

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

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ABSTRACT

The biodegradable waste disposal problem and benchmarks for cleaner and safer environment provide an abundant component of scientific research towards eco-composite material . 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 in polymer matrices. The test of water absorption and flexural strength were carried out according to American Standard Testing Machine (ASTM) D570 and ASTM D638 respectively. The result obtained at different percentages of egg shell filler loading with polymer matrices composite showed that HDPE composite for water absorption test were found to be 6% (0.85%) < 12% (0.88%) < 9% (3.11%) < 3% (4.28%) < 15% (8.95%) respectively. GPS - 15% (0.49%) < 9% (1.13%) < 12% (2.18%) < 6% (7.49%) < 3% (8.24%) respectively. PP - 15% (0.67%) < 6% (0.78%) < 3% (3.06%) < 12% (3.99%) < 9% (5.02%) respectively. ABS – 9% (0.83%) < 3% (1.02%) < 15% (1.50%) < 12% (5.03%) < 6% (5.52%) respectively. The result of the flexural test showed HDPE composite 12% (33.57N/mm²) > 9% (25.43N/mm²) > 6% (18.77N/mm²) > 3% (16.50N/mm²) > 15% (16.25N/mm²) respectively. GPS - 6% (34.84N/mm²) > 3% (27.35N/mm²) > 15% (24.24N/mm²) > 12% (18.65N/mm²) > 9% (14.32N/mm²) respectively. PP - 6% (27.35N/mm²) > 3% (22.37N/mm²) > 9% (19.90N/mm²) > 12% (13.72N/mm²) > 15% (6.22N/mm²) respectively. ABS - 9% (28.60N/mm²) > 6% (26.67N/mm²) > 15% (17.50N/mm²) > 12% (15.65N/mm²) > 3% (13.67N/mm²) respectively. The control for water absorption was: HDPE; 0.00%, GPS; 0.12%, PP; 0.13% and ABS; 0.11%. These results were compared with the control of different polymers(HDPE,0.00%;GPS,0.12%;PP,0.13%;ABS,0.11%). The result 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. The flexural strength was found to be slightly higher compared to the control showing good adhesion to the composite.

Key words: Composites, polymer matrices, palm kernel, water absorption, flexural strength.

1. 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 fiber 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 fibers 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. Hence, blend of agro waste as a filler and polymer are composites.

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.

2. MATERIALS AND METHOD

2.1.SAMPLE COLLECTION AND PRETREATMENT

Sample Collection and Pretreatment

The egg 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 were cleaned using water and then they were broken into pieces. They were first ground in a ball mill to produce filler powder and then 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 Fibers

Inside a beaker 1% NaOH and 99% of distilled water were mixed to make solution. After drying the fibers in normal shade for 2 to 3 hours, they filler were taken and soaked in the prepared NaOH solution. Soaking was carried out at different time intervals depending upon the strength of filler required. After they were removed and taken to the next fabrication process. The advantage of this chemical treatment with NaOH was to remove moisture content from the filler thereby increasing its strength and 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

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 and rapid cooling (quenching) were applied at the end of the holding time ⁽⁷⁾.

One hundred grams (100g) of percentage of polymer matrices were used as control, these 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 egg shell filler to makeup 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.

3. WATER ABSORPTION (WA) TEST

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

Procedure:

The specimen was dried in a ventilated oven at a temperature of 105°C to 115°C 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 $25 \pm 27^{\circ}\text{C}$ 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 were 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 ($300 \times 19 \times 3.2$) mm dimension, then the Sample were inserted into the 3-point flexural tester chamber and ensured a firm grip and also the tensometer graphs were fixed to the graph drum of the machine and ensure a firmed grip.

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. 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).

4. RESULTS

Table 1 Water Absorption Test for Egg Composite

Specimen	Dry Mass(g) W_1	Dry Mass(g) W_1	Wet Mass(g) W_2	Wet Mass(g) W_2	WA (%) $\frac{W_2 - W_1}{W_1} \times 100$
HDPE					
CONTROL	11.42	11.49	11.42	11.49	0.00
3%	11.84	15.25	11.94	16.31	4.28
6%	15.84	17.15	16.04	17.23	0.85
9%	16.46	15.01	16.98	15.47	3.11
12%	18.39	17.95	18.46	18.20	0.88
15%	11.24	11.33	12.34	12.26	8.95
GPS					
CONTROL	8.37	7.75	8.38	7.76	0.12
3%	12.69	12.79	13.56	14.01	8.24

