



# Investigation of Mechanical and Physical Properties of Palm Kernel Shell (PKS)/Palm Kernel Fibre (PKF) Polyester Matrix Reinforced Composites

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## ABSTRACT

The development of particulate palm kernel shell (PKS)/palm kernel fibre (PKF) reinforced polyester matrix composites was carried out using varying percentage compositions of palm kernel shell/palm kernel fibre in ratios of 100:0, 75:25, 50:50, 25:75 and 0:100 weight percent. A standard mould of 300 x 30 x 30 mm having a glass base and wooden sides was used for casting the composites. Polyvinyl Alcohol (PVA) was applied to the wood surface to form a releasing agent. As a standard procedure, the ratio of the polyester with density of 1.90 g/m<sup>3</sup> to the accelerator and hardener was 10:1:1 part by weight respectively. The mixture of the matrix material and reinforcement was done using hand lay-up method. The investigations show that the sample with 75% PKS 25% PKF had the highest compressive strength of 9.33 MPa while the lowest was 100% PKS 0% PKF with 4.67 MPa. However, the highest value of flexural strength of 5.01 MPa was obtained from the sample with 0% PKS 100% PKS. The toughness, hardness, wear and water absorption decreased with increase in percentage of PKF. The produced composites.

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## Introduction

Composite materials are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. However, composite materials comprise a strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load [1, 2].

Natural fibres, as reinforcement, have recently attracted the attention of researchers because of their advantages over other established materials. They are environmentally friendly, fully biodegradable, abundantly available, renewable and cheap and have low density [2 – 5]. Natural fibre composites are used in place of glass mostly in non-structural applications. A number of automotive components previously made with glass fibre composites are now being manufactured using environmentally friendly composites. This may be attributed to low-weight ratio of the composites.

Polymer matrix composite has been developing and is been utilized in the engineering field with developing technologies, due to its inherent properties like light weight, corrosion resistance, wear resistance among other properties. On the

account of these properties, composite materials have been replacing some other material for structural application, in the automobile industry and other fields. Many of the composite are subjected to different service environment which may likely alter or affect their properties and make them have low durability and longevity in service. In recent years many researches has been done to utilize lignocellulosic fillers such as coconut shell, palm kernel shell, wood, pineapple leaf, etc. as fillers so as to replace synthetic fillers in an attempt to enhance mechanical properties, minimize cost and increase productivity of the product [6 – 9].

Most developing countries like Nigeria are not yet properly utilizing agricultural wastes such as palm kernel for gainful engineering production. Palm kernel ash constitutes environmental pollution and causes health hazards like silicosis, cancer, tuberculosis, chronic cough and sight disorder in areas where it is dumped. Therefore, there is need to develop more ways of reducing the amount of the waste in the environment. One of the easiest ways of solving the problem is to use palm kernel shell and palm kernel fibre as filler in polymer matrix to form polymer matrix composite.

Palm kernel shell (PKS) is the hard endocarp of palm kernel fruit that surrounds the palm seed. The shells are flaky and of irregular shape that depend on the breaking pattern of the nut. The shell is made up of 33% charcoal, 45% pyro ligneous liquor and 21% combustible gas. Palm kernel shell fibre is



gotten during the fruit removal. It is the part that covers the shell and retains the oil gotten from the palm fruits. The fibre is mostly used as reinforcement and also is used as bio-fuel.

The aim of this research is to investigate some Mechanical and Physical properties of palm kernel shell (PKS)/palm kernel fibre (PKF) reinforced polyester matrix composites using predetermined proportions of the materials.

**Materials and Methods**

The materials used in this research include palm kernel shell and palm kernel fibre, polyester resin, an accelerator (cobalt) and hardener. Also, the equipment used include a grinding machine, digital weighing balance, measuring cylinder, impact testing machine, universal testing machine, Vickers hardness tester, hammer mill, sieve shaker and iron brush.

