EUROPEAN JOURNAL OF MATERIALS SCIENCE AND ENGINEERING
Volume 7, Issue 1, 2022: 015-027 | www.ejmse.ro | ISSN: 2537-4338

EJMSE

DOI: 10.36868/ejmse.2022.07.01.015

DEVELOPMENT OF POLYMER - BAMBARANUT SHELL COMPOSITE FOR STRUCTURAL BOARD APPLICATION

Dahiru Yau GITAL[1,*], Abdulkabir RAJI[2]

[1]Mechanical Engineering Department, Abubakar Tatari Ali Polytechnic, Bauchi, Nigeria.
[2]Mechanical Engineering Department, Modibbo Adama University, Yola, Nigeria.

Abstract

This paper is aimed at investigating the use of Bambaranut shell powder as reinforcing material in polymer matrix for structural board production and to investigate its effect on the physical and mechanical properties of the resulting composites. Composites were prepared with 10%, 20%, 30%, 40% and 50% by weight of Bambaranut shell of particle size 150 µm. SEM was used to analyze the internal structure of the composites. Analysis of variance was employed to investigate the influence of the addition of Bambaranut shell particle on both the mechanical and physical properties of the samples. The properties measured range as follows: water absorption (0.65 to 1.95 %); density (0.1044 to 0.1129 g/〖cm〗^3); ultimate tensile strength (20.90 to 11.76 MPa); tensile modulus (102.55 to 161.41 MPa), flexural modulus (3818.53 to 2283.70 MPa) and flexural strength (29.96 to 53.09 MPa). Results show that as percentage of Bambaranut shell particle increased from 10% to 50% there was a decrease in tensile, compressive, impact Strength and flexural modulus. Also, increase in weight percentage of Bambaranut shell particles lowered the density and raised the hardness, and water absorption of the composites. The mechanical properties showed that the composites produced can be used for structural application.

Keywords*: Bambaranut shell, Composite, polyester resin, Polymer matrix, Reinforcing phase, Strength, Structural board*

Introduction

Composite is a material that combines two or more different constituents with distinct interface and having properties better than each individual component [1]. Constituents are the individual materials that forms the composite. The constituents of a composite may be classified as a binder or matrix, and a reinforcement [1]. The main function of the matrix is to hold or binds the reinforcement together and also to transmit load from the matrix to the reinforcement. Reinforcements are generally strong and ductile which gives the composites its good properties. Metals, ceramics, polymers, and now agro-waste can be used as reinforcing material. The aim of combining the strength of the reinforcement with the toughness of the matrix is to achieve a set of properties not available in any single material [2].

Due to its unique properties, polymer has been adjudged as one of the best material ever, and has gained predominance in large areas of application [3]. The need to improve the properties of polymers for better performance has led to the reinforcement of polymers with fibers or particles to form polymer matrix composite [3]. Either organic or inorganic polymers are you used as matrix while organic or inorganic fibers or particles could be used as reinforcement. To enhance the physical and mechanical properties of polymers as material, and also lower their production cost, various sources of organic fillers are used in the production of polymer matrix composites. The commonly used organic fibres and fillers are rice husk, woods, sisal fibre, etc.

*Corresponding author: dahiruygital@gmail,com, +2347031200435

Due to environmental concerns, interest has been moved towards the development of green composites to substitute the conventional composite which uses non-renewable fillers as reinforcement The obvious reasons for using various organic fillers in composite production are because of their availability, environmentally friendly, weightless, inexpensive, sustainable and also their ability to enhance quality in composites [2]. Particleboard or structural-board is a panel product that is manufactured under high temperature and pressure from particles of woods and resin [4]. Flooring, wall bracing, ceiling boards, furniture are some application areas of structural board. Development in technology and sudden increase in worlds' population has led to the rise in the demand of woods in recent years. To conserve our forest resources, there is need to explore alternative biomass as raw materials in particleboard production. The necessity to minimize the reliance on forest resources has given rise to an interest in the use of agricultural waste for particleboard production. Municipal solid waste, saw dust and plant waste in different combination was used in particleboard production [5]. Agro waste composite ceiling board was produced from rice husk [6]

Bambaranut (Vigna subterranean) is an indigenous African crop grown across the continent from Senegal to Kenya and from Sahara to South Africa. Bambaranut is the third most important grain after groundnut and cowpea [7]. Oluwole et al [7] further reported that, in separate report by [8] and [9], it was noted that in Nigeria Bambaranut is widely produced in Borno, Anambra, Plateau, Taraba, Sokoto, Bauchi, Benue, Kano, Yobe, Adamawa and Gombe. The annual production of Bambaranut in Nigeria is estimated to be over 100,000 metric tons [10] which offers abundant Bambaranut shell that could be used as possible source of filler in the production of composites.

