Original Research Article

PROPERTY EVALUATION OF RAFFIA SEEDS REINFORCED EPOXY MATRIX COMPOSITE

ABSTRACT

This research centred on property evaluation of raffia seeds reinforced epoxy matrix composite. Raffia seeds particulates are potential reinforcement materials for making cost-effective polymer-based composite. This is verified in several industrial sectors, from packaging to automotive and civil construction. This paper presents the results obtained from a study of physical and mechanical properties of raffia palm particulates (RPPs) derived from the raffia palm tree (*Raphia farinifera*).

The raffia seeds were crushed and grinded into powdered particles, separated and sieved to 36µm particle size was used. The matrix phase is epoxy which is a mixture of epoxide and polyamine. Polyamine serves as the hardener for this type of epoxide used. The mixing ratio is 2:1. This ratio is selected based on manufacturer specification. The composites were developed by mixing the epoxy and the raffia seed particles (RSP) in predetermined proportion of: 5, 10, 15, 20, 25, 30.wt%. Each mixture is poured into plastic moulds that specify the samples for wear, tensile, flexural, impact and soil burial tests. The mixture is allowed to cure at an average of 4 hours per batch although some of the samples showed variation in curing time. The evaluation of mechanical properties shows that there is significant increase in the strength of epoxy reinforced raffia seed composite with notable increment at 20wt% to 30wt% of RSP.

Keywords: Raffia seeds, epoxy, biodegradability, curing, composite

1. INTRODUCTION

The mechanical properties of polymers are inadequate for many structural purposes, particularly their strength and stiffness which are lower than those of ceramics and metals (Santhosh *et al*, 2014). The only way to overcome this challenge is by reinforcing them with materials with stronger and stiffer components. The reinforcing fibers are the primary load carriers of the material, with the matrix component transferring the load from fiber to fiber. Reinforcement of the matrix material may be achieved in a variety of ways Reinforcement may also be in the form of particles. The matrix material is usually one of the many available engineering plastics/polymers. Selection of the optimal reinforcement form and material is dependent on the property requirements of the finished part (Claudia and Navarro, 2013). Properties of composite are therefore strongly dependent on the properties of their constituent materials, their distributions, and the interaction among them (Deepika *et al*, 2013). Composites are fast becoming the most exploited class of available engineering materials by manufacturers and engineers. Yakubu *et al*, (2013) observed that properties embedded in the materials are responsible for their excellent physical and mechanical properties namely light weight, corrosion resistance and high weight to length ratio, and so on. Composite Materials are substance that is made up of combination of two or more different materials. Most commercially produced composites use a polymer matrix material often called a resin solution. There are many different polymers available depending upon the starting raw ingredients. There are several broad categories, each with numerous variations. The most common are known as polyester, vinyl ester, epoxy, phenolic, polyimide, polyamide, polypropylene, PEEK, and others. The reinforcement materials are often fibers but also commonly ground minerals. (Agunsoye *et al*, 2017).

Raffia seed is an oval shaped, brown, hard seed, commonly found in west Africa and some part of south Africa, the seed is a waste from raffia palm commonly grown for the purpose of obtaining a white, sweet liquid, also known as palm wine, this drink is most prevalent in some part of west Africa, raffia seed particles was used as reinforcement with epoxy resin to form a composite (Elakhame *et al*, 2014). Oladele (2022) also observed that polymeric materials are favoured by materials designers due to its light weight, easy forming, and resistance to corrosion, resilience and low electric conductivity. In view of the many advantages polymer has it also has its own disadvantages; its low strength limits its application especially for automobile and structural purpose. Polymeric materials are non-biodegradable i.e. they do not decompose on time, they are difficult to recycle, so the need for reinforcement to make it stronger and meet the necessary required specification for structural and automobile applications (Otto, 2012). Natural fibres are attractive fillers because of their promising properties such as low density, recyclability, biodegradability, non-toxicity and eco-friendliness (Ariwoola, 2021; Oladele and Agbeboh, 2017; Oladele et al., 2014). Natural fibres/epoxy composite can be used in place of pure polyester depending on the filler content and areas of application of interest like aerospace, maritime, auto parts and many more (Adeyanju, 2018).

