THE EFFECTS OF HYBRIDIZATION ON THE MECHANICAL PROPERTIES OF BAGASSE/SISAL/COIR REINFORCED EPOXY HYBRID COMPOSITE

R.O. OGABI[1], B.M. DAUDA[1], A. S. LAWAL[1], S GADIMOH,[3]
M. ABDULRAHIM[2] AND S. OLADIRAN[1]
[1]Department of Polymer and Textile Science, Ahmadu Bello University, Zaria
[2]Department of Mechanical Engineering, Ahmadu Bello University, Zaria
[3] Department of Textile Technology, NARICT, Zaria, Nigeria.
[raphaelogabi@yahoo.com]

ABSTRACT
Biomass fibres obtained from agricultural wastes have found application in the production of structural reinforcement for bio-composites used for manufacturing engineering components because of their low cost, biodegradable and eco-friendly advantages. The effects of hybridization on the mechanical properties of bagasse/sisal/coir reinforced epoxy hybrid composites have been studied. Bagasse has gained applications in paper making and as a biofuel in industries especially in Egypt, India and Cuba. However, its potentials have not been fully utilized as engineering materials due to its moderate strength. This work is therefore aimed at tailoring its properties through hybridization with other supporting natural fibres for better performance and applications. Hybridization was found to increase both the tensile strength and flexural modulus of the composites in the order: Bagasse/Epoxy < Bagasse/Coir/Epoxy < Bagasse/Sisal/Epoxy < Bagasse/Sisal/Coir/Epoxy. The tensile strength of the three-fibre/matrix hybrid system of Bagasse/Sisal/Coir reinforced epoxy composites was 53.25 MPa, showing an improvement of 70.1 % over the pure Bagasse/Epoxy composite. However, when blended with sisal and coir, the tensile strength value was raised to 43.6 MPa with the composition of 60%B/40%S having an improvement of 39.3% over the pure Bagasse/Epoxy composite while that of 60%B/40%C registered a strength value of 40.6 MPa. On the other hand, the hardness of the composites decreased with the hybridization of the fibres. The hardness strength value for the hybrid composites showed that as the sisal component increased from 40 % to 60 %, the composition with 50 %B/50 %C showed the highest numerical strength of 8.87 RHF followed by 60 %B/40 %C having 8.63 RHF. As fibre loading increases, the rate of water absorption increases and the rate of water absorption is higher for the hybridized composite than for the unhybridized composite system. The specific water absorption value of the hybrid composite is as follows 60 wt%B40%S < 40 %B60 %C <60 %B/10 %S/30 %C having absorption rate of 6.5 %, 7 % and 10.8 % respectively.

Keywords: *Natural Fibre, Bagasse, Sisal, Coir, Epoxy resin, Hybridization.*

1.0 INTRODUCTION

Composites, are becoming an essential part of today's materials due to the advantages such as low weight, corrosion resistance, high fatigue resistance and faster assembly. They are extensively used as materials in making aircraft structures, electronic packaging, medical equipment, space vehicle to home building materials (Shaw et al., 2010).

In recent years; there has been growing environmental consciousness and understanding of the need for sustainable development, which has raised interest in using natural fibres as reinforcements in polymer composites to replace synthetic fibres such as glass, graphite and carbon fibres (Netravali and Luo, 1999), which are non-biodegradable.

Countries such as Egypt, Cuba, etc. use bagasse fibre in pulp and paper industries and for production of board materials (Silva and Al-Qureshi, 2010), but in Nigeria, they are left to waste and litter the environment. Thus, the main objective of this work is to use bagasse fibres as reinforcement in composite materials with the expectation that the resulting composite will have tailored properties for the development of engineering materials.

Earlier works by Khan et al., (2000) have shown that bagasse is a relatively weak fibre, thus as a secondary objective, bagasse was hybridized so that the resulting composite would have enhanced mechanical properties.
Hybrid composites which contain two or more types of fibres in single matrix have been found to be more advantageous as one type of the fibres can complement what is lacking in the other. Hybrid composites fabricated by proper material design help to achieve balance in cost and performance (John and Thomas, 2008).

3.0 MATERIALS AND METHODS

3.1 MATERIALS

Bagasse fibre; Sisal fibre; Coir; Epoxy resin (LY 556) & Tetraethelene pentaamine, SY 31 (B); distilled water

3.1.1 EQUIPMENT

Measuring cylinder; Analytical balance (Sartorius. Model; ED2245); 200 x 120 x 6 mm glass mould; Blending machine (Signora brand, Jumbo mix type); Glass rod stirrer; Tensometer type "w" (Monsanto, UK); Universal Material Testing Machine. (Cat Nr. Model: 261); Indentec Universal Hardness Testing Machine (model: 8187.5) LKV "B"

3.2 METHODS

3.2.1 Extraction and alkaline treatment of Bagasse

Chewed Sugarcane *(Saccharum Barberi)* was collected from Sabon Gari environs of Zaria metropolis and cleaned by soaking water at 60 ^{o}C for about one hour with gentle stirring. This procedure removes fine bagasse particles, sugar residues and organic materials from the samples. The fibres were air dried for 40 min at 26 ^{0}C. The long bagasse fibres (rind portion only) were cut into an average length of 7.5 mm. Established works by Raj, R.G, Maldas, D, Kokta B.V. and Daneault, C, (1990) have shown that alkali treatment of natural fibres results in improved mechanical properties of composites reinforced with such fibres by removing the hemicellulose and lignin thereby improving the fibre-matrix interface; thus the bagasse fibre was subjected to alkali treatment by dipping the bagasse fibres in 5 % NaOH solution for 2 hours at 60^{o}C. The fibres were further washed with distilled water and 2 % acetic acid to neutralize any remaining alkali.