6%	9.73	10.83	10.89	11.20	7.49
9%	10.61	15.89	10.82	15.98	1.13
12%	10.10	13.77	10.56	13.83	2.18
15%	11.38	17.07	11.49	17.10	0.49
PP					
CONTROL	6.18	9.22	6.19	9.23	0.13
3%	6.77	10.85	7.01	11.15	3.06
6%	8.44	11.96	8.53	12.03	0.78
9%	11.64	9.07	12.04	9.71	5.02
12%	7.35	10.70	7.92	10.86	3.99
15%	17.32	18.59	17.35	18.81	0.67
ABS					
CONTROL	9.33	8.73	9.34	8.74	0.11
3%	8.87	8.72	8.96	8.82	1.02
6%	10.52	11.21	10.98	11.95	5.52
9%	16.99	19.10	17.06	19.34	0.83
12%	17.21	17.00	18.00	17.93	5.03
15%	15.78	17.71	16.91	17.08	1.50

Table 2 Flexural Test for Egg 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%	18.35	24.45	16.50
6%	24.50	24.19	18.77
9%	32.25	33.70	25.43
12%	45.15	41.93	33.57
15%	19.35	22.80	16.25
GPS			
CONTROL	25.80	19.35	17.41
3%	32.25	38.70	27.35
6%	42.00	48.38	34.84
9%	19.40	17.74	14.32
12%	22.58	25.80	18.65
15%	27.40	35.48	24.24
PP			
CONTROL	30.70	32.25	24.27
3%	25.80	32.23	22.37
6%	32.25	38.70	27.35
9%	22.58	29.03	19.90
12%	16.25	19.35	13.72
15%	6.45	9.68	6.22
ABS			
CONTROL	9.68	8.39	6.96
3%	16.10	19.35	13.67
6%	30.70	38.48	26.67
9%	38.70	35.50	28.60
12%	19.40	21.20	15.65
15%	21.60	23.80	17.50

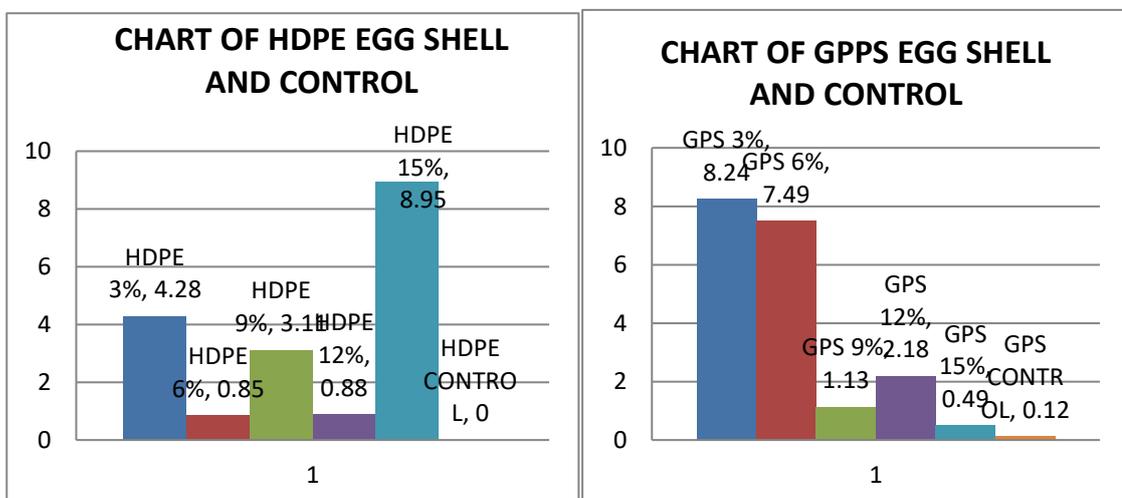
Different percentage values of egg shell-HDPE composite for water absorption test were found to be viz; 6% (0.85%) < 12% (0.88%) < 9% (3.11%) < 3% (4.28%) < 15% (8.95%) respectively. GPS –egg shell composite for water absorption test was found to be viz; 15% (0.49%) < 9% (1.13%) < 12% (2.18%) < 6% (7.49%) < 3% (8.24%) respectively. PP –egg shell composite for water absorption test was found to be viz; 15% (0.67%) < 6% (0.78%) < 3% (3.06%) < 12% (3.99%) < 9% (5.02%) respectively. ABS –egg shell composite for water absorption test was found to be viz; 9% (0.83%) < 3% (1.02%) < 15% (1.50%) < 12% (5.03%) < 6% (5.52%) respectively.