Table 1: COMPOSITION OF RAFFIA SEED PARTICLES (Source: Yeng 2013)

COMPOSITION	DRY SOLID (%, W/W)
Cellulose	41.27 – 45.72
Hemicellulose	46.00 – 50.00
Lignin	7.40 – 9.20
Other Components	5.33

MATERIALS AND METHOD

The major materials used for this work are raffia seed (RS) which was bought from local farmers in Ekiti State, South-west Nigeria while epoxy resin and hardener were gotten from Lagos State, Nigeria. The raffia seeds were sundried for 10 days to remove moisture content and it was stopped when it was observed there was none moisture in it again, it was later crushed using ball mill. The particles were sieved with a sieve shaker to obtain particle size of 36 µm. Raffia seed particle reinforced epoxy composite is produced at room temperature; the granulated particle is mixed with the epoxide-hardener mixture at predetermined proportion and poured into the moulds. The three moulds used for the fabrication were for tensile specification, flexural specification wear and impact specification. The main processes involved in fabrication are mould preparation and curing of samples. The samples were removed from the mould after curing for investigation. Figure 1 (a-b) showed the raffia seeds and raffia trees, respectively.

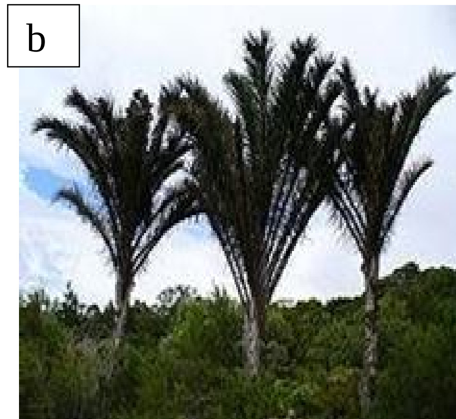

Figure 1: Agricultural wastes used: (a). Raffia seeds (b).Raffia trees

Composites formation

The composites were developed using open mould method that was formed based on the shape and size of the tests which was done using the hand lay-up process.

The raffia seed particle (RSP) were mixed with epoxy matrix varying particle fraction from 5 to 25 wt.% proportion. The composites were formed by pouring the mixture (RSP, epoxy resins and hardener) into prepared test mould and removed after curing. The developed composites samples are shown in Figure 2. Both mechanical and physical tests were carried out on the samples based on ASTM format.

Table 2: Formulation of the composites

Filler (%)	Epoxy	Hardener	Cow bone/Snail Shell
5	47.50	23.75	2.50
10	45.00	22.50	5.00
15	42.50	21.25	7.50
20	40.00	20.00	10.00
25	37.50	18.75	12.50
Control	50.00	25.00	-

Figure 2: Developed composite samples

2. MATERIALS TESTING

Tensile Strength Test

Tensile test was performed to investigate properties of the composites. This was done in accordance to ASTM standard using Instron at a crosshead speed of 1mm/min. The samples were mounted on the Instron machine between two fixtures known as grip which serves as sample holder. Three (3) samples each were tested and the average values were obtained and used as the representative values.

Flexural Test

Flexural test which is also known as bending test was also carried out on the samples using Universal Testing Machine. The size for the flexural samples were of 120 x 50 x10mm in dimension. The flexural test was carried according to ASTM D7264 at a cross-head speed of 20 mm/min maintaining a span of 100 mm .When the beam is bent in clear that the samples of the upper half are compressed and those of the lower half are stretched. Between these region of compression and stretching, there is a layer which is neither compressed nor stretched. This surface is called the neutral surface of the beam and the cure of any particular sample on this surface is known as an elastic curve or deflection curve of the beam. The line in which any plane section of beam cuts the neutral surface is called the axis of the section.

The Impact Test

The impact energy test of the composite samples was determined using Charpy impact testing machine with model no 412-07-15269C. The procedure used was in accordance with ASTM D-256. Samples were sectioned to 100 x 10 x 3 mm dimensions and notched at the middle after which 3 samples were each prepared, mounted on the machine, and a swinging pendulum released, under gravity, to hit the sample(s). The energy at impact was read directly from a dial indicator of the machine and the average values of the results obtained were recorded.