Using standard procedure the palm kernel shells (PKS) was soaked into a solution of Sodium hydroxide diluted in distilled water at room temperature and was stirred mechanically for 2 hours. The shells were then washed with distilled water and sun dried for 48 hours. The same treatment process was done with the palm kernel fibres (PKF). The PKS were then crushed into small pieces using hammer mill. The collected powder was sieved using a set of sieve with different mesh sizes in which 1000 g of PKS was poured into the sieve shaker and shaken for 20 minutes. The ratio of the polyester to the accelerator and hardener was 10: 1:1 weight respectively. The density of the polyester is 1.90 g/m<sup>3</sup>. A mould of 300 x 30 x 30 mm having a glass base and wooden sides was used for the casting of the composite. Polyvinyl Alcohol (PVA) was then applied to the wood surface to form a thin film on the mould as the PVA dries which acted as a releasing agent. The composite was fabricated in the ratio of (100:0, 75:25, 50:50, 25:75 and 0:100 %) for PKS and PKF (by weight) and the samples were labelled as 1, 2, 3, 4, and 5 respectively as shown in Table 1.

The measured weight of hardener was mixed with PKS/PKF in a container and stirred at low speed for 10 minutes until the mixture became uniform and sticky, after which the hardener was added. The mixture of the matrix material and reinforcement was then poured into the mould and allowed to cure at room temperature for 24 hours. Finally, the composite plates were removed from the mould and cut into different dimensions to be used for the Mechanical tests.

A 3x10x7x3 factorial experimental design consisting of 2 composite matrix materials (PKS and PKF), 10 sample weight ratios (100:0,75:25, 50:50, 25:75, 0:100) and the revise order of (0:100, 25:75, 50:50, 75:25, 100:0) respectively, 7 Mechanical

properties (Compressive strength, Impact strength, Flexural strength, Hardness test, Wear rate, Water absorption, and Micro-structural analysis) and 3 average samples for each mechanical properties which sums up to a total of 210 Samples/Specimens.

The following Mechanical tests were then carried out on the samples using standard procedures on the samples/specimens: Compressive strength, Impact strength, flexural strength, Hardness test, Wear rate, Water absorption and Micro-structural analysis. For each test, three Composite samples were tested and the average result taken.

A Compressive testing machine model ELE compact-1500 was used in carrying out the test. This was loaded to fracture by applying uniaxial compressive force. The maximum compressive force that crushed the specimen was read from the scale. The compressive strength (CS) was calculated using equation 1.

$$CS = \frac{Max. Compressive Force (N)}{Area (mm^2)} \tag{1}$$

**Table 1: Composition of the composites**

Sample	Weight of PKS (g)	Weight of PKF (g)
1	100	0
2	75	25
3	50	50
4	25	75
5	0	100

The specimen was notched at the middle to a depth of 2 mm to create an area of stress concentration for initiating fracture. The specimen was fixed on a Charpy Impact Testing Machine model A-D Leeds LS102DE and was hit by a fast moving hammer released from a fixed height on the machine. The reading on a dial gauge on the machine showed the energy absorbed (toughness) by the respective specimen.

The flexural test was performed using three point bending method as a standard procedure (ASTM D790-03). The composite samples/specimen was tested at a cross head speed of 2 mm/min, at a temperature 22°C. Flexural stress in a three point bending test was found using equation 2.

$$\sigma_{max} = \frac{3P_{max}L}{bh^2} \tag{2}$$

where  $\sigma_{max}$  = maximum load at failure (N), L = span (mm), b = width of the specimen (mm), and h = thickness of the specimen (mm) .

An automatic electric powered Vickers hardness testing machine model, LECO 320 was used to determine the hardness value of the different weights ratio of the composite specimen/sample. The desired load of 30 kgf was selected and the indenter was released which made indentations on the composite and readings were instantly shown on the dial indicator.

Wear test was carried out by taking the different sample composition and placing each along a disc of an electronic grinding machine, model GRYPHON BS 5000 for 5 seconds. The weight of the samples was taken before and after grinding using an electronic weighing balance. The weight difference from each sample indicated the lost in weight. The speed of the grinding machine and the diameter of the disc were 3000 rpm and 150 mm respectively. The wear rate (WR) was calculated using equation 3.

$$WR = \frac{\Delta w}{s} = \frac{\Delta w}{2\pi N D t} \quad (3)$$

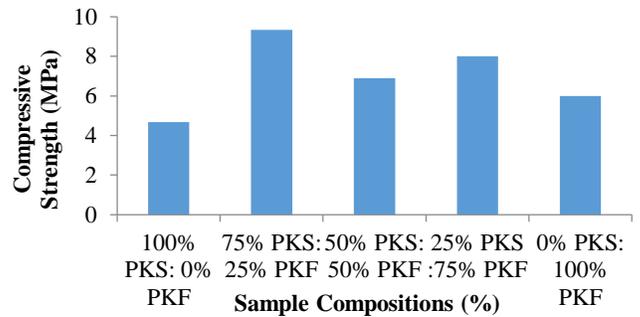
where  $\Delta w$  = weight loss,  $S$  = sliding distance,  $D$  = diameter of the disc,  $N$  = rpm and  $t$  = time exposed on the grinding machine.