Different percentage values of egg shell-HDPE composite for flexural test were found to be viz; 12% (33.57N/mm²) > 9% (25.43N/mm²) > 6% (18.77N/mm²) > 3% (16.50N/mm²) > 15% (16.25N/mm²) respectively. GPS - egg shell composite for flexural test was found to be viz; 6% (34.84N/mm²) > 3% (27.35N/mm²) > 15% (24.24N/mm²) > 12% (18.65N/mm²) > 9% (14.32N/mm²) respectively. PP - egg shell composite for flexural test was found to be viz; 6% (27.35N/mm²) > 3% (22.37N/mm²) > 9% (19.90N/mm²) > 12% (13.72N/mm²) > 15% (6.22N/mm²) respectively. ABS - egg shell composite for flexural test was found to be viz; 9% (28.60N/mm²) > 6% (26.67N/mm²) > 15% (17.50N/mm²) > 12% (15.65N/mm²) > 3% (13.67N/mm²) respectively.

5. DISCUSSIONS

Egg Shell Filler Loading Reinforced On Polymeric Matrices Composite;

The effects at different percentages of egg shell filler with HDPE on the physical water absorption of the composite are shown in Table 1. HDPE can be seen having all the percentage filler loading of egg shell used at 15% (8.95%) > 3% (4.28%) > 9% (3.11%) > 12% (0.88%) and > 6% (0.85%) respectively which showed poor water absorption, that is they tend to retain or absorb water more than the control (0.00%). GPS can be seen that all the percentage filler loading of egg shell used at 3% (8.24%) > 6% (7.49%) > 12% (2.18%) > 9% (1.13%) and > 15% (0.49%) respectively also showed poor water absorption than to the control (0.12%). In PP, all the percentage filler loading of egg shell used at 9% (5.02%) > 12% (3.99%) > 3% (3.06%) > 6% (0.78%) and > 15% (0.67%) respectively also showed the same poor water absorption than the control (0.13%). ABS can be seen that all the percentage filler loading of egg shell used at 6% (5.52%) > 12% (5.03%) > 15% (1.50%) > 3% (1.02%) and > 9% (0.83%) respectively also showed poor water absorption than the control (0.11%).



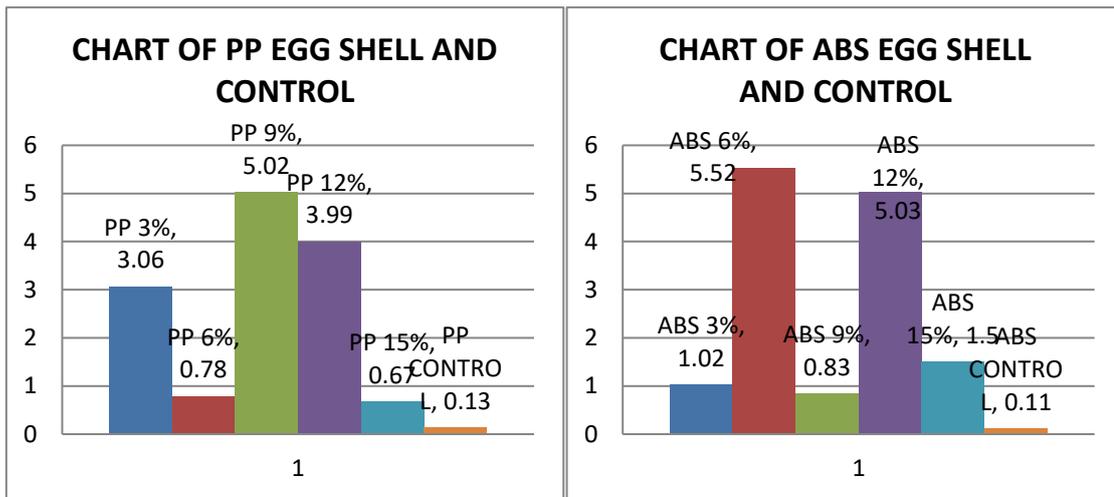
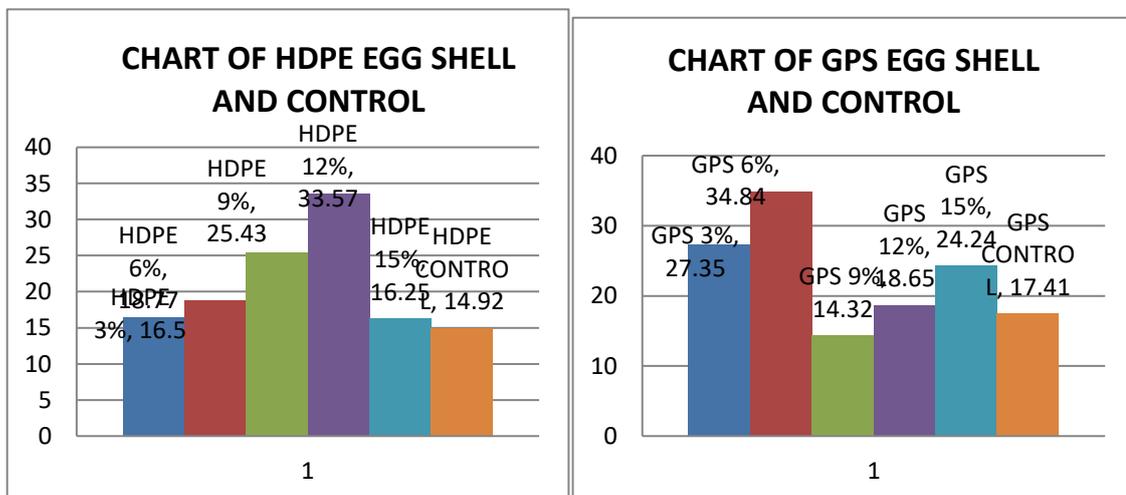


