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THE EFFECT OF PALM KERNEL SHELL AS FILLER ON THE PHYSICO-MECHANICAL PROPERTIES IN POLYMERIC MATRICES COMPOSITES

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Abstract
The effects at different percentages of palm kernel shell filler loading in polymer matrices on water absorption and flexural strength of the composite were studied. Different percentages of filler loadings used were 3%, 6%, 9% 12% and 15% in order to gain insight into the effect of filler content on the physical and mechanical properties. The test of water absorption and flexural strength was carried out according to American Standard Testing Machine (ASTM) D570 and ASTM D638. The result obtained at different percentages of palm kernel shell filler loading with polymer matrices composite showed that HDPE composite for water absorption test was found to be 12% (38.22%) > 3% (8.62%) > 6% (7.66%) > 9% (6.05%) > 15% (1.90%). GPS: 3% (19.37%) > 12% (0.71%) > 6% (0.50%) > 9% (0.49%) > 15% (3.40%). PP: 15% (35.88%) > 9% (11.12%) > 6% (3.61%) > 12% (1.79%) > 3% (1.22%). ABS: 15% (19.50%) > 6% (5.25%) > 3% (2.90%) > 12% (2.12%) > 9% (2.11%). The result of the flexural test showed HDPE composite 15% (24.87N/mm^2) > 9% (18.65N/mm^2) > 12% (10.88N/mm^2) > 6% (8.05N/mm^2) > 3% (6.84N/mm^2). GPS: 6% (32.75N/mm^2) > 9% (27.59N/mm^2) > 15% (26.11N/mm^2) > 3% (20.83N/mm^2) > 12% (14.93N/mm^2). PP: 9% (13.74N/mm^2) > 12% (13.37N/mm^2) > 3% (13.35N/mm^2) > 6% (11.30N/mm^2) > 15% (8.32N/mm^2). ABS: 15% (18.64N/mm^2) > 9% (14.12N/mm^2) > 6% (10.52N/mm^2) > 12% (8.17N/mm^2) > 3% (6.65N/mm^2). The control for water absorption was: HDPE; 0.00%, GPS; 0.12%, PP; 0.13% and ABS; 0.11%. The control for flexural strength was: HDPE; 14.92N/mm^2, GPS; 17.41N/mm^2, PP; 24.2741N/mm^2, ABS; 6.96N/mm^2. The results of water absorption test showed higher amount of water absorbed than the control under specified conditions. This was expected since natural particles fillers are hydrophilic in nature, it tends to absorb and retain water. However, treatment with NaoH should increase in quantity to reduce water uptake of the hydrophilic nature in palm kernel shell, by contracting the particle filler cellulose walls. The flexural strength was found to be slightly higher compared to the control.
Keywords: *Composites, polymer matrices, palm kernel, water absorption, flexural strength*

Introduction

There is increased demand for eco-friendly materials due to increasing depletion rate, soaring prices of petroleum based plastics and pressing environmental regulations have all triggered a growing interest towards the field of composites (1). In the present time, development of material tending towards green composite due to challenges of global environmental concerns such as rising sea levels, rising average global temperatures, decreasing polar ice cap and rapidly depleting petroleum resources etc.

These issues intensified pressures on researchers, academicians and industrialists towards manufacturing new product design using green material partially or fully. The biodegradable waste disposal problem and benchmarks for cleaner as well as safer environment provide an abundant component of scientific research towards eco-composite materials, which easily have degraded or bio-assimilated. The abundant presence of natural fibre and any other available agro-waste has been responsible for latest development in research towards green composite material. Agro-waste products produced in large quantities in Nigeria and are being burnt off or dumped in water bodies thereby causing environmental pollution. The utilization of agro-waste products would help solve some of the problem of environmental pollution which they constitute. It will also serve as a means of turning waste to wealth by reinforcing agro-waste products in developing a low cost polymer composite to serve a number of applications.

According to literature, fillers or fibres are very good in reinforcing and enhancing the properties of polymer matrices, it is, therefore, imperative that the use of waste agricultural products and extracts obtained from them be used material development and applications.

Composite materials composed of two or more different materials with the properties of the resultant material being superior to the properties of individual material that make up the composites [(2)]. Hence, blend of agro waste as a filler and polymer are composites [(2)].