In this research work, polymer matrix composite had been developed from unsaturated polyester and Bambaranut-shell for structural board application in building industry.

Materials and Methods

Materials

The major ingredients used in this work were Bambaranut shell, Unsaturated polyester resin (UPR), Polyvinyl acetate, Methyl ethyl ketone peroxide, and Cobalt octoate. Unsaturated Polyester resin served as the matrix while Bambaranut Shell served as raw material for fillers. Methyl ethyl ketone peroxide and cobalt octoate were used as initiator and accelerator, respectively. Due to large shrinkage value for unsaturated polyester resin polyvinyl acetate was used to compensate for the shrinkage.

Bambaranut shell, which is an agro waste, was obtained from Alkaleri, north-eastern part of Nigeria. Fig. 1 shows the image of un-milled Bambara nut shell.

The resin used in this work was a commercial general-purpose unsaturated polyester based on orthophthalic anhydride, maleic anhydride and propylene glycol. The average molecular weight of the resin is 2750 g/mol and the equivalent molecular weight/mol (C=C) is 468 g/mol. The molar ratio of styrene/unsaturated polyester is 2.7. Methyl ethyl ketone peroxide (MEKP) is the catalyst added to polyester resins and vinyl ester resins. MEKP used has a chemical formula $C_8H_{18}O_6$, molar mass of 210.226 g/mol and density of 1.170 g/cm^3. Cobalt octoate is used as accelerator in polymerization of unsaturated polyester resin. It has 8% cobalt content and a density of 0.950 g/cm^3. Polyvinyl acetate is a synthetic resin prepared by polymerization of vinyl acetate. When it is added as low-profile additive, it compensates the high-volume shrinkage of unsaturated polyester. It has a formula of $(C_4H_6O_2)_n$ and molar mass of 86.09 g/mol. The resin and all the chemicals were used as received from Steve Moore Chemicals, Zaria.

Equipment and Tools

The equipment used in this study include tensile testing machine of the type A260-2 MOSANTO, England, Indentec universal hardness testing machine of Model: 8187.5 LKV (B),

flexural testing machine and Charpy impact testing machine of the type Cat., Nr. 412 with a maximum capacity of 25J. Others include compression testing machine of the type Cat. Nr. 261, electronic weighing balance, mechanical press, scanning electron microscope and vernier caliper.

Materials Preparation and Moulding

The collected Bambaranut consist of multiple contaminations such as small pieces of Bambaranut grain, dirt, and fine sand dust. Therefore, it needs to be cleaned in order to get pure Bambaranut shell. The shells were mercerized using 5% w/v sodium hydroxide (NaOH) at room temperature for 24 hours in accordance with [11]. After the alkaline treatment, the shells were thoroughly washed in running tap and sun dried. The dried shells were then milled into small particles of Bambaranut shell particle (BSP), and screened to 150µm mesh size. Then, it was weighed in accordance to the planned percentage required (10, 20, 30, 40, and 50 wt %). Thereafter, UPR, MEKP (initiator), cobalt octoate (accelerator) and polyvinyl acetate were added in right proportion and stirred for proper mixing. Gradual addition of Bambara nut shell particle and proper agitation was employed to allow proper dispersion of particles within the gel like mixture. Before the mixtures were poured into the prepared mould of dimensions 150 mm x 150 mm x 20 mm, release agent (vinyl acetate) was firstly applied in the inside to prevent the composites from sticking to the mould during removal. Finally, after the mixture had been poured into the mould, it was taken to a mechanical press, where a pressure of 30 MPa was maintained at room temperature for 24 hours to obtain the samples. After curing, the solidified samples were thereafter ejected, cut into the required sizes, machined into various shapes and taken for test.