Figure 1: Bar Chart on Egg Shell Polymeric Composite of Water Absorption

The flexural strength of different percentages of egg shell as in a polymeric composite of HDPE, GPS, PP and ABS are shown in Table 2 and Figure 2 respectively. The result of HDPE can be seen that the values at different percentages are seen to be greater than the control indicating the importance of the reinforcement with the egg shell filled, in the flexural strength. On GPS polymeric composite, only 9% (14.32N/mm²) value has lesser flexural strength than the control (17.41N/mm²) whereas at 6% (34.84N/mm²) > 3% (27.35N/mm²) > 15% (24.24N/mm²) and >12% (18.65N/mm²) respectively had higher values than the control. The highest flexural strength was at 6% (34.84N/mm²). For PP, the percentage filler that is greater than the control is 6% (34.84N/mm²). The other percentages (3% (22.37N/mm²), 9% (19.90N/mm²), 12% (13.72N/mm²) and 15% (6.22N/mm²) respectively) are less than the control. The condition changed at ABS polymeric composite where at different percentages the effect on the flexural strength was better than control [9% (28.60N/mm²), 6% (26.67N/mm²), 15% (17.50N/mm²), 12% (15.65N/mm²) and 3% (13.67N/mm²) respectively control (6.96N/mm²). It can be said that HDPE and ABS matrices composite reinforced with egg shell at different percentages had better flexural strength.



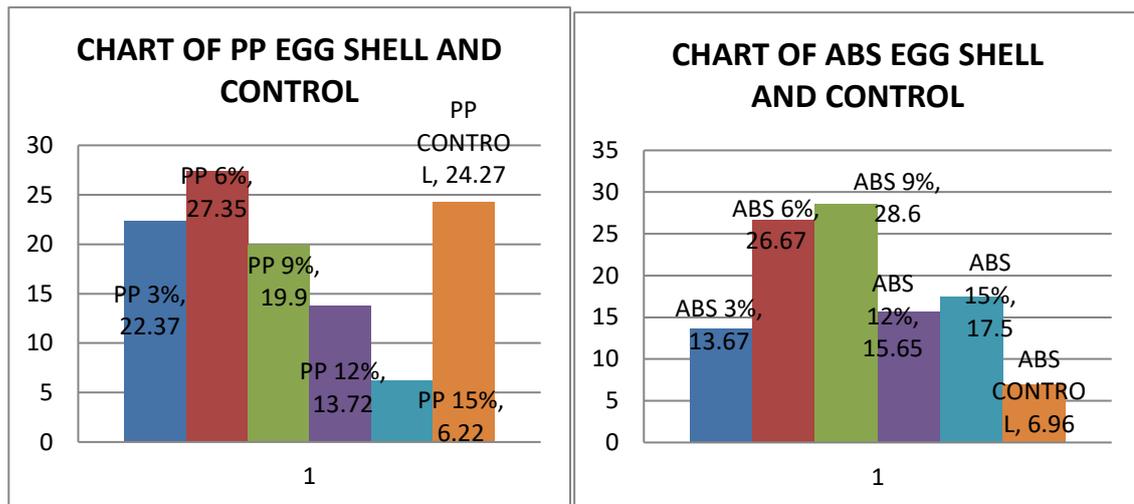


Figure 2: Bar Chart on Egg Shell Polymeric Composite of Flexural Strength

6. 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⁾. Whereas 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 contributed a lot such that 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, managing of agro-wastes such as cow horn for sustainable economy and creating job opportunities in industries and finally leads to wealth creation.

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