The Wear Test

The wear tests were determined using a polisher machine with load. The set up was similar to the concept of the pin-on-disc test. The tested samples have a dimension of 40mm in diameter and 10mm in height.

The samples were placed in the rotating wheel of the polisher machine. All tests were conducted at room temperature. The pin with a 8mm diameter with a load of 10N was placed on each sample rotating with a speed of 100rpm (Adegbola *et al*, 2017). The samples were weighed before and after testing to determine weight loss within an accuracy of 0.0001mg.

Water Absorption

The composite samples were dried at room temperature for six weeks and immersed in distilled water at room temperature. The water absorption was determined by weighing the samples at regular intervals. The specimens were daily taken out of the water wiped with tissue paper and weighed. The percentage of water absorption was calculated by:

$$M_1 = \frac{W_N - W_d}{W_d} \; x \; 100\%$$

Where W_d is the original dried weight and W_n is the weight after exposure.

Figure 3. Water absorption test

Soil Burial Test (biodegradability)

The soil degradability test for the composite was carried out according to ASTM D 5338 standard. The test was conducted in a pressurized soil prone to moisture and human activities such as transportation, the samples were buried for 30days as shown in figure 4. The weights of the samples were taken before and after the test. The difference in initial weight and the final weight showed the rate of biodegradation property of the composites.

Figure 4. Burial test (biodegradability)

RESULTS AND DISCUSSION

Tensile Results/Discussion

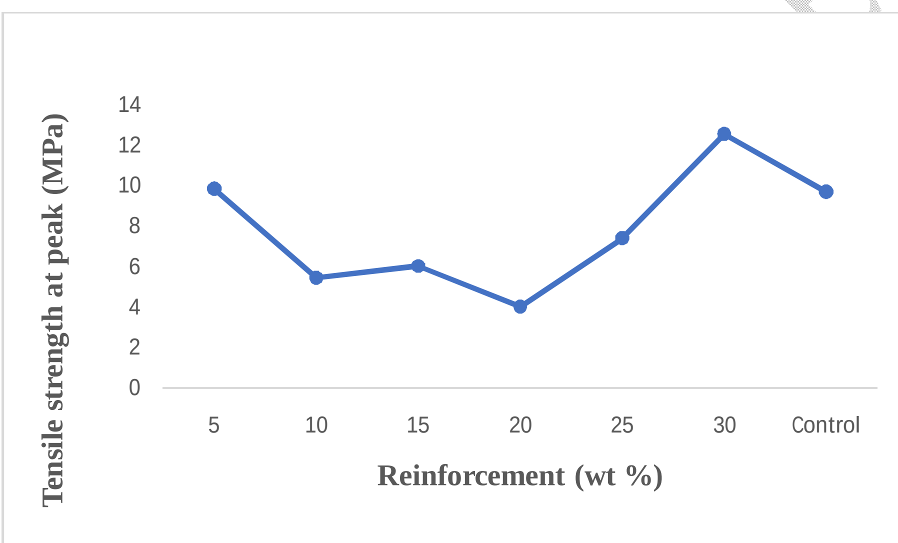

Figure 5. Variation of tensile strength at peak (MPa) with the composite and control

Figure 6. Variation of tensile strength at break (MPa) with the composite and control