Fig 1. Un-Milled Bambaranut Shell

Experimental Design

Several panels were made by varying the amount of Bambaranut shell powder from 10% to 50% by weight and unsaturated polyester resin from 90% to 50% by weight, as shown in Table 1.

Table 1. Experimental Design

Sample code	Polyester (wt %)	BSP (wt %)	Number of samples
UP10B	90	10	3
UP20B	80	20	3
UP30B	70	30	3
UP40B	60	40	3
UP50B	50	50	3

Test

Load carrying capacity, stiffness and dimensional stability are especially relevant to structural boards. Consequently, a number of tests were conducted and these include tensile test, flexural test, scanning electron microscopy, hardness test, compression test and impact test. Others include density and water absorption tests.

Tensile test was conducted at a temperature of 23 ºC ± 2 and relative humidity of 50 ± 5%. The tensile property measurements (tensile strength, % elongation at yield and young's modulus) were carried out on a universal testing machine according to ASTM D638-98 at a crosshead speed of 5 mm/min. The flexural test was carried out in Masanto Tensometer according to ASTM D7264.

The Rockwell hardness value was measured using Indentec hardness test machine.1/16'' diameter indenter was used. The indenter was released and the diameter of indentation made on the specimen was recorded. The hardness value was then calculated. Pre-load/minor load of 10kgf and total major load of 60kgf were used. The hardness value was then tabulated. Impact test was conducted to decide on the impact energy of the specimen. ASTM D256-98 was used in conducting the experiment. The compressive test was carried on Universal material testing machine Cat. Nr. 261, according to ASTM D256-98.

Scanning electron microscopy was conducted on each of the five samples, UP10B, UP20B, UP30B, UP40B and UP50B. Scanning electron microscopy was done at 150X magnification.

ASTM D570-98 was used in determining the percentage water absorption. The samples were weighed, and then immersed in distilled water for 24 hours at room temperature. Their soaked weight was measured using a weighing balance. The percentage water absorption was calculated using equation 1.

$$percentage\ water\ absorption = \frac{(w-D)}{D} * 100 \quad (1)$$

Where:
D = weight of Dry sample;
W = weight of soaked sample

The specimens were weighed in a weighing balance and their weights recorded. Their volumes were calculated from their dimensions. The density was calculated using equation 2.

$$Density\ ({}^{g}/_{cm^3}) = \frac{mass}{volume} \quad (2)$$

Statistical Analysis Used

The statistical tool used in this work was one-way analysis of variance (ANOVA). It compares the means among two or more groups and decides whether any of those means are statistically significantly different from each other.

Results and Discussions

SEM Images

The surface morphology of the composite is shown in Fig. 2. The Bambaranut particles are clearly seen as solid in nature with some variation in size. Fibre-matrix interface provides an important function in composite properties. This is because the formation of mechanical bonding at the surface is mainly dependent on surface topology of the fibre/filler. The surface features of the developed composites such as contours, cracks, and voids are clearly observed in the photomicrographs.

Fig. 2 revealed that the composite consists of Bambaranut particles which are strongly bonded with each other and with the matrix. It can be observed that as the percentage by weight of Bambaranut shell powder increases, the surface defects such as cracks and voids decrease.

