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Physico–Mechanical Properties of Cast and Reinforced Bioresin from Ground Nut (Arachis Hypogaea) Oil.

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ABSTRACT: The paper presents experimental report on some physico–mechanical propertiesof cast and reinforced bioresin produced from ground nut (Arachis hypogaea) oil. The cast bioresin specimens were produced by Cast polymer moulding method while the reinforced ones was by hand layup method with chopped strand mat glass fibre as reinforcement.The average compressive strength of the cast bioresin was 94.8KN/m^{2}while that of the reinforced was 120.7KN/m^2.The average tensile strength of the cast bioresin was 96.7KN/m^{2}while that of the reinforced was 987.6KN/m^2. The physical properties of the cast and reinforced bioresin determined were Void and Moisture contents.The void content of thecast bioresin was 3.70% while that of reinforcedwas 3.33%. The moisture content ofthe cast bioresin was 3.98% whilethe reinforced was 3.38%. Comparism of these mechanical and physical properties with polyester resin (synthetic resin) whose same properties were previously determined showed that the polyester resin composite can withstand more compression and tensile loads than the bioresin produced from ground nut oil. The results of moisture and void contents showed that the bioresin composite laminates are more susceptibility to trap air or gas and absorb water than the polyester resin. The reason is unconnected with the inherent properties and the production method of the bioresin. These tend to weaken the cross linking bond strength between the matrix and reinforcement thereby reducing the magnitude of the mechanical properties. However, the overall results showed that bioresin from ground nut oil has appreciable physico-mechanical properties that canmake it serve as either substitute or alternative resin to the petrochemical one at lower stress conditions.

Keywords: Composite material,Bioresin, Polyester resin, Hand layup, Cast moulding, Void content, Moisture content, Compressive strength, Tensile strength

I. INTRODUCTION

Composite material is one of the man-made materials widely used nowadays in the fields of Air, Land and Sea transportation among others for production of materials that have high strength to light weight ratio coupled with corrosion resistance, [1] and [2].The materials are generally used for production of light weight and high strength structures of machine component without compromising its efficiency.

Composite materials generally consist of two major constituents, reinforcement (i.e. glass fibre) and polymer matrix (i.e. polyester resin) commonly called resin. Resin (polymer matrix) of composite material constitutes a significant volume fraction (above 50%) of any fibre reinforced composite material that requires proper impregnation of the reinforcement.

Despite the fact that the reinforcement (i.e. glass fibre) carries the bulk of the load that the composite is subjected to, it is hardly possible to use the reinforcement alone as a single entity in any load bearing structure without the resin (polymer matrix), [3]. According to [4], resin in cast state may be used alone in a low load bearing structure without reinforcement. This indicates one of the importance of resin in composite material.

Resin, as defined by [1] and [5] separately, is a viscous and transparent liquid either from organic or inorganic source that will transform (cured and hardened) into solid when treated with suitable catalyst, accelerator with or without heat. Those from inorganic sources (petrochemicals) are commonly called synthetic resins while those from organic sources (such as plant or animal) are called bioresin or renewable resins. Going by [2], any type of resin has several functions: it is a binder that holds the reinforcement (fibre) in place, transfers external loads to the reinforcement and redistributes the load to surrounding fibers when an individual fiber fractures and laterally supports the fibers to prevent

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buckling in compression among others. It also gives the shape of the composite and protects it and reinforcement from adverse environmental effects and others.

Considering the problems associated with linear use of synthetic (petrochemical related) resins for composite manufacturing activities and the increasing global demand for composite materials, it was noted by [2] that concerted efforts were made by researchers across the globe to source for alternative materials that are not only sustainable, but renewable and affordable for resin or the reinforcement.

Going by the work of [6], Ground nut oil (GO) is one of the renewable and sustainable sources of oils in Nigeria and many other countries that can be used for bioresin synthesis. The use of this oil for bioresin production did not only help to cushion the adverse effects associated with linear use of synthetic resins, but also add more value to it and encourage more production thereby busting more economic activities. Bioresin from ground nut oil had been successfully producedby [6]. This work is centered on determination and analysis of some physico-mechanical properties of cast and reinforced bioresin earlier produced.

Polyester resin is the commonest and most popular synthetic resin used for wide range of production activities. One of the objectives of this work is to see how the determined physico-mechanical properties of GO bioresin vary with polyester resin.This will give room for suggestion of the bioresin either as alternative or substitute for the polyester resin.