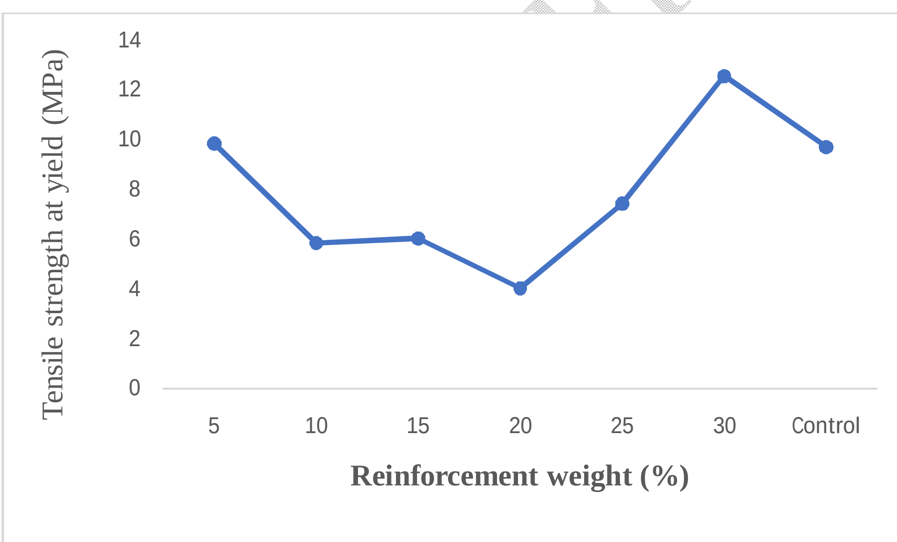

Figure 7. Variation of Tensile strength at yield (MPa) with the composite and control

From figure 5., it was observed that there is an upthrust or enhancement of tensile strength at peak and tensile modulus from 15 to 30 weight percent, this may be due to the fact that there is increase in particulate weight, and this result to high lignin content in the particles, lignin not just binds the lignocellulose materials together, yet as well behaves as a stiffening agent for the cellulose molecules inside the lignocellulose cell wall. However there is reduction in 25 percent which may be caused due to production error.

The increase in reinforcement resulted in irregular increase and decrease in tensile stress at break.

The highest tensile strength at break was achieved at 20% particle weight with a value of 1.23940 MPa. There is a regular upthrust and enhancement of tensile strength at yield from 20% to 30% weight percent.

Flexural Result/Discussion

Figure 8. Variation of flexural strength at peak (MPa) with the composite and control

Figure 9. Variation of flexural strength at break (MPa) with the composite and control

Figure 10. Variation of flexural strength at yield (MPa) with the composite and control

Figure 11. Variation of energy at yield with the composite and control

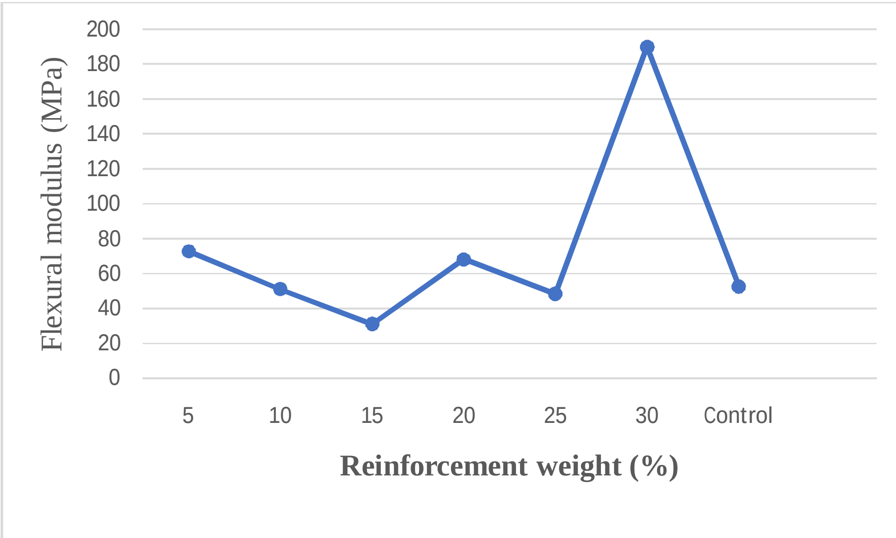

Figure 12. Variation of flexural modulus (MPa) with the composite and control

Flexural Test

From Figure 8, the increase in particles reinforcement resulted in irregular increase and decrease in the bending strength at peak of the composite. The highest bending strength at peak was achieved at 30% weight reinforcement with a value of 11.366MPa compare to other reinforcements and the control sample has 2.935MPa.

The increase in particles reinforcement resulted in decrease in bending strength at 5%, 10%, 15% and 20%. At figure 9, the highest bending strength at break was achieved at 15% weight reinforcement with a value of 6.851MPa, while the control sample has 0.667MPa.