3.2.2 Extraction and alkaline treatment of Sisal

The Sisal plant (*Agave sisalana) was* obtained from NARICT, Zaria. The fibre was extracted through a process called decortication, where leaves are crushed and beaten manually by a smooth edged stick so that only fibres will remain (mechanically). After extraction, the fibres were then washed in plenty of water to remove excess wastes such as chlorophyll, leaf juices and adhesive solids (hemicelluloses). The fibres were then dried in an open air and brushed. The lustrous strands are creamy white in colour. The Sisal fibres were also subjected to alkali treatment as described above. Among other properties, sisal is a strong fibre which has been used in rope making for marine applications and as reinforcement in composite materials for structural use.

3.2.3 Extraction and alkaline treatment of Coir

The husk of coconut fruit fibre (Cocos nucifera) was obtained from Ifo Local Government Area, Ogun State. Coir is highly resistant to abrasion, durable and biodegradable. It has gained application in crash helmet fabrication (Yuhazri and Dan, 2007). The fibrous layer of the fruit was extracted from the hard shell (husk) manually (dehusking) and subjected to alkali treatment as discussed above.

3.2.4 DESIGN OF EXPERIMENT

Composites with different compositions of bagasse fibre content (0, 5, 10, 15 and 20 wt %) were first fabricated. Then another set of hybrid composites were produced based on the optimum point of bagasse-epoxy composite at a particular volume fraction by blending the bagasse with sisal and coir respectively. Finally, the three fibres were blended together and reinforced in the epoxy matrix to examine the best formulation and performance of the hybrid composite produced as seen in table 1 below.

Table 1: Percentage fibre loading of Bagasse/Epoxy Composites.

S/N	wt% of Bagasse (g)	wt% of Epoxy	Mass of BF (g)	Mass of Epoxy (g)	Total mass (g)
1	0	100	NIL	90.72	90.72
2	5	95	4.50	86.22	90.72
3	**10**	**90**	**9.07**	**81.65**	**90.72**
4	15	85	13.61	77.11	90.72
5	20	80	18.15	72.57	90.72

Table 2: Compositions of Bagasse/Sisal Reinforced Epoxy Composites at 10% bagasse/epoxy (9.07g).

S/N	wt% of BF	wt% of SF	Mass of fibre blend (g)	Mass of Epoxy (g)	Total mass (g)
1	70	30	9.07	81.65	90.72
2	60	40	9.07	81.65	90.72
3	50	50	9.07	81.65	90.72
4	40	60	9.07	81.65	90.72

Table 3: Compositions of Bagasse/Coir Reinforced Epoxy Composites.

S/N	wt% of BF	wt% of CF	Mass of fibre blend (g)	Mass of Epoxy (g)	Total mass (g)
1	70	30	9.07	81.65	90.72
2	**60**	**40**	**9.07**	**81.65**	**90.72**
3	50	50	9.07	81.65	90.72
4	40	60	9.07	81.65	90.72

Table 4: Compositions of Bagasse/Sisal/Coir Reinforced Epoxy Composites at 60/40 of bagasse/sisal

S/N	wt% of BF	wt% of SF	wt% of CF	Mass of fibre blend (g)	Mass of Epoxy (g)	Total mass (g)
1	60	10	30	9.07	81.65	90.72
2	60	20	20	9.07	81.65	90.72
3	60	30	10	9.07	81.65	90.72

Where BF= Bagasse fibre, SF= Sisal fibre, CF= Coir fibre

3.2.5 FABRICATION OF COMPOSITES

The composites were produced based on standard conditions. The epoxy resin was mixed with the amine hardener in the ratio of 2:1 and stirred for 5 mins in other to facilitate curing. The weighed bagasse fibre was carefully laid (using hand lay-up technique) in the prepared glass mould containing some portion of the calculated amount of matrix based on the mould volume capacity, after which the remaining epoxy resin was poured onto the fibres in the mould to ensure that the fibres are completely dispersed and embedded in the matrix.

Similar procedure was followed to fabricate the hybrid reinforced composites made of sisal and coir. However, the heterogeneous fibres were mixed thoroughly in a mixer (flat type blade, with a rotating speed of 17.5rpm) for about 3 mins for proper blending. In other to ensure adequate mixture, little quantity of the fibres were mixed simultaneously and gradually first before the entire bulk of the fibres.

3.2.6 EXPERIMENTAL PROCEDURES FOR CHARACTERIZATION

3.2.6.1 TENSILE STRENGTH AND MODULUS

Tensile strength is the force required to pull a composite material apart. The tensile strength of the composite depends on the strength of the fibre, length of fibre and the fibre matrix interaction. The test specimens in dumb-bell shape of the required standard dimensions according to ASTM D638 were cut and clamped between the upper and lower jaws of the type "W" The values of the breaking load and elongation were taken accordingly. The test was repeated three times for each sample of the composite and the average value was recorded.

Flexural modulus also referred to as stiffness, is the measure of resistance of the composite material to deformation. It was obtained from the flexural strength using the formula below:

Flexural strength = $3PL/2bd^2$ ………………. 1.