This study aimed at the effects of different percentages of palm kernel shell as filler on polymer composites and their physico-mechanical properties such as water absorption and flexural strength in thermoplastic Polymeric matrices composites over properties of the starting thermoplastic polymer.

Materials and Methods

Sample Collection and Pretreatment

Sample Collection and Pretreatment

The palm kernel shell agro-waste material used in this research was collected from the surroundings of Ekwulumilli in Nnewi- South L.G.A of Anambra State Nigeria where they have been dumped after usage. They were washed and sun dried, the filler was cleaned using water and then it was broken into pieces. This was first ground in a ball mill to produce filler powder and then was separated and sieved to get the particle form.

Commercial virgin polymer matrices were purchased from Indorama Eleme Petrochemicals Limited (IEPL) Port Harcourt, Rivers State, Nigeria. The polymer matrices used in this research are pellets of Polypropylene (PP), Polyethylene (HDPE), Acrylonitrile Butadiene Styrene (ABS) and Polystyrene (PS).

Chemical Treatment of Agro-Waste Fibres

Inside a beaker 1% NaOH and 99% of distilled water were mixed to make solution. After drying the fibres in normal shading for 2 to 3 hours, the filler was taken and soaked in the prepared NaOH solution. Soaking was carried out at different time intervals depending upon the strength of filler required. The filler was then removed and taken for the next fabrication process. The advantages of this chemical treatment with NaOH were to remove moisture content from the filler thereby increasing its strength, it enhances the flexural rigidity of the filler; it clears all the impurities that are adjoining the filler material and also stabilizes the molecular orientation [(2)].

Compression Moulding Method in Processing of Agro-Waste and Polymer Matrices

The first step in the preparation of the polymer matrices composites is processing. Processing can be defined as the technology of converting raw polymer to materials in a desired shape. Compression moulding method is one of the processing techniques for preparing the polymer matrices composites and was used in this study; it contains stationary and movable moulds. Release agents were coated into polymer matrix composite to prevent adhesives from bonding to the plastic surface. Zinc stearate was used as release agent that is mixed with resin for compression moulding. Polymer matrix composite was placed between them and then the mould was closed, heat and pressure were applied to obtain a homogeneous composite. A preheating time of about 1 hour at 220°C was needed for moulding and 30 minutes for cooling to get the solid moulding. Slow cooling or rapid cooling (quenching) was applied at the end of the holding time [(7)].

One hundred grams (100g) of percentage of polymer matrices were used as control, there were substituted each with palm kernel shell fillers to the different polymer matrices used. Each of the 100grams of different polymer matrices were substituted with 3%, 6%, 9%, 12% and 15% of each palm kernel shell filler to make up 100 grams. After processing, specimens were cut into the desired size and shape before characterization of the samples. Each of the experiment was carried out twice in order to obtain accurate data.

Water Absorption (WA) Test

The test was carried out according to ASTM D570 to find out the swelling of specimen. The apparatus used was a sensitive weighing balance, ventilated oven and sample size of 100 × 20 × 3.2 mm (L × B × T) dimension.

Procedure

The specimen was dried in a ventilated oven at a temperature of 105^{0C} to 115^{0C} till it attains substantially constant mass and allowed to cool at room temperature and obtained its Mass (W_1). Dried specimen was immersed completely in clean water at a temperature of 25 ± 27^{0C} for 24 hours and the specimen was removed and wiped out any traces of water with damp cloth and weighed the specimen after it has been removed from water (w_2).

Water absorption WA in percentage (%) is given as:

$$WA = \frac{W_2 - W_1}{W_1} \times \frac{100}{1}$$

Flexural Tests/ Bending Strength Test

Flexural test was prepared according to International Standard (i.e. ASTM: D638). The equipment used was Hounsfield Tensometer (made in England).

Procedure

The prepared polymer piece was cut with respect to ASTM (300× 19 × 3.2) mm dimension, then the Sample were inserted into the 3-point flexural tester chamber and ensured a firm grip and also the tensometer graphs was fixed to the graph drum of the machine and ensure a firmed grip. The working fluid (mercury) of the machine were adjusted to zero load/ extension Scale and applied gradual but continuous load through the longer handle of the machine, to help the working fluid began its movement.