There are different types of physico-mechanical tests or otherwise that can be conducted on composite materials, however, going by [7], [8] and [9], the type of tests conducted on fibre reinforced composites is inclined towards intended applications. Fibre reinforced composite materials are mostly used as components of Automobile or similar systems that aresubjected to either tensile, compression, impact forcesetc or combination ofthese and other forces as the case may be. The results of these tests would not onlyserve as data guide for selection of the composite materials in that condition, but will also give idea about the expectation of the composite materials when in service.

II. EXPERIMENTATION

2.1 Materials/devices/equipment and machines

These include:

Bioresin from ground nut oil, Catalyst (methyl ethyl Ketone peroxide, Accelerator (cobalt amine), glass fibre (Reinforcement), Digital weighing machine, Measuring cylinder, Rollers and brush, cylindrical pipes, Wooden moulds, Steel rule, Hacksaw, Hand files, Small plastic containers, Universal testing machine. Some of the materials are shown in plate I.

Plate I. Some of the materials used for production of biocomposites

2.2 Production of specimens

2.2.1 Cast specimens

All the cylindrical shape cast specimens were producedby cast polymer molding method.In this simple method, methyl ethyl Ketone peroxide (MEKP), catalyst and cobalt amine, accelerator were added to the desired quantity of the bioresin and mixed thoroughly without reinforcements before pouring the content into the cylindrical pipe mold. The ratio of catalyst, accelerator and bioresin mixture depends on how quickly one wants the composite to harden. In this work the ratio was 1:2:100 (catalyst, accelerator, resin) in ml. The moulded specimens were sun dried for five days to cure and harden fully. Plate 1I shows some sample of the specimens.

Plate 1I. Some samples of the cylindrical cast specimens.

2.2.2 Reinforced specimens

The rectangular shape reinforced composite specimens were produced by hand layup method described by [1] and [5].In this method, methyl ethyl Ketone peroxide (MEKP) catalyst and cobalt amine(accelerator) were added to the bioresin and mixed thoroughly. The ratio of catalyst, accelerator and bioresin mixture was 1:2:100 (catalyst, hardener, resin) in ml.

After the application of release agent (waste engine oil in this case) on the inner surface of the produced rectangular wooden mould, an appropriate amount of the catalyzed and accelerated bioresin was applied and distributed on top of the mould release agent and the chopped strand mat glass fibre was placed by hand on top of the resin. The reinforcement was then pressed on the bioresin with a hand-held roller which also compact the laminate and he remove some voids (trapped air or gases). After one reinforcement layer has been satisfactorily impregnated and compacted, more bioresin was applied and another glass fibre reinforcement layer was placed on top of the bioresin and the impregnation and compaction were repeated until the desired thickness of the composite laminate was reached. The ratio of mass of bioresin to glass fibre in this work was 60:40 proper impregnation of the reinforcement.

The moulded specimens were sun dried for five day to cure and harden fully before removing for finishing and tests. Plate III shows sample of the specimens.

Plate III: Some samples of the rectangular reinforcedbiocomposite specimens

2.3Preparation of specimens

Prior to testing, the demoulded specimens were cut and finished to the dimensions suitable for each test.

(a). Cast specimens

i. Tensile tests: 180mm length by 20mm diameter, three pieces.

Cross sectional area (Ac) of each specimen = 3.14 $x10^{-4}m^2$

ii.Compression tests: 70mm height by 15mm diameter, three pieces.

Cross sectional area (Ac) of each specimen = 1.77 $x10^{-4}m^2$

(b). Reinforced specimens

i. Tensile tests: 180mm length by 35mm breadth by 12mm thick, three pieces.

Area (A) of each specimen = 4.2 $x10^{-4}m^2$

ii. Compression tests: 70mm height by 30mm breadth by 12mm thick, three pieces.

Area (A) of each specimen = 3.6 $x10^{-4}m^2$

2.4 Testing of specimens

2.4.1 Void and Moisture contents in the cast and reinforced composite laminates

The void content in the reinforced composite laminate was determined by comparing the theoretical density with its actual density as reported by [10].