Flexural modulus = $PL^3/4wbd^3$ …................. 2.

where: P= maximum load in KN, L = gauge span of the sample in mm, b = sample width in mm, d = sample thickness in mm, w= deflection

3.2.6.2 HARDNESS

This is a measure of the degree of penetration or impression the test ball makes on the surface of the composite materials.

The "Indentec Universal Hardness Testing Machine Model 8187.5LKV"B" Rockwell RHF indentor (1/16" steel ball) with minor load 10kg and major load 60kg was used in measuring the hardness using the shore scale according to ASTM2240.

It consist of an indenter, a graduated circular tube and a flat surface which the sample to be tested are mounted or laid on. The sample was placed on the flat surface and the indenter was made to make an impression the specimen material, the load was maintained at a minimum time of 10 to 15 seconds. The test was repeated for about five times and the average values were obtained.

3.2.6.3 WATER ABSORPTION

Water absorption was conducted according to ASTM 2842. Twelve (12) samples were cut to a specific size (3x4) and weighed using weighing balance correct to 2 decimal places.

The weighed samples were completely immersed in distilled water. The composites samples were left in the water for 24 hours. Thereafter, the samples were removed, cleaned with a soft cloth to remove surface moisture and reweighed. The same procedure was repeated for thirty (30) days and the percentage water absorption was calculated using the formula below:

$$Moisture\ absorption\ (\%) = \frac{W_2 - W_1}{W_1} \times 100 \quad \ldots 3$$

W_1=Initial weight of composite, W_2=Final weight of composite

4.0 RESULTS AND DISCUSSION

4.1 Effect of hybridization on Tensile Strength and modulus of the hybrid composites

The force necessary to pull a specimen apart, as well as how the material stretches before breaking indicates how tough or brittle the material may be. Therefore the tensile test measures the maximum stress that a material can withstand while being stretched or pulled.

From the result in figure 1, it was observed that the tensile strength of the bagasse/epoxy composite increases as the fibre loading increases. But beyond 10 % fibre loading, the composite material experienced a decrease in the tensile strength. The decrease in tensile strength could be attributed to the low wettability of the fibres by the matrix. The properties of the composites with different hybridization under this investigation are presented in Figure- 2 and figure 3. Result shows the effect of hybridization on the tensile properties of natural fibre composites. Among all the composites, the one having composition of 60 % Bagasse/40 %Sisal had the highest tensile strength of 43.60 MPa with an improvement of about 39.3 % over the Bagasse/Epoxy composite.
At that composition, coir fibre was incorporated into the bagasse/sisal composite system.

The characterization of the composites reveals that hybridization has significant effect on the mechanical properties of composites. However, in the case of the three-fibre hybrid composite system, the composite with composition of 60 %B/10 %S/30 %C had the highest tensile strength of 53.25 MPa with an improvement of about 70.1 % over the Bagasse/Epoxy composite. While that of 60 % B/30 % S/10 %C showed the lowest tensile strength of 46.2 MPa having an improvement of 47.6 %.

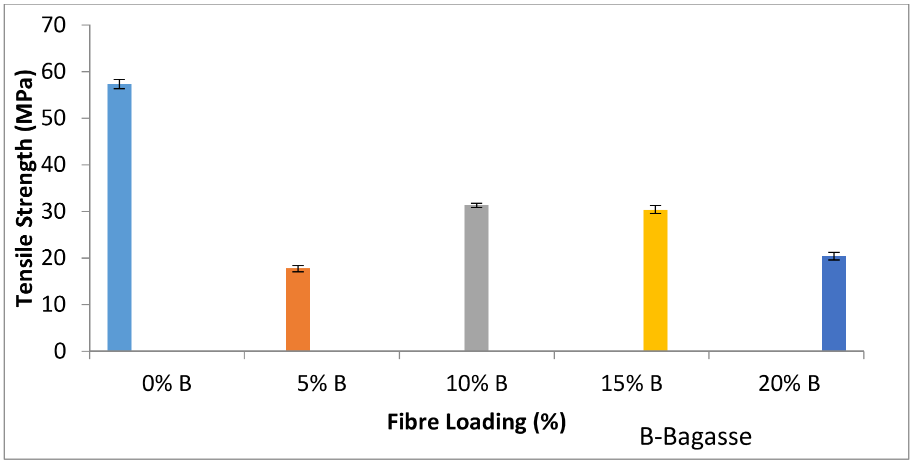

Figure 1: Effect of Fibre loading on the Tensile Strength of Bagasse/Epoxy Composite.

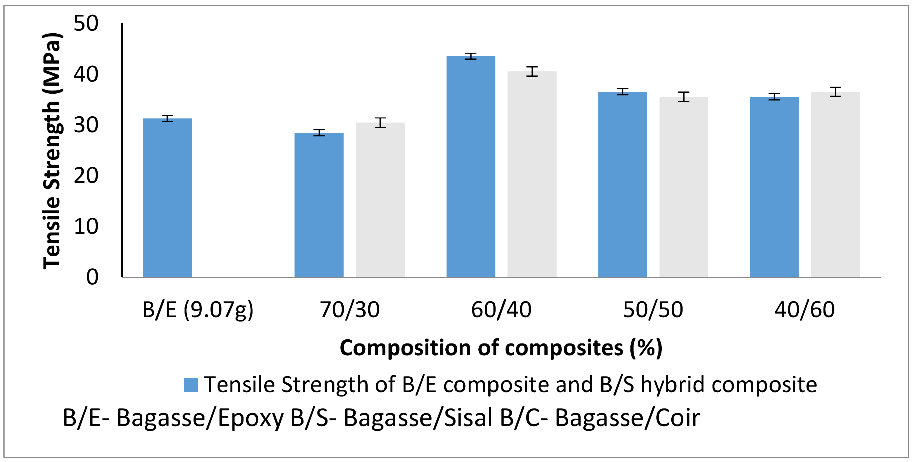

Figure 2: Effect of hybrid composition on the tensile strength of bagasse/epoxy composite at 10% fibre loading (9.07g)