At each interval, the recording pin attached to the cursor was pressed down with the left hand while the right hand was gradually loading the machine and then the test piece is drawn on the grapy attached to the revolving recording drum which was removed when its failure occurs as the mercury level returns and the corresponding value of the load on the graph was noted with that the flexural load recorded, the flexural strength of the sample were calculated using the equation below:

$$F_t = \frac{PL}{2bd}^2$$

Where F_t = Flexural strength (N/mm^2)

P = recorded constant load (N)

L = the span length of the test piece = (300mm)

b = breadth of the test piece = (19mm) and

d = thickness/depth of the sample = (3.2mm).

Results

1. **Water Absorption Test**

Water Absorption Test for Palm Kernel

Specimen (%)	Dry Mass(g) W_1	Dry Mass(g) W_1	Wet Mass(g) W_2	Wet Mass(g) W_2	WA (%) $\frac{W2 - W1 \times 1(}{W1 \times 1}$
HDPE					
Control	**11.42**	**11.49**	**11.42**	**11.49**	**0.00**
3%	8.47	9.50	9.77	9.76	8.68
6%	7.88	7.26	8.33	7.97	7.66
9%	10.33	9.51	10.55	10.48	6.05
12%	9.71	4.46	9.81	9.78	38.22
15%	9.57	9.37	9.76	9.54	1.90
GPS					
Control	**8.37**	**7.75**	**8.37**	**7.76**	**0.12**
3%	15.16	7.65	15.22	12.01	19.37
6%	17.02	14.75	17.10	14.83	0.50
9%	15.91	16.71	15.99	16.78	0.49
12%	13.71	11.66	13.78	11.77	0.71
15%	12.92	17.07	12.99	18.02	3.40
PP					
Control	**6.18**	**9.22**	**6.19**	**9.23**	**0.13**
3%	11.47	9.78	11.58	9.94	1.22
6%	16.84	14.15	16.92	15.20	3.61
9%	10.40	8.11	11.21	9.36	11.12
12%	10.71	9.40	10.92	9.56	1.79
15%	9.22	9.33	10.98	14.23	35.88
ABS					
Control	**9.33**	**8.73**	**9.34**	**8.74**	**0.11**
3%	6.82	8.34	7.08	8.51	2.90
6%	11.10	11.74	11.82	12.21	5.25
9%	10.71	9.15	10.95	9.32	2.11
12%	9.25	9.62	9.36	9.92	2.12
15%	14.10	10.82	14.76	14.95	19.50

Flexural Strength Test

Flexural Strength Test for Palm Kernel Composite

Specimen	Bending Force P_1(N)	Bending Force P_2(N)	Flexural Strength (Nmm^2) $F_{t=PL/2bd}{}^2$
HDPE			
Control	**16.13**	**22.58**	**14.92**
3%	8.06	9.68	6.84
6%	8.87	12.00	8.05
9%	22.58	25.80	18.65
12%	12.09	16.13	10.88
15%	29.03	35.48	24.87

GPS			
Control	**25.80**	**19.35**	**17.41**
3%	28.03	26.00	20.83
6%	45.15	39.81	32.75
9%	32.05	39.51	27.59
12%	22.58	16.13	14.93
15%	32.25	35.48	26.11
PP			
Control	**30.70**	**32.25**	**24.27**
3%	16.26	18.35	13.35
6%	13.01	16.30	11.30
9%	15.32	20.32	13.74
12%	19.35	15.32	13.37
15%	9.68	11.90	8.32
ABS			
Control	**9.68**	**8.39**	**6.96**
3%	8.03	9.21	6.65
6%	11.90	15.40	10.52
9%	16.13	20.50	14.12
12%	9.70	11.50	8.17
15%	22.56	25.80	18.64

1) Water Absorption

Different percentage values of palm kernel shell-HDPE composite for water absorption test were found to be viz, 12% (38.22%) > 3% (8.62%) > 6% (7.66%) > 9% (6.05%) > 15% (1.90%). GPS –palm kernel shell composite for water absorption test was found to be viz, 3% (19.37%) > 12% (0.71%) > 6% (0.50%) > 9% (0.49%) > 15% (3.40%). In PP –palm kernel shell composite for water absorption test was found to be viz; 15% (35.88%) > 9% (11.12%) > 6% (3.61%) > 12% (1.79%) > 3% (1.22%). ABS –palm kernel shell composite for water absorption test was found to be viz, 15% (19.50%) > 6% (5.25%) > 3% (2.90%) > 12% (2.12%) > 9% (2.11%).