Thus Void = $\frac{pt-pa}{pt}$ …….(1)

Where,

Pt = theoretical density of composite material

pa = actual density of composite material

The theoretical density of composite is calculated as: $Pt = P_f v_f + P_m v_m$ ……(2)

Where,

P_f and P_m are the densities of fibres and matrix respectively while v_f and v_m are the volume fractions of fibres and matrix respectively.

The void content of the reinforced composite laminate was calculated using equations 1 and 2 and experimental data values in table 1.

The Moisture content of the cast composite laminates was determined by weight loss method reported by [11] and [12].

Moisture content (Mc) = $\frac{Ww - Wd}{Ww}$x100% ……(3)

Where,

W_w = wet weight of material before drying in the sun.

W_d = dry weight of material after drying in the sun.

The Moisture content of the cast bioresin was calculated using equation 3 and experimental data in table 1.

Table 1: Experimental data on reinforced and cast bioresin for Void and Moisture contents determinations.

Resin	Parameter	Dimension & mass	Density
AEGO	Cast bioresin	$13cm^3$ = 17.6g before drying $13cm^3$ = 16.9g after drying	Theoretical density = $1.35g/cm^3$ Actual density = $1.30g/cm^3$
AEGO	Reinforced bioresin	$13cm^3$ = 23.7g before drying $13cm^3$ = 22.9g after drying	Theoretical density = $1.82g/cm^3$ Actual density = $1.76g/cm^3$

2.4.2 Mechanical properties tests

Both thetensile and compression tests were conducted on universal testing machine.The tests were performed as reported by [13] and [14]. The tensile force was gradually applied until failure occurred while the same procedure was adopted for compression tests.In each case the maximum applied (breaking) force was read from the machine after which the tensile and compression strengths were respectively calculated using the formula obtained from [13] and [14].

Tensile strength = $\frac{Breakingforce}{Originalareaofspecimen}$ or $\sigma = \frac{F}{A}$ …… (4)

Where,

σ = Tensile Stress

F = Force at failure

A = Original cross sectional area of specimen

The compressive strength = $\frac{Crushingforce}{Originalareaofspecimen}$

or $\sigma = \frac{F}{A}$ …….. (5)

Where,

σ = Compressive Stress

F = Crushing force

A = Original cross sectional area of specimen

III. RESULTS AND DISCUSSIONS

3.1 Moisture contents results.

The Moisture contents of the cast and reinforced biocomposites are shown in table 2.

Table 2. Results of moisture and void contents of cast bioresin from GO.

Parameters	Composite laminate	Determined value (%)
Moisture content	Cast bioresin	3.98
	Reinforced bioresin	3.38
Void content	Cast bioresin	3.70
	Reinforced bioresin	3.33

Moisture as defined by [11] and [12], is simply water diffused in a relatively small quantity in a material or substance. The amount of this water in the material constitutes its moisture content. Nearly all materials contain at least a diminutive volume of moisture as a component of the molecular makeup. In this work, the moisture content of the cast GO bioresin composite was 3.98% while that of the reinforced was 3.38%. Comparing these results with reinforced polyester resin, 0.5%previously determined and reported by [15], showed that GO bioresin specimens are much more susceptible to absorb water than the polyester specimens. This will advertently affect the binding force of the bulk material and of course the mechanical properties as shown in tables 3-4 and figures 1 and 2.

The void contents of the cast and reinforced biocomposite laminates were 3.70% and 3.33% respectively.Comparing these results with reinforced polyester resin, 3.20% previously determined and reported by [15], showed that GO bioresin composites value were slightly higher than the polyester resin. GO bioresin composites are susceptibility to trap air or gas than the polyester resins. As the case with moisture contents results, high value of the void contents will advertently affect the binding force of the bulk material and of course the mechanical properties as shown in tables 5-6 and figures 3 and 4.

The higher values of moisture and void contents of the biocomposite from GO as compared to polyester resin is unconnected with the chemical makeup of the bioresin andthe effective control of the processes involved in the production of the bioresin.

3.2 Mechanical tests results

3.2.1 Tensile tests results

The results of the tensile tests results on cast and reinforced bioresin from GO are shown in tables 3-4 while figures 1-2 are histograms showing the variations of the average strengths.