The Composite samples were dried at 80 °C for 24 hours and then immersed in distilled water at room temperature. The samples were weighed at regular intervals of 15 minutes to determine the water absorption. All the specimens were taken out of the water periodically and wiped with dry cloth and then weighed. The percentage increase in weight (IW) was calculated to the nearest 0.01% by using equation as 4.

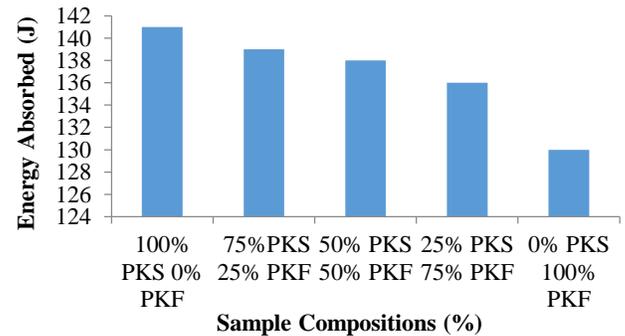
$$IW (\%) = \frac{Wet\ weight - Conditioned\ weight}{Conditioned\ weight} \quad (4)$$

**Results and Discussion**

Figure 1 shows that the maximum compressive strength was 9.33 N/mm<sup>2</sup> with a compressive force of 8400 N on the 75% PKS 25% PKF composite weight ratio and the minimum compressive value was 4.67 N/mm<sup>2</sup> with a compressive load of 4200 N at the 100% PKS 0% PKF Composite. From the result, the maximum value of energy absorbed was 141 J at the 100% PKS 0% PKF sample composition and the minimum was 130 J at the 0%PKS 100%PKF sample composition as shown in Figure 2. The value gotten was as a result of good adhesive properties of the particulate as the particulates are closely packed.



**Fig 1. Compressive strength against sample composition**

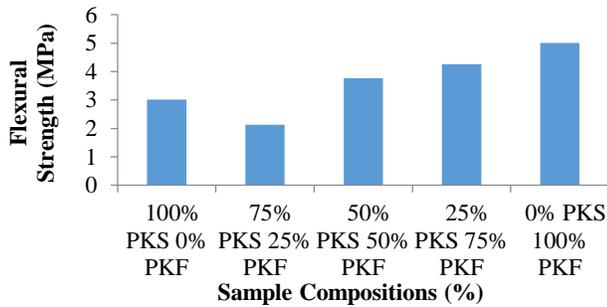


**Fig 2. Impact strength against sample composition**

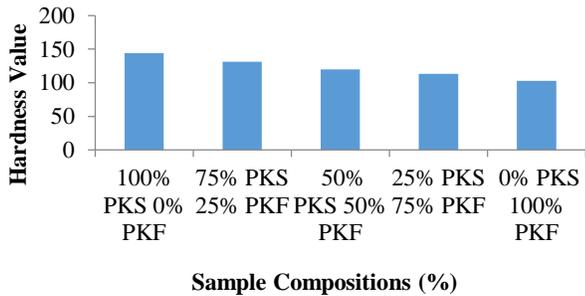
It was observed that the maximum Compressive Strength was 5.01 MPa at the 0% PKS 100% PKF with a flexural force of 392.28 N. However, the minimum compressive strength was 2.13 MPa at 100% PKS 0% PKF with a flexural force of 166.719 N as shown in Figure 3. The high flexural strength shows that fibre has greater flexural strength properties. This result is in agreement with the research work of Sanjay (2010).