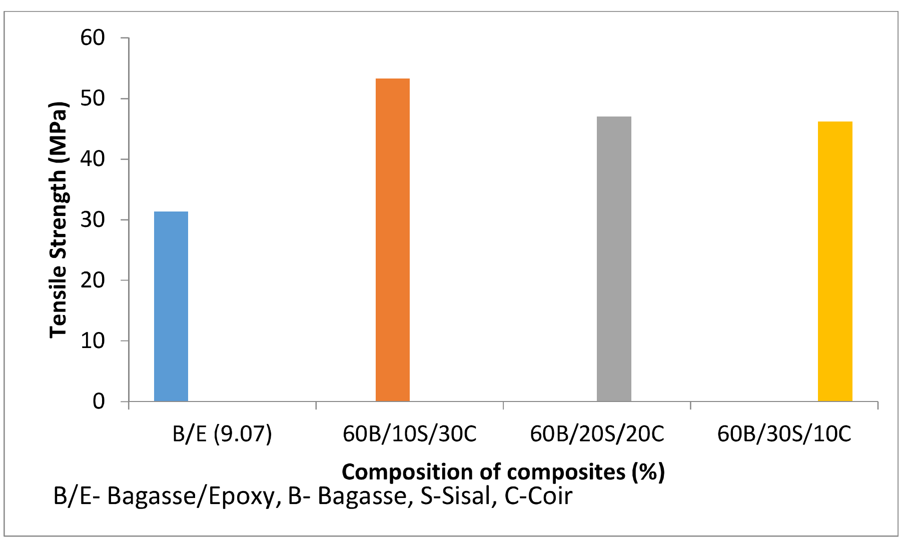

Figure 3: Effect of hybrid composition on the tensile strength of bagasse/sisal composite at 60/40 fibre loading (9.07g)

Thus, there is a considerable improvement in the tensile properties of bagasse/epoxy when blended with sisal and coir in two and three-fibre reinforced epoxy hybrid composites system respectively. This improvement in tensile strength is as a result of the incorporation of stronger into the bagasse/epoxy composite.

Similarly, as seen from figure- 4, 5 and 6; the flexural modulus of bagasse is lower before reinforcement but after blending with the sisal and coir fibres, the flexural strength was raised until it got to an optimum. The high modulus of elasticity of these fibres helped to carry a large amount of loads and consequently improved the strength. The numeric value for the flexural modulus of 100% epoxy, 5 %, 10 %, 15 % and 20 % bagasse/epoxy composites are 464.42 MPa, 1561.21 MPa, 2199.46 MPa, 1041.76 MPa and 1922.48 MPa respectively (revealed in fig 4). The 100% had the lowest modulus because of its brittleness (revealed in fig 4).

In figure 5 below, the composite having composition of 50 % Bagasse/50 %Sisal had the highest flexural modulus value of 2773.42 MPa with an improvement of 43.7% over the Bagasse/Epoxy composite, While the composite having composition of 50 %Bagasse/50 % Coir shows a flexural modulus of 3147.78 MPa with a better synergistic improvement of 50% over bagasse/epoxy composite revealing that coir is a stiffer fibre compare to sisal.

However, in the case of the three-fibre hybrid composite system in figure 6, the composite with composition of 60 %B/20 %S/20 %C had the highest flexural strength value of 135.6 MPa with better improvement of about 51.3 % over the Bagasse/Epoxy composite. While that of 60 %B/30 %S/10 %C showed the lowest flexural strength of 74.4 MPa.

The improvement in the flexural strength is attributed to the fact that there is a synergistic interaction between the fibres in the hybrid situation. The improvement of the flexural strength and modulus was also confirmed by Cao *et al.,* (2006).

4.2 Effect of hybridization on the hardness of the hybrid composites.

Figure-7 represents hardness values of the hybrid composites with numerical values of 8.5 RHF, 8.4 RHF, 8.0 RHF and 7.8 RHF for 5 %, 10 %, 15 % and 20 % fibre loading respectively.

The hardness value decreased when the resin is reinforced by fibres, as the fibre loading increased from 5 % to 20 %. Due to distribution the test load on fibres which increase the penetration of test ball to the surface of composite material and by consequence raise the hardness of this material. (Abbasi, 2003) obtained similar trend of result in is work, 'preparation and characterization of polypropylene composite'.

However, in Figure 8, the hardness strength for the hybrid composites showed that as the sisal component increased from 40 % to 60 %, the composition with 50 %B/50 %C showed the highest numerical strength of 8.87 RHF followed by 60 %B/40 %C having 8.63 RHF. In Figure 9 above, the hardness of the three-fibre hybrid composite system are as follows: 60 %B/10 %S/30 %C > 60 %B/20 %S/20 %C > 60 %B/30 %S/10 %C having numerical values of 6.6 RHF, 6.5 RHF and 5.8 RHF respectively.

4.2.2 Water Absorption Test Result

The percentage water absorption of the composites was determined according to ASTM 2842 standard. The samples were weighed and immersed in distilled water for 24 hrs and thereafter reweighed. The percentage water absorption was examined for 30 days.