Table 3: Tensile tests results of cast bioresin

Specimen	Breaking Force (N)	Tensile strength (KN/m^2)	Average(KN/m^2)
CBt_1	29.06	92.5	96.7
CBt_2	31.3	99.7	
CBt_3	30.7	97.8	

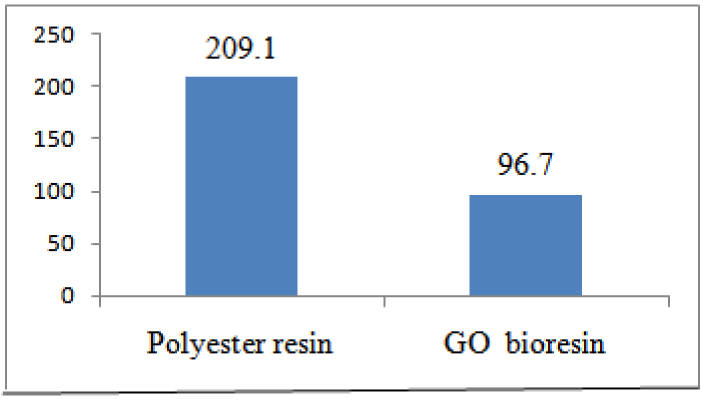

Figure 1: Histogram showing the variation of Tensile strengths of the cast bioresin and Polyester resin composites.

Table 4: Tensile tests results of glass fibre reinforced bioresin

Specimen	Breaking Force (N)	Tensile strength (KN/m^2)	Average(KN/m^2)
RBt_1	415.7	989.8	987.6
RBt_2	411.6	980.0	
RBt_3	417.0	992.9	

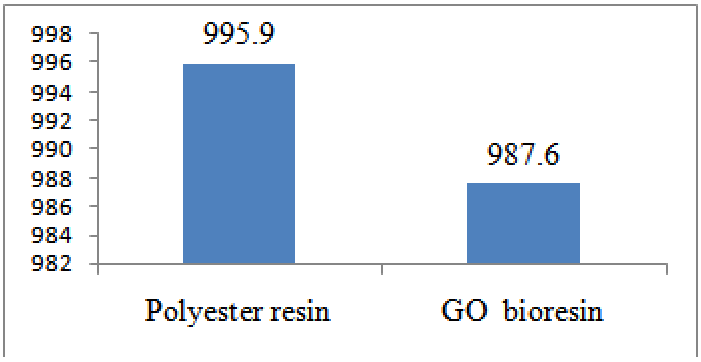

Figure 2: Histogram showing the variation of Tensile strengths of the reinforced bioresin and Polyester resin composites

Tables 3-4 showed the tensile results of the cast and reinforced biocomposite from GO while figures 1-2 showed the variations of the average results compared with that of polyester resinpreviously determined and reported by [15].Considering table 3 and figure 1, the average tensile strength of the cast bioresin composite was 96.7KN/m^2 while that of cast polyester resin composite was 209.1KN/m^2. The results showed that cast GO biocomposite is weak in tension load than cast polyester resin composite. Although, the cast polyester resin composite has higher value than its counterpart, GO bioresin composite can be used as alternative to polyester resin in a situation where the percentage tensile load tolerated is either 54% or more of that of the polyester resin composite.

Considering the tensile results of the reinforced resins in table 4 and figure 2,the average tensile strength of the reinforced bioresin composite was 987.6KN/m^2 while that of reinforced polyester resin composite was 995.9KN/m^2. The results showed that the GO biocomposite has appreciable value close that of the polyester composite. This simply mean that biocomposite from GO performs better in tension load when reinforced with suitable material.

3.2.2Compression test results.

The results of compression tests on cast and reinforced bioresin from GO are shown in tables 4 and 5 while figures 3 and 4 are histograms showing the variations of the average results as compared with polyester resin.

Table 4: Compression tests results of cast bioresin from GO.

Specimen	Breaking Force (N)	Compressive strength (KN/m^2)	Average(KN/m^2)
CBc_1	16.4	92.7	94.8
CBc_2	17.2	97.2	
CBc_3	16. 7	94.4	