Figure 10, the increase in particles reinforcement resulted in irregular increase and decrease in the bending strength at yield of the composite. The highest bending strength at yield was achieved at 30% weight reinforcement with a value of 11.366MPa compare to other reinforcements and the control sample have 2.935MPa.

Figure 11 shows the increase in particles reinforcement resulted in irregular increase and decrease in the energy at yield of the composite. The highest bending strength at yield was achieved at 30% weight reinforcement with a value of 0.30679MPa compare to other samples and the control sample have 0.07039MPa.

Impact Result/Discussion

Figure 13. Variation of impact energy with the composite and control

From figure 13 sample with 15wt (%) shows exceptional impact energy having the value of 5.48(J) this is due to the fact that the amount of lignin in the reinforcement at 15 % enhances this ability of the sample to withstand impact force, than any other samples, other samples have almost the same impact force, because the lignin in the reinforcement is either too low or too high for it to withstand impact force.

Biodegradability Result/Discussion

Figure 14. Variation of Biodegradability with the composite and control

Biodegradable test, Figure 14 revealed that the higher the reinforcement the higher the biodegradability, the highest value occurred 25wt % with value of 0.12g because plant particles are generally biodragradable.

Water Absorption Result/Discussion

Figure 15. Variation of water absorption (%) with the composite and control

The relationship between water absorption and particulate of epoxy raffia particles composite at different content was shown in Figure 15 increasing at 15 to 25% weight reinforcement, at 25% weight the highest water absorption weight was obtained. Raffia seed particles are natural particles generally hydrophilic materials with many hydroxyl groups (-OH) in the fibers structure and moisture absorption. The hydrophilic nature of raffia seed particles causes water uptake by these lignocellulosic materials which due to formation of hydrogen bonds between filler and water molecules.it is well known that particles absorbs water by forming hydrogen bonding between water moloecules on the all cell wall of the filler (husseinyah 2011).

However 25% gave the best water resistance having average value of 1.84g while the control do no absorb water due to the fact that epoxy resin of hydrophilic

Wear (Abrasion Resistance) Result/Discussion

Figure 16. Variation of Abrasion (wear) property with the composite and control

Figure 16 indicates that the wearing of the composite has the lowest value of abrasion resistance at 5% with the value of 0.14 g compare to other samples, while the control has 0.11, 30wt% has the highest abrasion resistance of 0.01.

5. CONCLUSION AND RECOMMENDATION

This chapter concludes the study done in this work. Recommendation is also discussed briefly. Nowadays, the world is concerned about the usage of biodegradable wastes which are the main sources of pollution. Therefore, this research was focusing on the production of polymeric composites with raffia seed particles serving as the reinforcement. The raffia seed was chosen because it is environmental-friendly and cheap. Result of the study showed that the tensile and flexural property of epoxy is appreciably improved by the raffia seed reinforcement phase. Epoxy matrix reinforced with 30 weight percent has led to the increase in bending strength with about 279% compared to the unreinforced epoxy matrix, this shows that high particle content is what can bring about good enhancement of this property. Result of the study also shows that the response of the material to tensile stress is improved especially when the matrix was reinforced by 30 weight percent of raffia seed particles. The Young's modulus for 20%wt raffia seed particles showed a higher modulus than the others reinforced and unreinforced sample. This result could be due to remove excess lignin and improve compactness in the composites. The result of wear test showed that the composite can withstand certain amount of friction before failing. Result shows that 30%. wt raffia seed has led to the increase in wear resistance, while higher particles content is what can bring about good enhancement of this property.

The overall best performance of the composite in all the tests was recorded at 30wt% raffia seed particulate reinforcement.

In conclusion, raffia seed is a good reinforcement for epoxy. Raffia seed is cheap and readily available. The properties of the composite improved significantly compared to the control sample. In addition, this composite can be applicable in car bumpers, car handles, interior car body and electronic products.

I recommend production of this composite mechanically, this will make the product free of defects, pores, and voids, it leads to better result and performance at service.

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