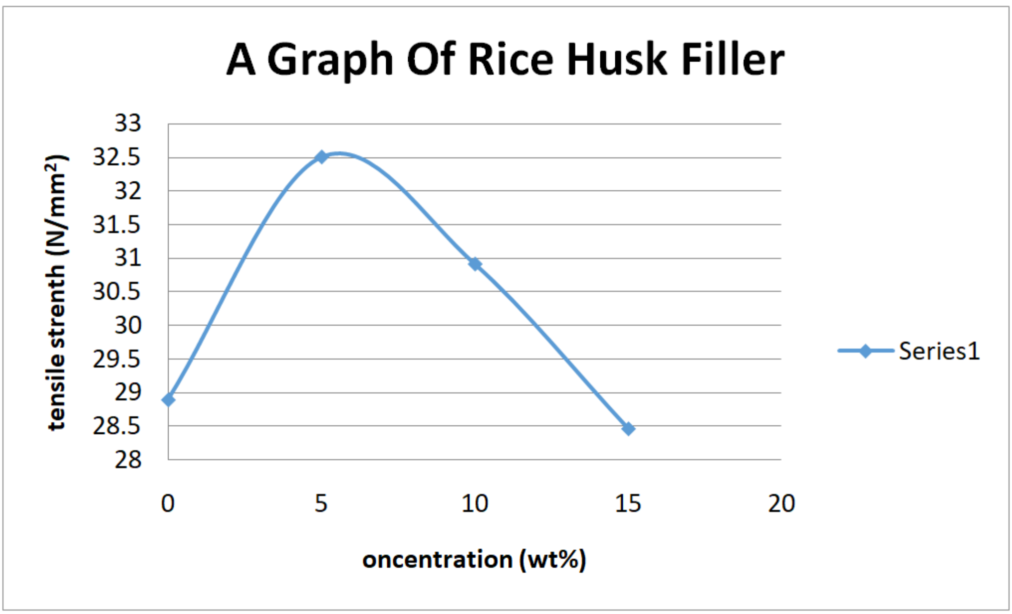

Figure 1: Variation of tensile strength with increase in rice husk concentration.

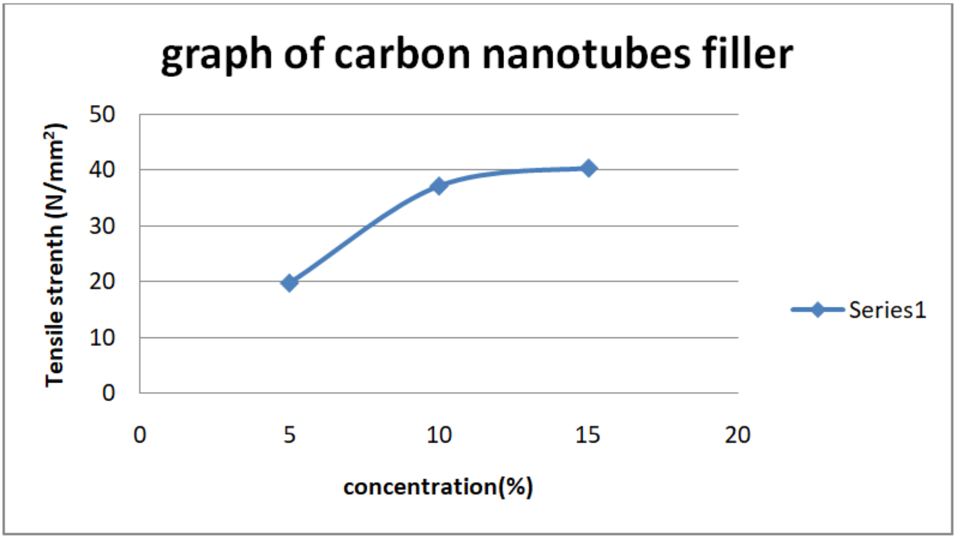

Figure 2: Variation of tensile strength with increase in carbon nanotubes concentration.