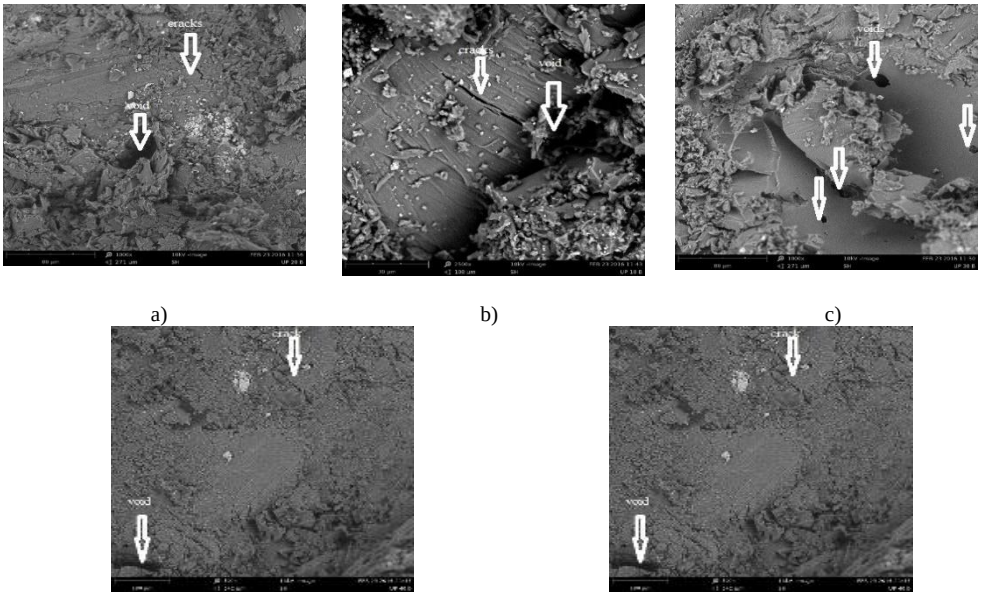

Fig. 2. SEM Images of Composite at 150x: (a) 10 % filler wt.; (b) 20 % filler wt.; (c) 30 % filler wt.; (d) 40 % filler wt.; (e) 50% filler wt.

Compressive Moulded Bambaranut Shell Particle Composite

Fig.3 shows the pictorial view of the Bambaranut shell/Polyester composites from which samples for various tests were obtained. Compression moulding produced mechanical linking and better grip between the particles, establishing intermolecular links in the contact area. As a result of adhesion, cohesion and attractive forces between fibres and the matrix, a binding force is developed in the interface which binds the fibre and the matrix together in the composite.

Fig. 3. Compressive Moulded Samples

Ultimate Tensile Strength

From Fig. 4, shows that the ultimate tensile strength (UTS) of the composites decreases when percentage weight of the Bambaranut shell particles (BSP) increases within the matrix of the composites. It ranges between 20.90 MPa and 13.76 MPa. The polyester composite with the lowest weight fraction of the filler UP10B, had the highest strength (20.90 MPa). The tensile strength of this type of composites have been investigated by Hossain et al [12] and, Hardinnawirda, and SitiRabiatul Aisha [13] and similar result have been found.

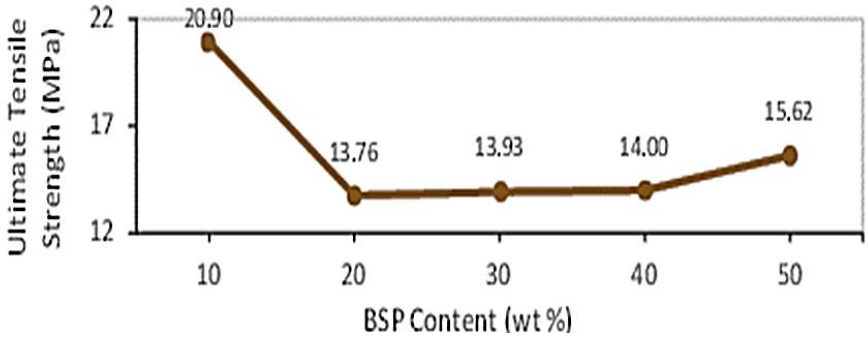

Fig. 4. UTS vs BSP content (wt. %)

Table 2. ANOVA for UTS

	Sum of Sqt	Df	Mean Sqt	F	Sig.
Between Groups	110.658	4	27.665	39.705	.000
Within Groups	6.967	10	.697		
Total	117.626	14			

A one-away analysis of variance was used to examine the consequence of Bambaranut shell particles increase on the UTS of the developed composites. An alpha level $\alpha = 0.05$ was used for the analysis. ANOVA of ultimate tensile strength (table 2) revealed a statistically significant main effect [$F(4,10) = 39.705$, $p = 0.000$] signifying that not all the five sample sets leads to the same ultimate tensile strength. This showed that the Bambaranut shell particles had a statistically significant effect on the tensile strength of particles reinforced polyester.

Percentage Elongation

Fig. 5 shows the graph of percentage elongation. It is between 11.52 and 15.24 %. In the graph the maximum elongation was 15.24% and it occurred at UP50B (i.e. the composite with the highest amount of Bambaranut particle), the lowest elongation of 11.52% occurred at UP20B which shows there was an increase in elongation as the amount of Bambaranut shell particles increases. The result obtained is in agreement with previous work by Joao Bessa [14].