2) Flexural Strength

Different percentage values of palm kernel shell-HDPE composite for flexural test were found to be viz, 15% (24.87N/mm^2) > 9% (18.65N/mm^2) > 12% (10.88N/mm^2) > 6% (8.05N/mm^2) > 3% (6.84N/mm^2). GPS -palm kernel shell composite for flexural test was found to be viz, 6% (32.75N/mm^2) > 9% (27.59N/mm^2) > 15% (26.11N/mm^2) > 3% (20.83N/mm^2) > 12% (14.93N/mm^2). For PP -palm kernel shell composite for flexural test was found to be viz, 9% (13.74N/mm^2) > 12% (13.37N/mm^2) > 3% (13.35N/mm^2) > 6% (11.30N/mm^2) > 15% (8.32N/mm^2). In ABS -palm kernel shell composite for flexural test was found to be viz, 15% (18.64N/mm^2) > 9% (14.12N/mm^2) > 6% (10.52N/mm^2) > 12% (8.17N/mm^2) > 3% (6.65N/mm^2).

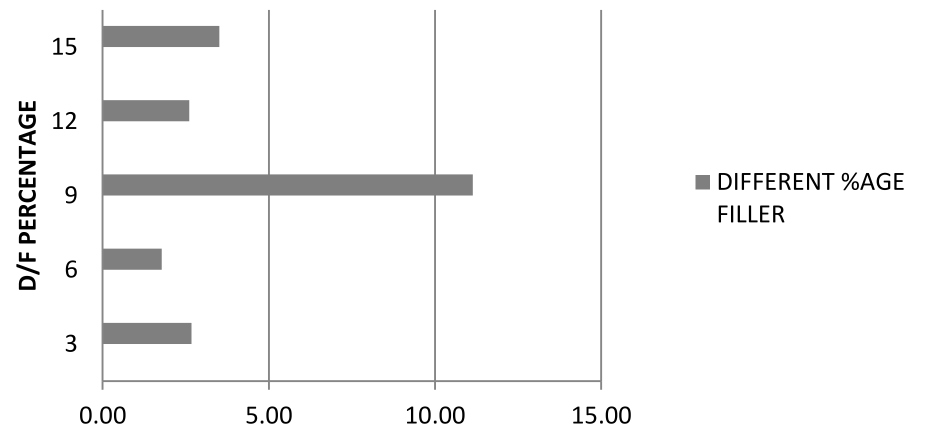

Fig 1: Water Absorption Test For Palm Kernel HDPE Composite and HDPE control

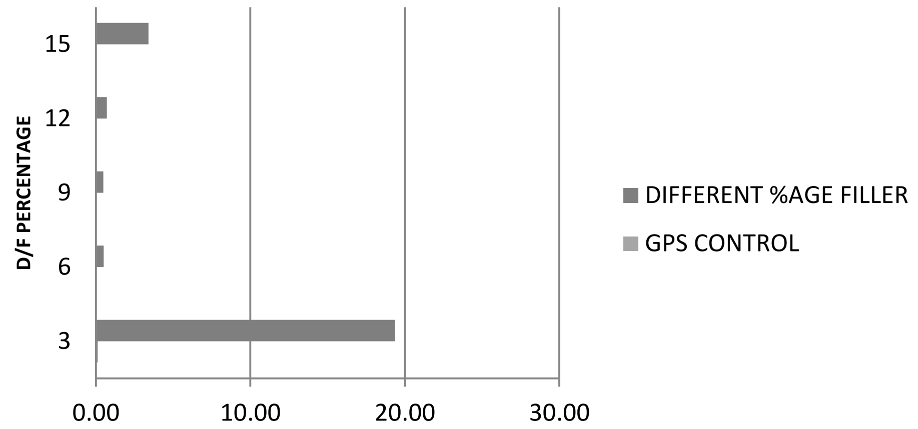