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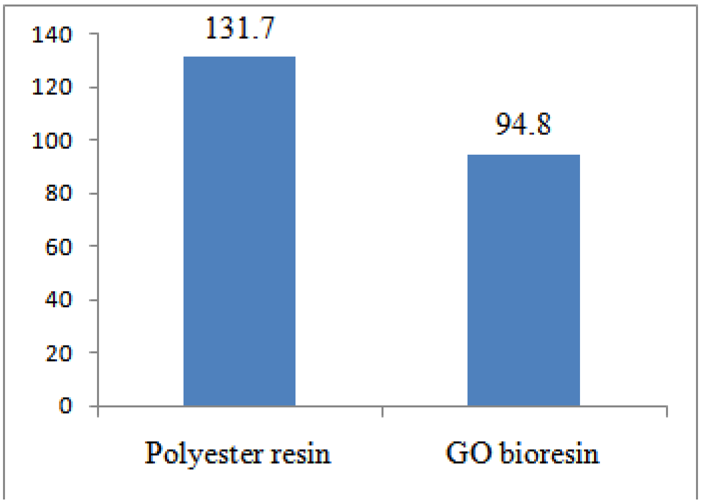

Figure 3: Histogram showing the variation of Compressive strengths of the cast Bioresin and Polyester composites

Table 5: Compression tests results of glass fibre reinforced bioresin from GO.

Specimen	Breaking Force (N)	Compressive strength (KN/m^2)	Average(KN/m^2)
RBc_1	43.6	121.1	120.7
RBc_2	43.7	121.4	
RBc_3	42.9	119.7	

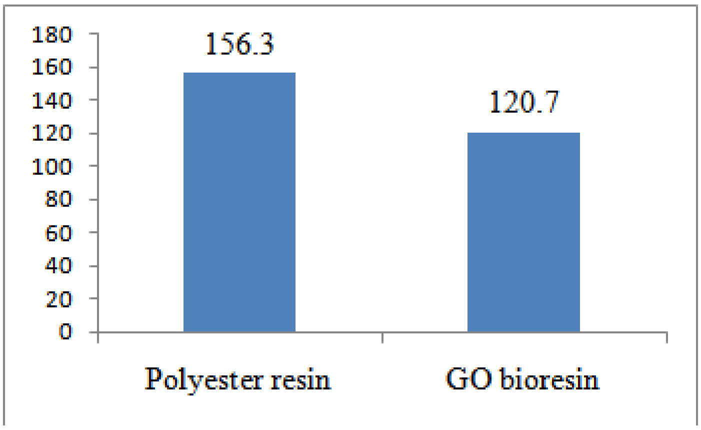

Figure 4: Histogram showing the variation of Compressive strengths of the reinforced Bioresin and Polyester composites

Tables 4-5 showed the compression results of the cast and reinforced biocomposite from GO while Figures 3-4 showed the variations of the average results as compared with that of polyester resinpreviously determined and reported by [15]. Considering table 4 and figure 3, the average compressive strength of the cast bioresin composite was 94.8KN/m^2 while that of cast polyester resin composite was 131.7KN/m^2. The results showed that cast bioresin from GO is weak in compression load than cast polyester resin composite. The results showed GO bioresin composite can be used as alternative to polyester resin in a situation where the percentage compressive load tolerated is either 28% or more of that of the polyester resin composite.

The compression tests results of the reinforced resins are shown in table 3 and figure 4. The average compressive strength of the reinforced bioresin composite was 120.7KN/m^2 while that of reinforced polyester resin composite was 156.3KN/m^2. The results simply showed that bioresin composite can be used as alternative to polyester resin in a situation where the percentage compressive load tolerated is either 23% or more of that of the polyester resin composite.

The large disparities between the reinforced and cast resins results were brought about by the important role played by reinforcement in composite material. Going by [1] and [5], the bulk of the load imposed by reinforced composite is carried by the reinforcement due to fact that the reinforcement (i.e. fibre) has much more strength and stiffness than the matrix material. This characteristic is displayed in these results. The reinforcement helps to improve the load carrying capacity of neat cast resin. The general results simply suggest that reinforced composite materials should be given more attention than the cast (neat) resin when it comes to load bearing structures and the void and moisture contents should be as low as possible.

IV. CONCLUSIONS

The following conclusions are made based on the outcome of the study:

(i). The results of Moisture and Void contents revealed that GO bioresin composites are more susceptible to absorb water and trap air or gas than the polyester resin composites. This is due to the chemical makeup of the resins. The high values of moisture and void contents in the specimens tend to weaken the bond strength of the composite and thus the mechanical properties of the materials as shown in the results.

(ii). The large disparities between the cast and reinforced composites were brought about by the role played by reinforcement in composite materials. This suggest that reinforced composite materials should be given more attention than the cast (neat) resin when it comes to load bearing structures and that the void and moisture contents should be as low as possible.