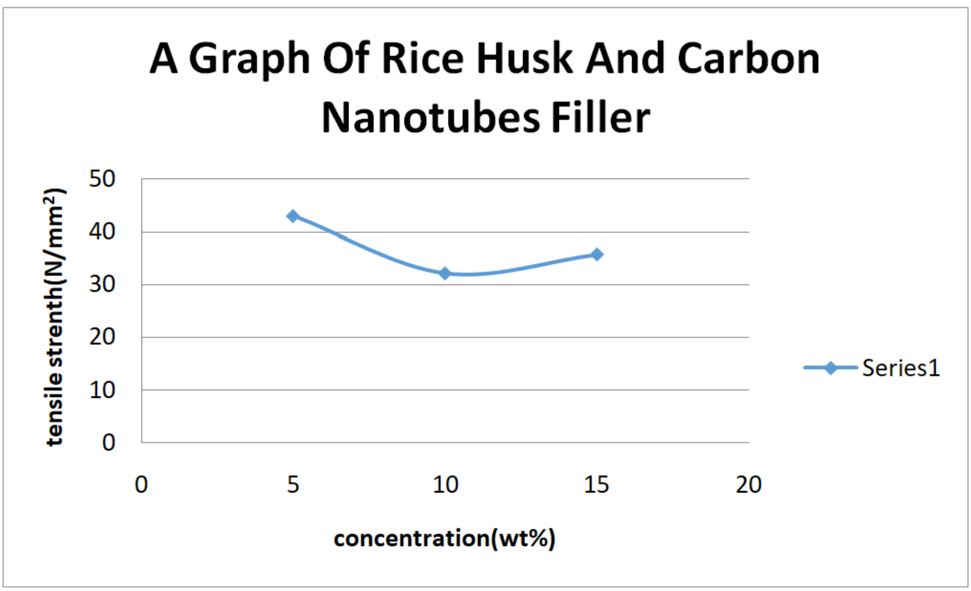

Figure 3: Variation of tensile strength with increase in carbon nanotubes and rice husk concentration.

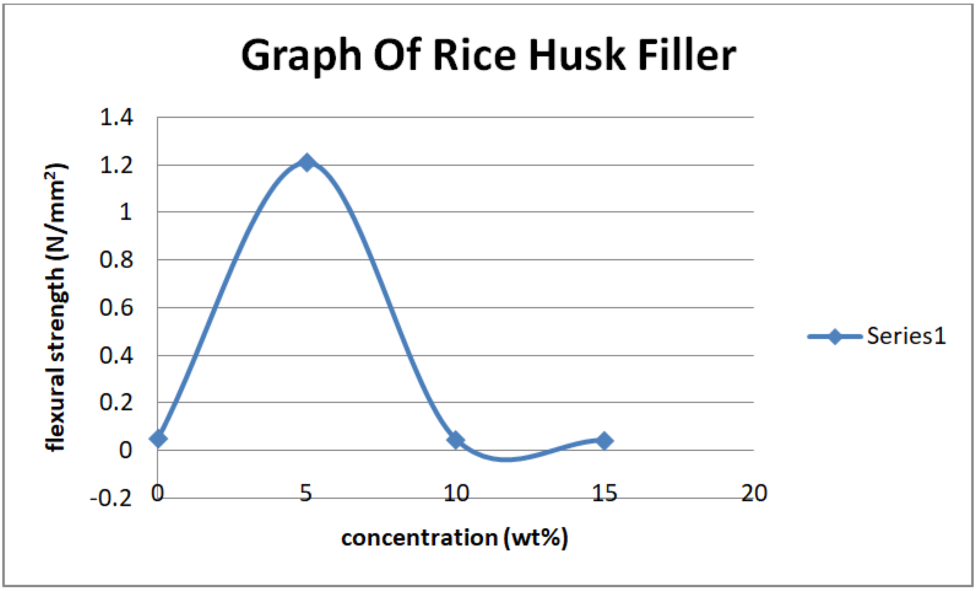

Figure 4: Variation of flexural strength with increase in rice husk concentration.

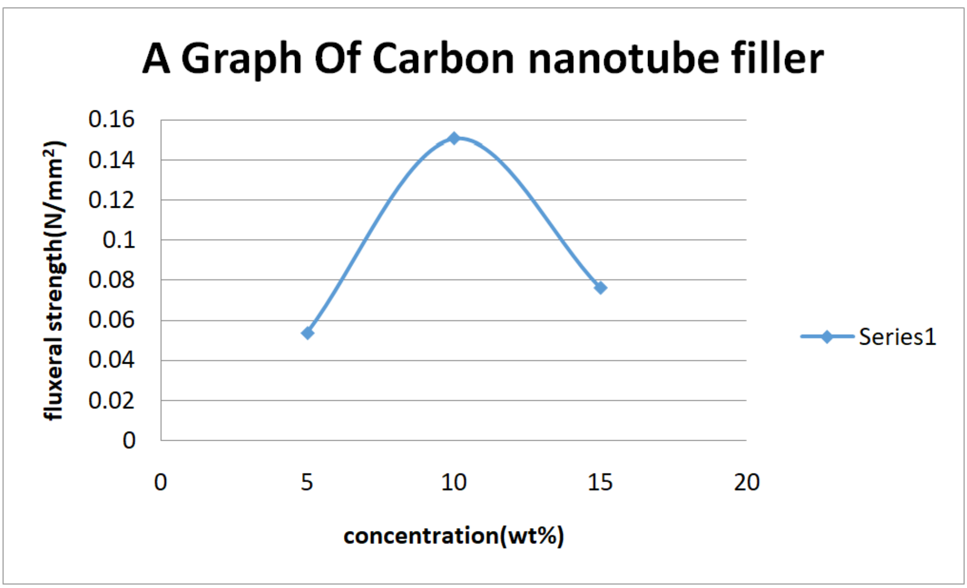

Figure 5: Variation of flexural strength with increase in carbon nanotubes concentration.