Fig 2: Water Absorption Test for Palm Kernel GPS Composite and GPS Control

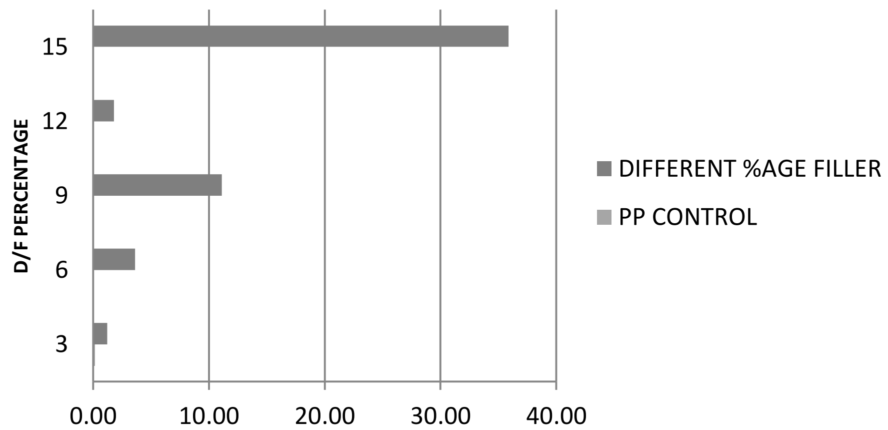

Fig 3: Water Absorption Test For Palm Kernel PP Composite and PP Control

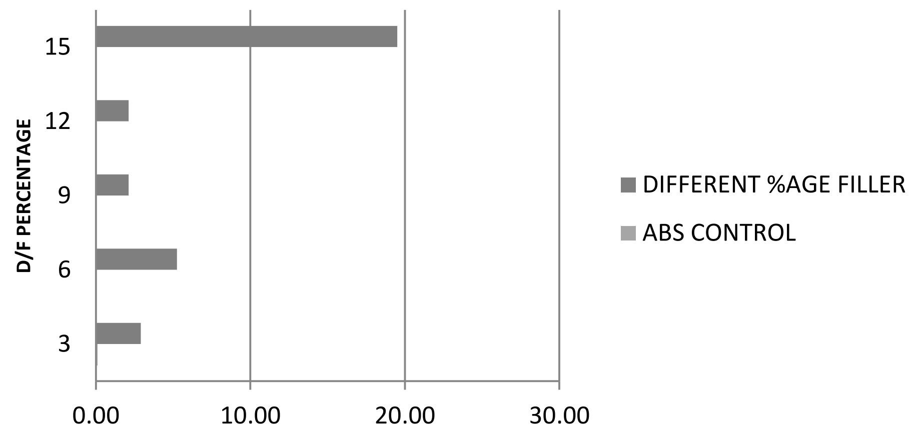

Fig 4: Water Absorption Test for Palm Kernel ABS Composite and ABS Control

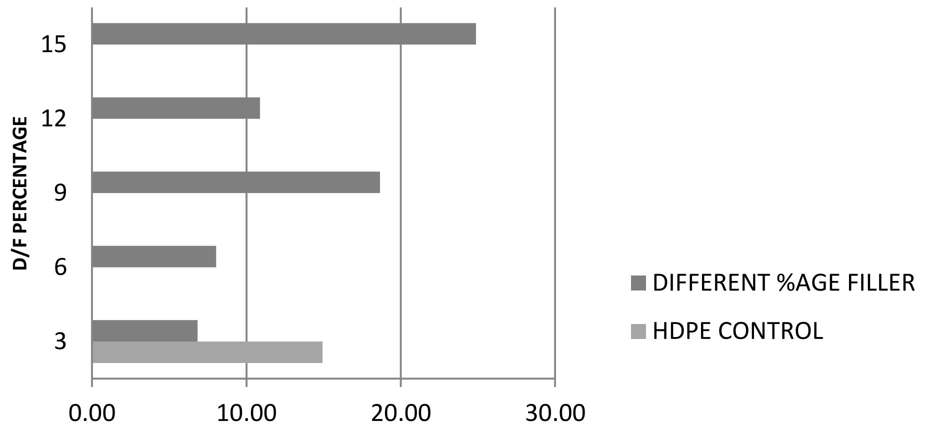

Fig 5Flexural Test for Palm Kernel HDPE Composite and HDPE Control

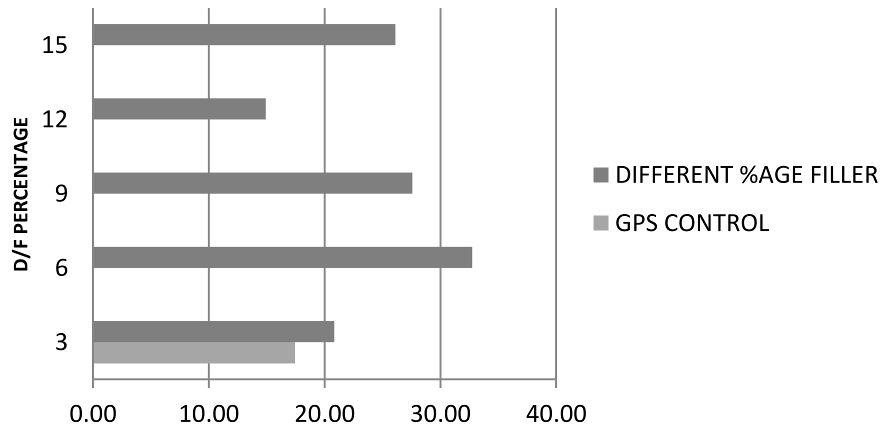

Fig 6: Flexural Test for Palm Kernel GPS Composite and GPS Control

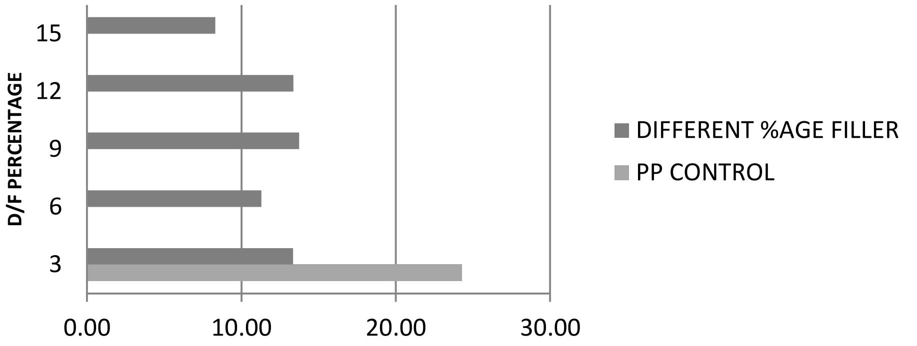

Fig 7: Flexural Test for Palm Kernel PP Composite and PP Control

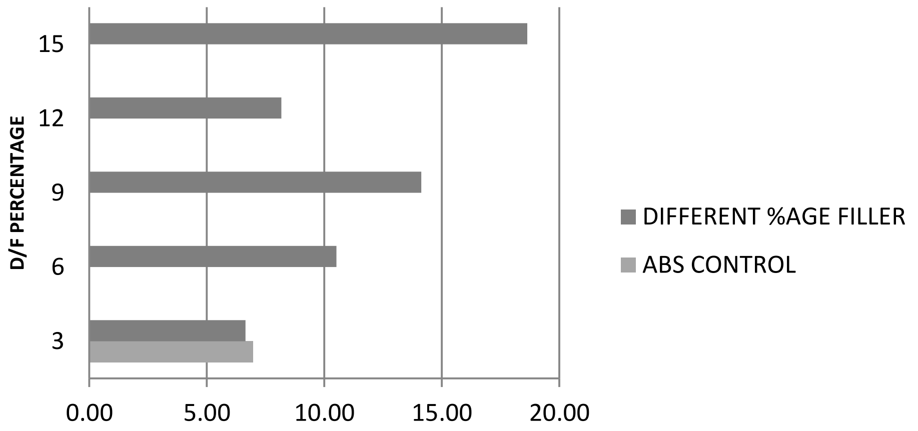

Fig 8: Flexural Test for Palm Kernel ABS Composite and ABS Control

Discussion

a) Water Absorption

The effects at different percentages of palm kernel shell filler with HDPE, GPS, PP, and ABS on the physical water absorption of the composite are shown in Table 1. HDPE can be seen that all the percentage filler loading of palm kernel shell used at 12% (38.22%), 3% (8.62%), 6% (7.66%), 9% (6.05%) and 15% (1.90%) showed higher water absorption compared to the control (0.00%). In GPS, all the percentage filler loading of palm kernel shell used at 3% (19.37%), 12% (0.71%), 6% (0.50%), 9% (0.49%) and 15% (3.40%) showed higher water absorption compared than to the control (0.12%). PP had all the percentage filler loading of palm kernel shell used at 15% (35.88%), 9% (11.12%), 6% (3.61%), 12% (1.79%) and 3% (1.22%) showed higher water absorption compared than to the control (0.13%). ABS also had all the percentage filler loading of palm kernel shell used at 15% (19.50%), 6% (5.25%), 3% (2.90%), 12% (2.12%) and 9% (2.11%) showed higher water absorption compared than to the control (0.11%).