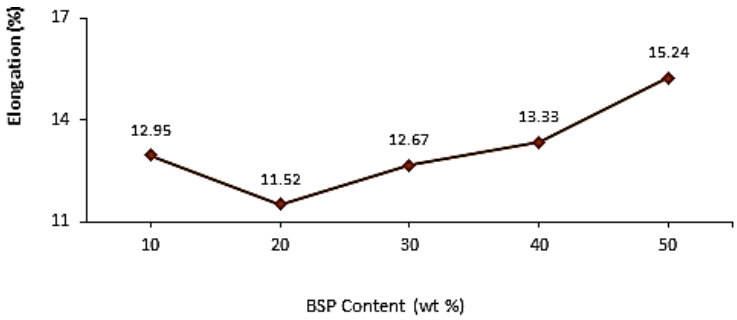

Fig. 5. Elongation vs BSP content (wt %)

Table 3. ANOVA for Percentage Elongation

	Sum of Sqrt	Df	Mean Sqrt	F	Sig.
Between Groups	39.480	4	9.870	3.930	.036
Within Groups	25.114	10	2.511		
Total	64.594	14			

One-way ANOVA was conducted to determine if Bambaranut shell particle addition has an effect on the percentage elongation of particulate reinforced polyester. The result of the analysis of variance is [F (4,10) = 3.930, p = 0.036] as shown in table 3 and it indicates a significant effect.

Tensile Modulus

Fig. 6 shows the variation of tensile modulus for the various composites. It ranges between 2.93 and 4.61 MPa. The tensile modulus of sample UP10B exhibits higher values (4.61 MPa) than other composites. It is evident from the graph that increase in Bambaranut shell particle content decreases the tensile modulus. The result is similar to the one found in Uygunoglu et al [15] which shows that there is an extensive reduction in modulus of elasticity with rise in waste content from 0 to 66%.

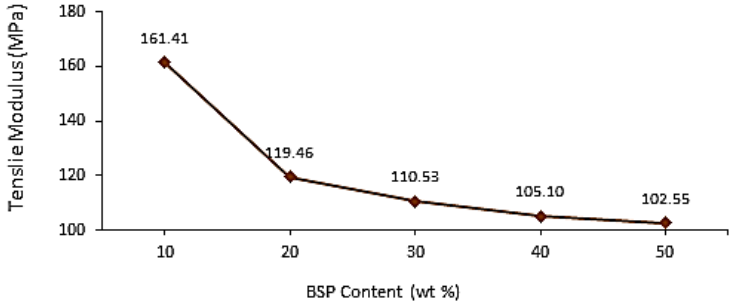

Fig. 6. Tensile Modulus vs BSP content (wt. %)

Table 4. ANOVA for Tensile Modulus

	Sum of Sqrt	Df	Mean Sqrt	F	Sig.
Between Groups	3683.105	4	920.776	32.094	.000
Within Groups	14176.752	10	1417.675		
Total	17859.856	14			

ANOVA was used to determine the effect of Bambaranut shell particle addition on the tensile modulus of the particulate reinforced polyester. ANOVA of ultimate tensile strength (table 4) revealed a statistically significant main effect [F (4,10) = 32.094, p = 0.000] showing that not all the five sample groups leads to the same tensile modulus. This showed that the Bambaranut shell particles has a statistically significant effect on the tensile modulus of particles reinforced polyester.

Flexural Strength

The variation of flexural strength versus filler content is presented in Fig. 7. From the figure, it can be inferred that as the wt% increases, the flexural strength decreases and becomes minimum at UP50B. The maximum and minimum values of the flexural strength were 53.09 MPa and 29.96 MPa, respectively. In a similar work on "The effects of incineration ash filler contents on the flexural and tensile strengths" investigated by Goh Chee Keong [16], it was established also, that both flexural and tensile strengths decreased with increase in incineration ash filler contents.