Water absorption is one of the major concerns in using natural fibre composites in many applications because the higher the rate of absorption, the lower the Mechanical properties of the composites. In this study, the rate of water absorption was measured by the weight change method for the composites. The results are shown in figure- 10, 11 and 12 respectively.

The effect of water absorption is important in case the material that has been developed for applications comes in contact with water.

The effect of this moisture absorbed leads to the degradation of fibre-matrix interface region creating poor stress transfer between fibre and matrix thereby reducing the lifespan of the composite material.

However from figure 10, 11 and 12 above, the results obtained show that the rate of water absorption could be considered generally low for the natural fibre reinforced epoxy composites used. This is due to the fact that the matrix is hydrophobic in nature i.e water hating thereby resisting the penetration of water. But as the percentage fibre loading increases, the rate of water absorption also increased in this order: 100wt% epoxy < 5w% < 10w% < 15% < 20wt% bagasse/epoxy composite having a numeric value of 2.5%, 2.7%, 3%, and 3.5% respectively.

The trend of the hybrid composite is as follows 60 wt%B40%S < 40 %B60 %C <60 %B/10 %S/30 %C having absorption rate of 6.5 %, 7 % and 10.8 % respectively. The increase is as a result of the incorporation of more hydrophilic cellulosic fibres into the composite system. However the rate of absorption is generally low.

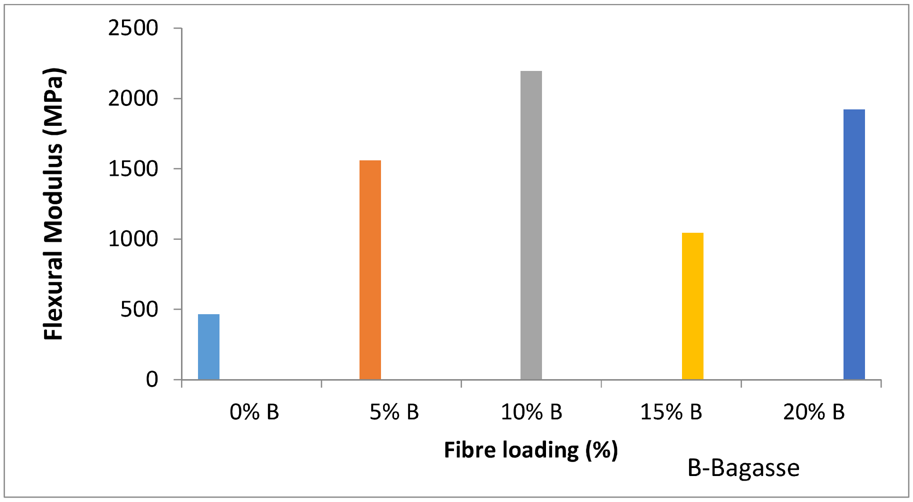

Figure 4: Effect of Fibre Loading on the Flexural modulus of Bagasse/Epoxy Composite.

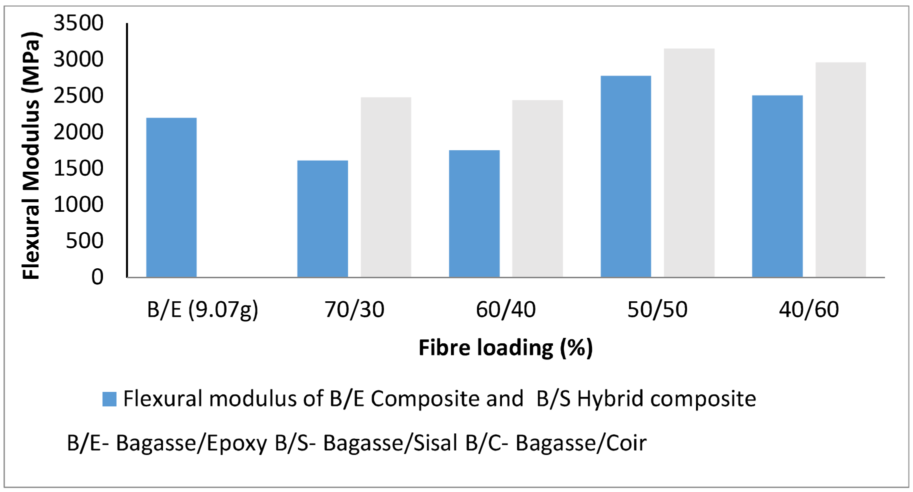

Figure 5: Effect of Hybrid composition on the Flexural modulus of Bagasse/Epoxy Composite

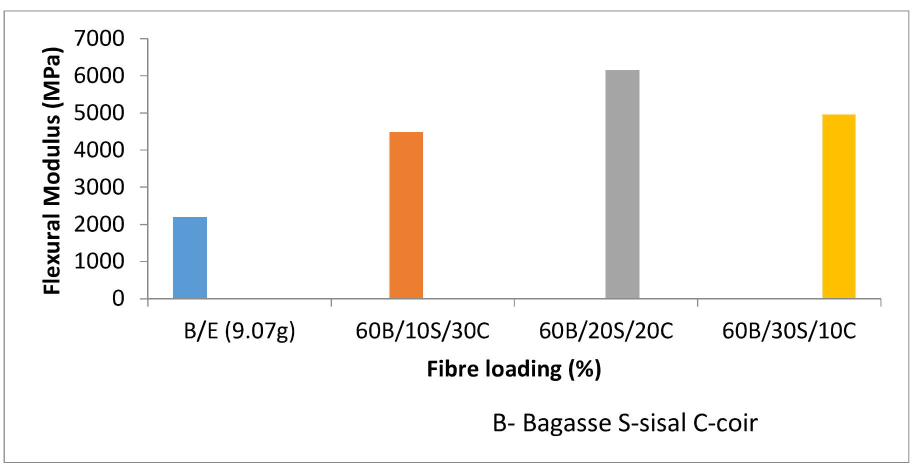

Figure 6: Effect of Hybrid composition on the Flexural modulus of Bagasse/Epoxy Composite