(iii) The overall results revealed that composite produced from GO bioresin has appreciable mechanical properties close to the polyester (synthetic) resin composite both in cast and reinforced states and thus can serve as alternative resin to the synthetic polyester resin at lower stress applications when the need arises.

REFERENCES

[1]. Astron, B.T. (1997). Manufacturing of polymer composites 1st Edition, London: Chapman and Hall, U.K.

[2]. Sadiq A. S. , A. A. Bello and A. Tokan (2016).Shift towards using renewable oil for resin production for fibre reinforced composite materials in Nigeria.Proceeding of the 29th AGM & International Conference of the Nigerian Institution for Mechanical Engineers(NIMechE) hosted by the Nigerian Institution for Mechanical Engineers, Uyo in AkwaIbom state, Nigeria. 18th – 21st October, 2016. PP.1-18

[3]. Sadiq A. S., A. A. Bello, A. Tokan and S. Abdulsalam (2018).Production and Analysisof bioresin from Mango (MangiferaIndica) Kernel Oil.International Journal ofModern Research in Engineering and Technology (IJMRET) Volume 3 Issue 12.PP. 5 –16

[4]. Sadiq A. S. A. A. Bello and M. A. Bawa (2019). Determination and analysis ofMechanical properties of cast resin from mango (Mangiferaindica) kernel oil.International Journal of Engineering Trends and Technology (IJETT)http://www.ijettjournal.org – Volume 67 Issue 9. Page 63-68.

[5]. Strong A.B. (1999). Fundamentals of composites manufacturing: materials, method andApplications 1st Edition, SME Publishing Ltd. Dearbarn, MI U.S.A

[6]. Sadiq A. S.,Alhassan A. .M.andOrisanaiye B. A (2020).Productionof bioresin from Ground nut (Arachis Hypogaea) oil.International Journal of Advances in Engineering and Management (IJAEM).Volume 2, Issue 10, pp: 347-354. www.ijaem.net

[7]. Jianmin Chang, Yong Cui and Wenliang Wang (2016). Fabrication of Glass FiberReinforced Composites based on Bio-Oil Phenol Formaldehyde Resin.www.mdpi.com/journal/materials

[8]. MohamadZaki Abdullah and NasrulHaziqCheAslan (2019). Performance Evaluationof Composite from Recycled Polypropylene Reinforced with Mengkuang Leaf Fiber.http:/www.mdpi.com/journal/resources. Page.1-8

[9]. Agarwal, B. D. and Broutman, L. J. (1990). Analysis and performance of fibercomposites, 2ndediton,Wiley

[10]. MahoorMehdikhani , Larissa Gorbatikh, IgnaasVerpoest and Stepan V Lomov (2019).Voids in fiber-reinforced polymer composites: A review on their formation, characteristics, and effects on mechanical performance. Journal of Composiste materials.Vol.52, No.12. Page 1579-1669

[11]. NooriHassoon Mohammed Al-Saadi and Samheri A. RedhaAlmuradi (2016). Anexperimental investigation of moisture effect on fatigue behavior of composite materials.European Journal of Mechanical EngineeringResearch (www.eajournals.org). Vol.3,No.1, pp.1-18,

[12]. Davies, P., Pomies, F. and Carlsson, A.L. (1996). Influence of Water Absorption onTransverse Tensile Properties and Shear Fracture Toughness of Glass/Propylene.Journal of Composite Materials, Vol.30, No.9. pp. 1004-1019

[13]. Kakani, S. L. and AmitKakani. (2004). Material science 1st Edition, new age international publisher, New Delhi, India

[14]. FazleElahi A.H.M, MilonHossain 1, Md., Shahida Afrin and Mubarak A. Khan(2014). Study on the Mechanical Properties of Glass Fiber Reinforced PolyesterComposites. Proceeding on International Conference on Mechanical, Industrial andEnergy Engineering. 26-27 December 2014. Bangladesh

[15]. Sadiq, A. S., Bawa, M. A. and Benjamin (2020).Physico-Mechanical Properties of Reinforced Bioresin from Mango (MangiferaIndica) Kernel oil.American Journal of Engineering Research (AJER), www.ajer.org Research Paper. Volume-9, Issue-6, pp191-197.