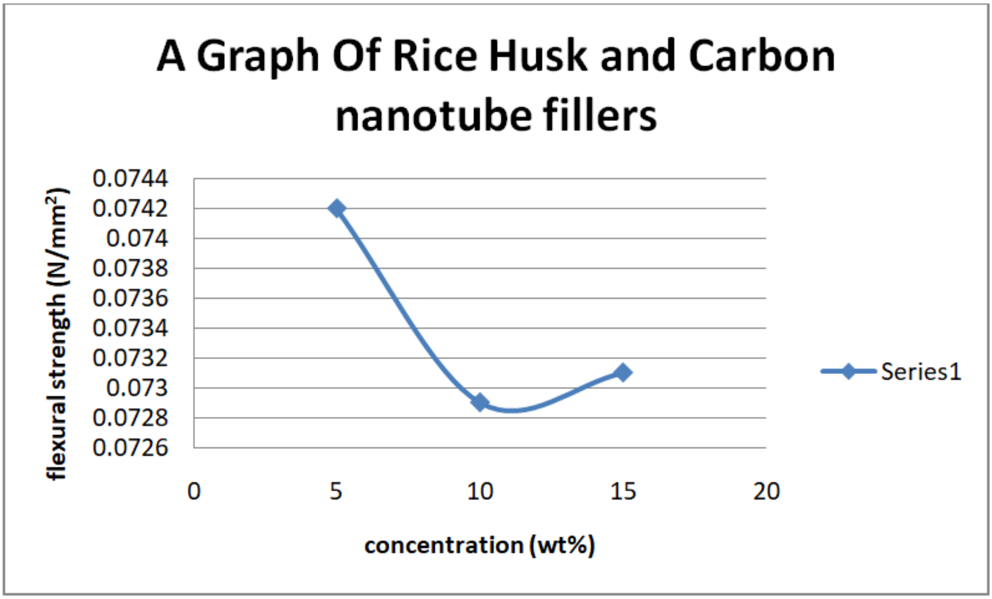

Figure 6: Variation of flexural strength with increase in carbon nanotubes and rice husk concentration.

Discussion

From Figure 1, there is an increase in tensile strength from the unreinforced PP to the reinforced PP at 5% Rice husk content. This effect may be attributed to better adhesion and compatibility of filler and matrix which were enhanced by alkali treatment of the filler. However, there is a sharp decrease in tensile strength with increase in the filler concentration from 5% to 15% which may be attributed to poor fiber dispersion (agglomeration) or excess of fiber, Figure 2 shows an increase in tensile strength with increase in the filler concentration carbon nanotube enforced PP. This effect may be attributed to better adhesion and compatibility of filler and matrix which were enhanced by treatment of the filler and absence of agglomeration, Figure 3 at 2.5% rice husk and 2.5% carbon nanotubes, the composite is having the highest tensile strength. Then there is a decrease in the tensile strength at 5% rice husk and 5% carbon nanotube, this could be due to poor fiber dispersion (agglomeration) of the filler or due to excess filler and lesser quantity of binder. Then at 7.5% rice husk and 7.5% carbon nanotubes there is a little increase in the tensile strength, this could be due to increase in the weighing accuracy of the composite.

The flexural modulus of the composites increased with increase in filler concentration as established the figure above. Although at 5% filler concentration there were a rise in modulus of the reinforced composites which were greater than that of the unreinforced composite, which is attributed to cellulosic materials such as rice husk particulates, Figure 5, there were sharp increase in the flexural properties of the composite from 5% to 10%, this is due to proper dispersion and adhesion between the carbon nanotubes and the poly propylene. While from 10% to 15% there were a decrease in the flexural strength, due to improper dispersion of the carbon nanotubes or due to excess carbon nanotubes in the composite, higher flexural strength composite at 5% were observed in Figure 6 this is due to proper dispersion and distribution of both carbon nanotubes and rice husk in the composite.

Conclusion

Alkali treatment is significant in enhancing the mechanical properties of the fiber through the removal of amorphous portion, and therefore increasing the crystallinity and strength of the natural fiber reinforced polymer composites since it reduces the hydrophilic tendency for the reinforcement to absorb moisture, thereby failing to meet the requirement for its end-use applications. From the tensile test results, it shows that the ultimate tensile strength at 5% for rice husk, carbon nanotubes and rice husk/carbon nanotubes and PP composite is significant for its application in fabrication of an industrial pipe system for oil pipelines and other industrial and engineering uses. Composite material with lower percentage elongation of 20% and high young's modulus is significant in making of articles such as dashboard components. Hence the degree of stiffness of a material depends on the content of the reinforcement in enhancing the load bearing capacity of the composite material. Agglomeration is a major factor that affects tensile and flexural strength of composite materials, a decline in tensile and flexural strength from 5% filled composite were attributed to agglomeration as filler concentration increased. Hence the better the dispersion of the filler in the macromolecular chains of the matrix, the better enhanced the mechanical property will be.

Recommendation

The following recommendations are made upon the conclusion of this research.

1) Further research can be carried out on the thermal properties of coconut shell particle filled high density polyethylene composites.

2) Other chemical treatment methods such as acetylation, silane, permanganate treatments etc., should be employed in enhancing the mechanical property of fiber filled composites.

3) Further research can be carried out to study the effect of coconut palm leaf particles on the tensile, flexural and impact properties of composite materials.

4) Modern equipment such as Extruder should be provided for proper research.

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