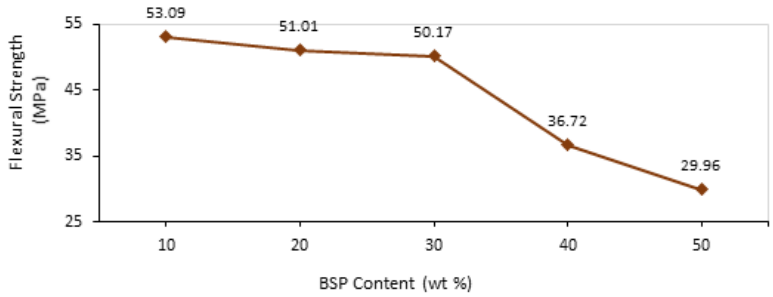

Fig. 7. Flexural strength vs BSP content (wt. %).

Table 5. ANOVA for Flexural Strength

	Sum of Sqrt	Df	Mean Sqrt	F	Sig.
Between Groups	1259.436	4	314.859	5.982	.010
Within Groups	526.322	10	52.632		
Total	1785.758	14			

One-way ANOVA was conducted to determine if Bambaranut shell particle addition has an effect on the flexural strength of the particulate reinforced polyester. There was statistically significant difference between groups as showed by the analysis of variance in table 5 [F (4,10) = 5.982, p = 0.010].

Flexural Modulus

Increasing the content of the Bambaranut shell particle does not significantly translate into either increase or decrease in the flexural modulus of the composites from UP10B to UP30B. On the other hand, appreciable decrease was observed from UP30B to UP50B. The maximum and minimum values of 3818.40 MPa and 2283.72 MPa were respectively obtained at UP20B and UP50B.

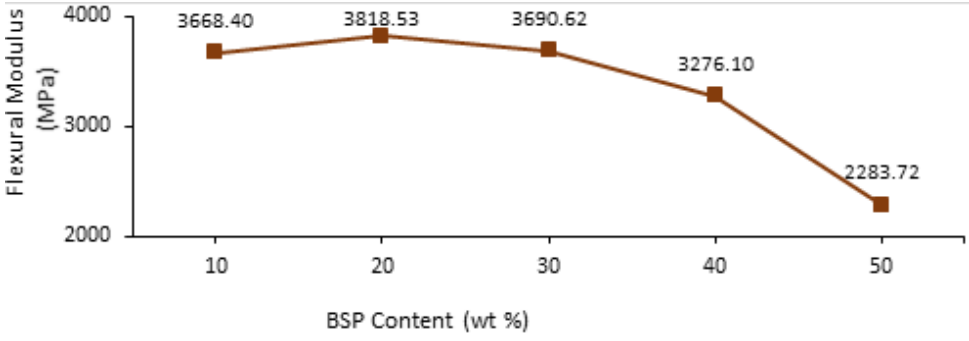

Fig. 8. Flexural modulus vs BSP content (wt. %)

Table 6. ANOVA for Flexural Modulus

	Sum of Sqrt	Df	Mean Sqrt	F	Sig.
Between Groups	4737961.278	4	1184490.320	3.223	.061
Within Groups	3675571.440	10	367557.144		
Total	8413532.718	14			

The result of the analysis of variance for the flexural modulus given in table 6, shows that the Bambaranut shell particle addition had little or no significant effect on flexural modulus of the particle reinforced polymer [F(4,10) = 3 .223, p = 0.061], which were in good agreement with those observed in Fig. 8.

Rockwell Hardness Value

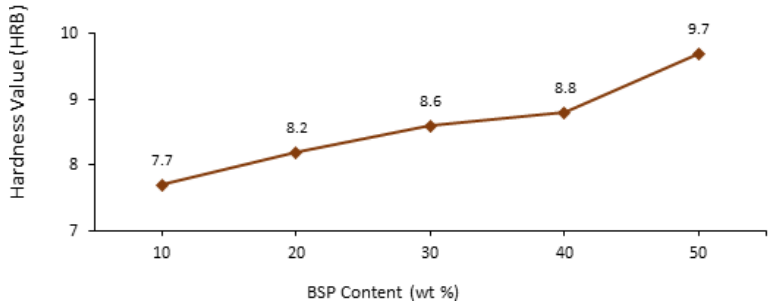

Fig. 9. Hardness value vs BSP content (wt. %)

Fig. 9 shows the result of the hardness value. It ranges between 9.7 and 7.7 HRB.