The bar chart figures 1-4 had all percentages palm kernel shell filler higher than the control with the highest at 9% HDPE, 3% GPS, 15% PP and ABS.
All palm kernel shell at different percentage fillers reinforced polymer matrices such as HDPE, GPS, PP and ABS composite by compression method showed higher amount of water absorbed than the control under specified conditions. Similar findings were reported in previous work [6].

This was expected since natural particles fillers are hydrophilic in nature, it tends to absorb and retain water. However, treatment with NaoH does reduce water uptake, by contracting the particle filler cellulose walls. [(4)]

b) Flexural Strength

The effects at different percentages of palm kernel shell filler with HDPE, GPS, PP and ABS on the flexural strength of the composite are shown in Table 2. HDPE can be seen that at 15% (24.87N/mm^2) and 9% (18.65N/mm^2) showed higher flexural strength compared than to the control (starting material of 14.92N/mm^2) when reinforced with palm kernel shell, while at 12% (10.88N/mm^2), 6% (8.05N/mm^2) and 3% (6.84N/mm^2) showed lower flexural strength compared than to the control. GPS can be seen that at 12% (14.93N/mm^2) showed lower flexural strength compared than to the control (17.41N/mm^2). While at 6% (32.75N/mm^2) > 9% (27.59N/mm^2) > 15% (26.11N/mm^2) > 3% (20.83N/mm^2) showed higher flexural strength than to the control. For PP, all the percentage filler loading of palm kernel shell used at 9% (13.74N/mm^2), 12% (13.37N/mm^2), 3% (13.35N/mm^2), 6% (11.30N/mm^2) and 15% (8.32N/mm^2) showed lower flexural strength compared to the control (24.27N/mm^2). In ABS, almost all the percentage filler loading of palm kernel shell used at 15% (18.64N/mm^2) > 9% (14.12N/mm^2) > 6% (10.52N/mm^2) > 12% (8.17N/mm^2) showed higher flexural strength than the control (6.96N/mm^2), at 3% (6.65N/mm^2) showed lower flexural strength.

The bar chart in fig 5, 6 and 8 had all percentages palm kernel shell filler higher than the control with the highest at 15% HDPE, 6% GPS, 15% ABS. Figures 7 had the control highest flexural strength.

Conclusion

There was a significant improvement in flexural strength properties when polymer matrices were reinforced with palm kernel shell fillers. This was due to the particle which acts as load carrying members, not only helping to stiffen the composite, but improve bending, flexibility and overall load distribution. GPS, PP and ABS matrices composite reinforced at different percentages of palm kernel shell showed the highest stress experienced within the material at its moment of yield.

The fabrication of agro waste on all polymeric composite using palm kernel shell at different percentage by compression method showed better or higher flexural strength than the control which could make palm kernel shell fillers loading on HDPE, GPS, PP and ABS matrix useful for the production of disposable plastic cutlery and dinner ware, CD ‘jewel’ cases, smoke detector housing, license plate frames, plastic model assembly kits, and many other objects where a rigid, economical plastics is desired [(5)]. While palm kernel shell at different percentage fillers reinforced polymer matrices such as HDPE, GPS, PP and ABS composite showed higher amount of water absorbed than the control under specified conditions. This was expected since natural particles fillers are hydrophilic in nature, it tends to absorb and retain water. However, treatment with NaoH should increase in quantity to reduce water uptake of the hydrophilic nature in palm kernel shell, by contracting the particle filler cellulose walls.

This study has made some contribution to knowledge, by using abundant combinations of biodegradable matrix/natural fillers to promote new classes of biodegradable composites with enhanced mechanical properties, as well as to obtain products with lower cost, also managing of agro-wastes such palm kernel shell for sustainable economy, creating job opportunities in industries and finally leads to wealth creation.

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