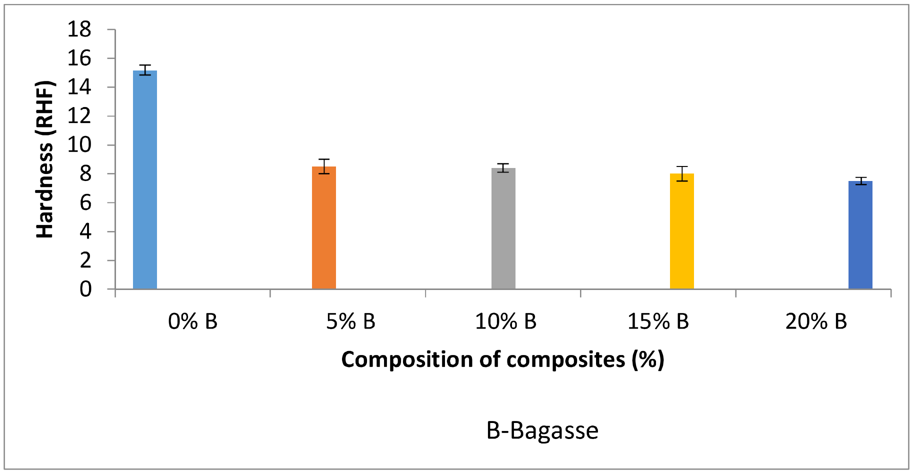

Figure 7: Effect of fibre loading on the hardness strength of Bagasse/Epoxy Composite.

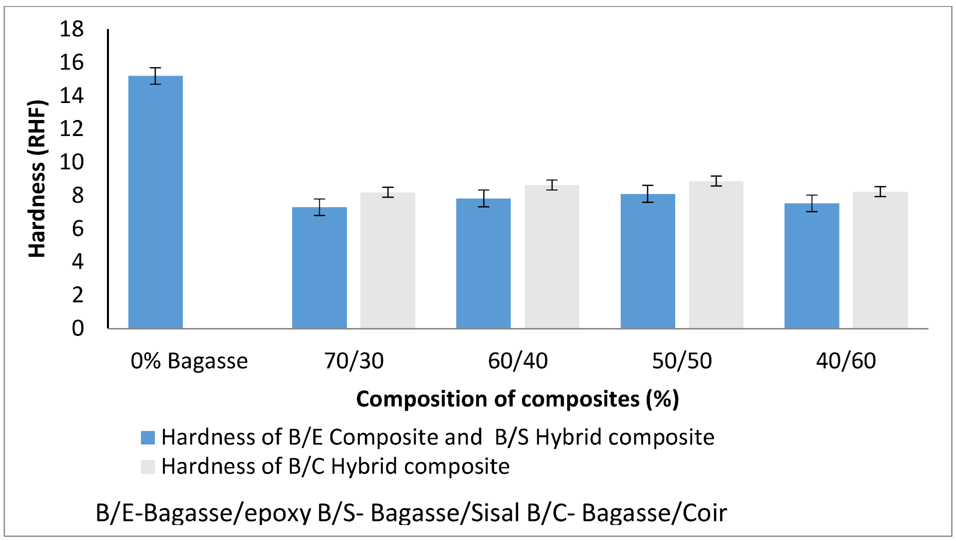

Figure 8: Effect of Hybrid composition on the Hardness of Bagasse/Epoxy Composite at 10% (9.07g)

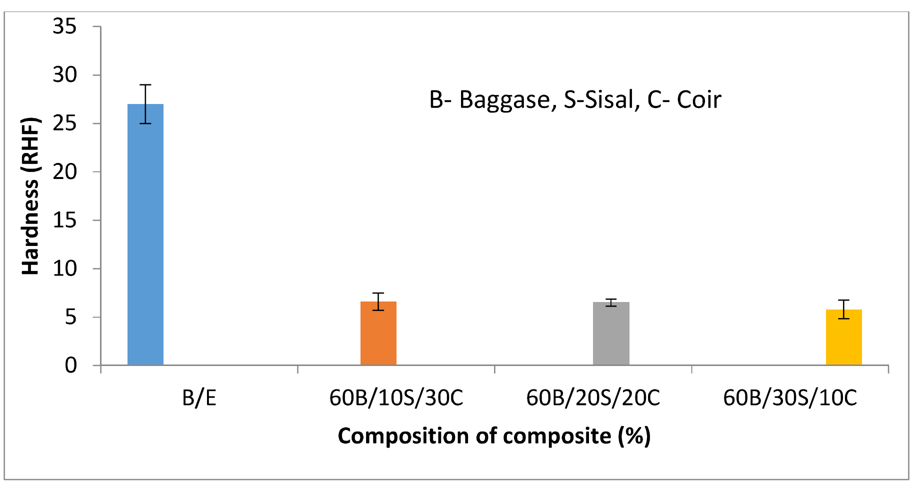

Figure 9: Effect of Hybrid composition on the Hardness of Bagasse/Sisal Composite at 60/40 (9.07g)