It was observed that the Vickers hardness value was highest at the 100% PKS 0% PKF with Vickers hardness of 141 and the minimum value was 103 at 0% PKS 100% PKF. Also it was observed that the hardness value decreases with an increase in the percentage of fibre as shown in Figure 4. The softness and lightness of the palm kernel fibre allowed quick penetration of the indenter on indentation. The high hardness values of the 100% PKS 0% PKF is due to the good adhesive forces between the particulates, while the low hardness shows that the adhesive forces between the fibres are weak [10].

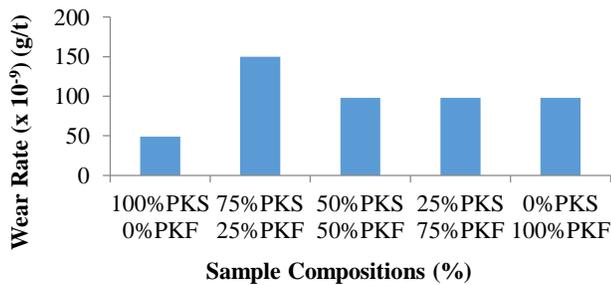
The sample with the lowest wear rate was the 100% PKS 0% PKF and this was because of the high strength of the sample as shown in Figure 5. The wear rate increased with the increase in fibre composition. This may be attributed to the loosed packing/bonding of the fibre samples with the resin.



**Fig 3. Flexural Strength against Sample Composition**



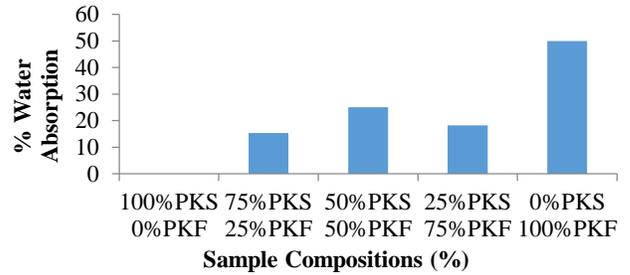
**Fig 4. Hardness Value against Sample Composition**



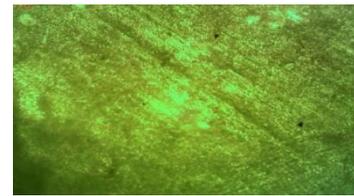
**Fig 5. Wear Rate against Sample Composition**

It was observed that the 100% PKS 0% PKF composition had the minimum water absorption rate while the 0% PKS 100% PKF has the maximum water absorption rate, which showed that the water absorption rate increases with increase in composition of the fibre as shown in Figure 6. The minimum water absorption rate is attributed to good interfacial adhesion between the particulate and the polyester while the maximum water absorption rate was due to the poor adhesion between the matrix and the reinforcement [10].

Figure 7 shows the Microstructure study which indicates poor interfacial bonding between reinforcement and matrix leading to low Mechanical Properties.

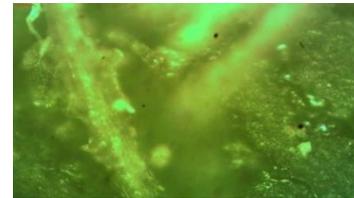


**Fig 6. Percentage Water Absorption against Sample Composition**



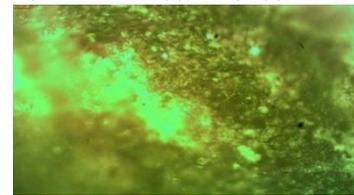
×200

SAMPLE 1: 100% PKS 0% PKF



×200

SAMPLE 2: 75% PKS 25% PKF



×200

SAMPLE 3: 50% PKS 50% PKF



×200

SAMPLE 4: 25% PKS 75% PKF

**Fig 7. Micro-structural analysis of the formulated composite samples.**



## Conclusion

From the results of the study, the following conclusions are drawn:-

- i. The successful development of PKS/PKF reinforced polyester composite.
- ii. It was found that the sample with the highest compressive strength was 75% PKS 25% PKF with 9.33 MPa and thus can be used in production of brake pads.
- iii. The Flexural strength increased with increase in the percentage of fibre in the composite. The highest value of Flexural strength was gotten from the 0% PKS 100% PKS with 5.01 MPa.
- iv. The Toughness, Hardness, Wear and water Absorption decreased with an increase in percentage of PKF. The highest values were gotten from the 100% PKS 0% PKF sample composition.

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