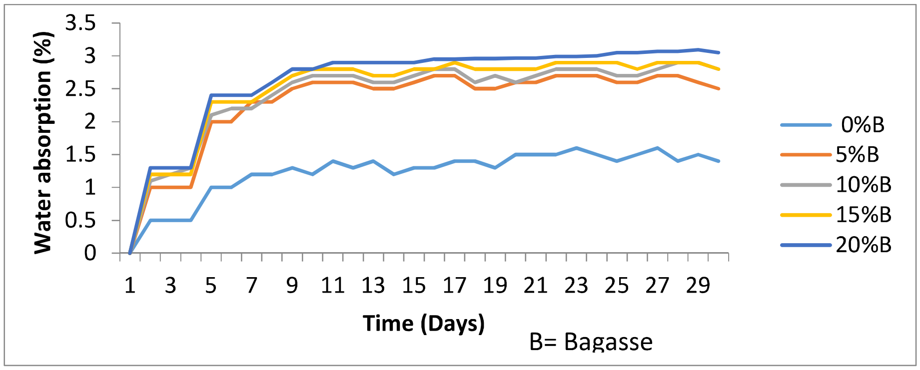

Fig 10: Percentage Water Absorption of a single fibre composite (Bagasse/Epoxy Composite).

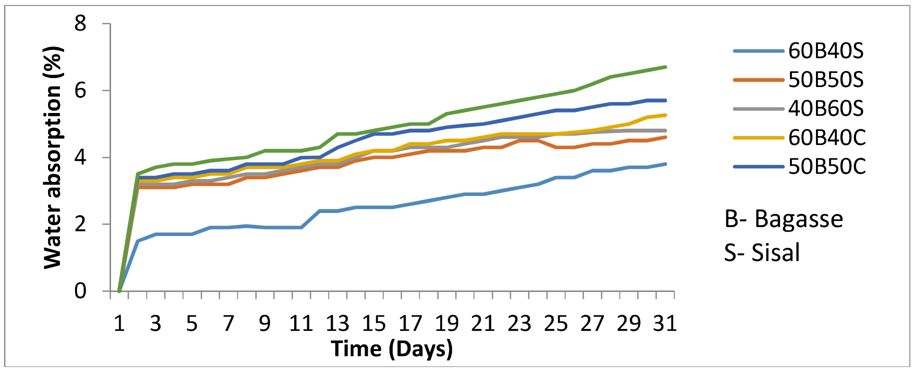

Fig 11: Percentage Water Absorption of hybrid composite system of Bagasse/Sisal Epoxy Composite with time

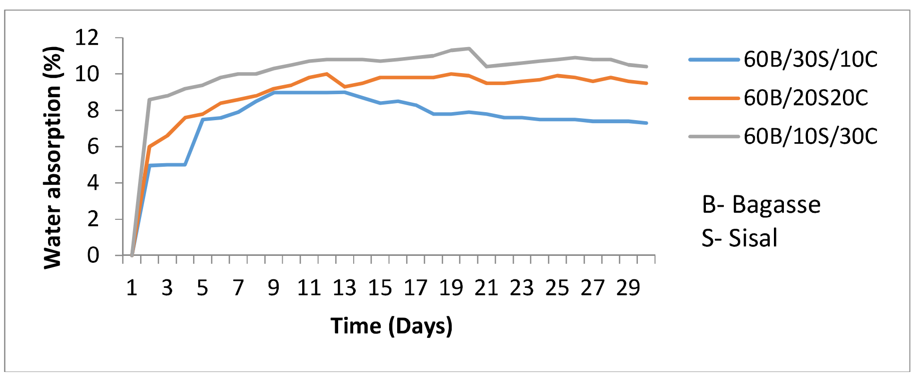

Figure 12: Percentage Water Absorption of three fibre composite (Bagasse/Sisal/Coir Reinforced Epoxy Composite).

CONCLUSION

This work shows the successful fabrication of Bagasse/sisal/coir reinforced-epoxy hybrid composites using simple hand lay-up technique. Most of the properties of the composites determined were greatly influenced by the hybridization compared to the unhybridized bagasse/epoxy composite. The hybrid composite with the composition of bagasse/sisal/coir reinforced composite exhibited higher tensile strength than bagasse/sisal and bagasse/coir reinforced composite. This is attributed to the fact that there is synergistic interaction and a good interfacial bond.

The tensile strength of Bagasse/Sisal/Coir reinforced epoxy composites registered the highest numerical strength value of 53.25 MPa having an improvement of 70.1 % over the pure Bagasse/Epoxy composite. This improvement was obviously as a result of the incorporation of stronger fibres into the composite system. The numerical strength values were improved after hybridization as follows in this order: 60 %B/20 %S/20 %C > 60 %B/40 %S > 60 %B/40 %C.

The hardness was improved when the coir fibre component was introduced into the composite. The increased in the Rockwell hardness value was observed in the following order: 50 %B/50 %C > 60 %B/40 %C > 40 %B/60 %C having values of 8.87 RHF > 8.63 RHF > 8.23 RHF respectively. Water absorption after 28 hours was negligible but after 48 hours it increases as the fibre loading increases. However the rate of water absorption displayed by the fabricated composite material was generally low.

Recommendations

These include**s:**

- **i.** The investigation of the performance of other low cost resin system like thermoplastics and biodegradable matrices such as starch and cellulose acetate reinforced with the bagasse, sisal and coir.
- **ii.** The alkaline treatment of the fibres could be varied for different concentrations for optimization.
- **iii.** The impact and ballistic test could be investigated and evaluated.

REFERENCES

Abbasi, S. H. (2003). Preparation and characterization of polypropylene/palm fibre composites, M. Sc. thesis, KingFahd University of petroleum and minerals, Saudi Arabia.

Abdelmouleh, M., Boufis, S., Belgacem, M. N., and Dufresne, A. (2007). Short natural-fibre-reinforced polyethylene and natural rubber composites: Effect of silane coupling agents and fibre loading. *Composite Science and Technology, 67*(7-8), pp.1627-1639.

Abubakar M.A., Ahmad S., Kuntjoro W. (2010). The mechanical properties of treated and untreated kenaf fibre-reinforced epoxy composite. *Journal of Biobased Materials and Bioenergy*; 4: pp. 159–63.

Adine G., Laetitia V., and Riette de B. (2007). Cotton/polyester and cotton/nylon warp knitted terry cloth: Why minority fibre content is important. *Journal of Family Ecology and Consumer Sciences*, Vol 35. pp. 1-8.

Al-Mosawi, A.I. (2009). Study of some mechanical properties for polymeric composite material reinforced by fibres. *Al-Qadisiya Journal for Engineering Science,* 2(1), pp. 14 – 24.

Alsina O. L. S., Carvalho L. H. D., Filho F. G. R. and. Almeida, J.R.M.D. (2005). Thermal properties of hybrid lignocellulosic fabric-reinforced polyester matrix composites, *Polymer Testing, 24,* pp.81-85.

American Composites Manufacturers Association (2004). Composites Basics: materials (Part 2), 1010 North Glebe Road, Arlington, Va 22201, New York. P: 703-525-0511, F: 703-525-0743 E: Info@Acmanet.Org

De Albuquerque, A., Joseph, K., Hecker de Carvalho, L. and Moraisd. Almedia, J. (1999). Effect of wetability and ageing conditions on the physical and Mechanical properties of uniaxiallly oriented jute-roving-reinforced polyester Composites. *Compos. Sci. Technol.* 60: pp. 833-844.

Deo C. and Acharya S.K. (2010). Effect of moisture absorption on mechanical properties of chopped natural fibre-reinforced epoxy composite. *Journal of Reinforced Plastics and composites*; 29: pp. 2513–21. 94.

Dixit S. and Verma P, (2012). "The Effect of Hybridization on Mechanical Behavior of Coir/Sisal/Jute Fibres Reinforced Polyester Composite Material", Research Journal of Chemical Sciences, www.isca.in, ISSN 2231-606, Vol. 2(6), 91-93.

Durand J. M., Vardavanlias M., Teandin M. (1995). Role of reinforcing ceramic particle in the

Gassan J, and Bledzki A K, (1999). Possibilities for improving the mechanical Properties of jute/epoxy composites by alkali treatment of fibres, Composites Science and Technology, Vol. 59, pp. 1303-1309.

Gosnell, J. M. and Koenig, M. J. P. (1972). Some effects of varieties on season Fluctuations in cane quality. SASTA Prcc. 46: 188-195.

Hassan M.L., Rowell R.M., Fadl N.A., Yacoub S.F. and Chrisainsen A.W.; Thermo Plasticization of Bagasse. I. Preparation and Characterization of Esterified Bagasse Fibres, *Journal of applied polymer science*, 76 (2000) 561- 574.

Harriëtte, L. (2004). "The Potential of Flax Fibres as Reinforcement for Composite Materials". Proefschrift —ISBN 90-386-3005-0, NUR 913, Bos. Eindhoven: Technische Universiteit Eindhoven.

Hedenberg, P. and Gatenholm, P. (1995). Conversion of plastic/cellulose waste into Composites. *Journal of Applied Polymer Science* 56: pp. 641-651.

Khan, M.A., Sultana, S, Ashraf, K.M., Islam, T. (2000). Preparation And Properties Of Coir Fibre-Reinforced Ethylene Glycol Di-methacrylate-Based Composite, *J. Thermo. Compos.Mater. 25(6)* 1-17.

Maldas,D. Kokta B.V. (1995). Studies on the preparation and properties of particleboards Made from bagasse and PVC: II. Influence of the addition of coupling agents, *Bioresource Technology* 35, 251-261.

Netravali, A andLuo, S. (1999). Mechanical and thermal properties of environment-Friendly "green" composites made from pineapple leaf fibres and poly (hydroxybutyrate-co- valerate) resin. *Polymer Composite* 20: pp. 367-78.

Raj, R.G, Maldas, D, Kokta B.V. and Daneault, C, (1990). Influence of coupling agents And treatments on the mechanical properties of cellulose fibre-polystyrene Composites. *Journal of Applied Polymer Science* 37: pp.751-775.

Shaw, A., Sriramula, S., Gosling, P.D., and Chryssanthopoulo, M.K. (2010) Composites Part B, 41, 446–453.

Shaw, A., Sriramula, S., Gosling, P.D., and Chryssanthopoulo, M.K. (2010) Composites Part B, 41, 446–453.

Silva JLG, Al-Qureshi HA. (2010). Mechanics of wetting systems of natural Fibres with Polymeric resin. J Mat Process Technol; 92–93:124,–8.