Table 7. ANOVA for Hardness

	Sum of Sqrt	df	Mean Sqrt	F	Sig.
Between Groups	8.929	4	2.232	4.244	.029
Within Groups	5.260	10	.526		
Total	14.189	14			

The result of the analysis of variance for the hardness value in table 7 shows that there was a significant difference in hardness value of the composite samples [F (4,10) = 4.244, p = 0.029].

Compressive Strength

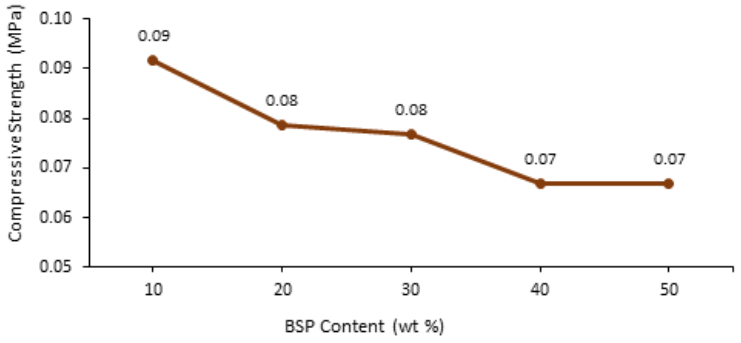

Fig. 10. Compression strength vs BSP content (wt. %)

Fig. 10 shows the graph of the effect of Bambaranut shell particle addition on the compressive strength of the particulate rereinforced composites. In the graph there was little decreased in compressive strength of the composite from 0.09 to 0.07 MPa.

Table 8. ANOVA for Compressive Strength

	Sum of Sqrt.	Df	Mean Sqrt.	F	Sig.
Between Groups	.077	4	.019	1.064	.423
Within Groups	.181	10	.018		
Total	.258	14			

The result of the analysis of variance for the compressive strength is given in table 8. It shows that the Bambaranut shell particle addition had no significant effect on compressive strength of the particle reinforced polymer [F (4,10) = 1 .064, p = 0.423]. Similar result was reported in Uygunoglu *et al* [15].

Impact Strength

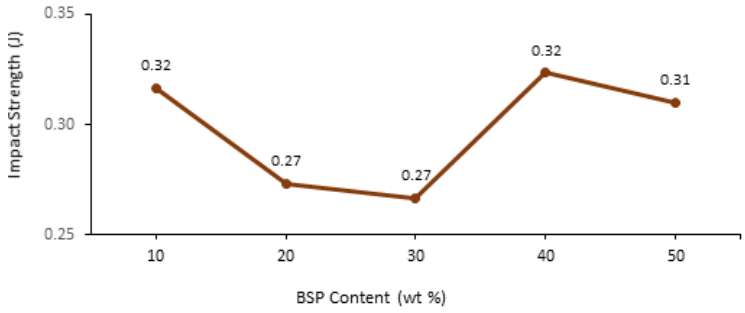

Fig. 11. Impact energy vs BSP content (wt. %)

"One of the main reasons of concern for composites generally is the low impact value" [17]. The means to increase the impact energy of composites are being made the area of great concern [17]. The experiment shows that the composite made with Bambaranut shell and Polymer were not good in impact stress as it shows very little values from the test performed. Fig. 11 shows the effect of Bambaranut Shell addition on impact strength of composites. The impact strength ranges between 0.32 and 0.27J.

Table 9. ANOVA for impact Energy

	Sum of Sqrt.	df	Mean Sgrt.	F	Sig.
Between Groups	.008	4	.002	1.952	.178
Within Groups	.010	10	.001		
Total	.019	14			

One-way analysis of variance was conducted to ascertain the effect of impact strength on the different composition of the composite. Table 9 shows that, the effect of the composition of the particulate on the impact strength of the composites [F (4,14) = 1.952, P = 0.178] was significant.

Water Absorption

The results of average water absorption properties of the polymer Bambaranut shell composites are presented in Fig. 12. It ranges between 0.65 and 1.9%. From the graph, it was observed that as the percentage of Bambaranut shell particles increases, the water absorption also increases. This could be due to the hydrophilic nature of the Bambaranut shell. The result is in agreement with [12].

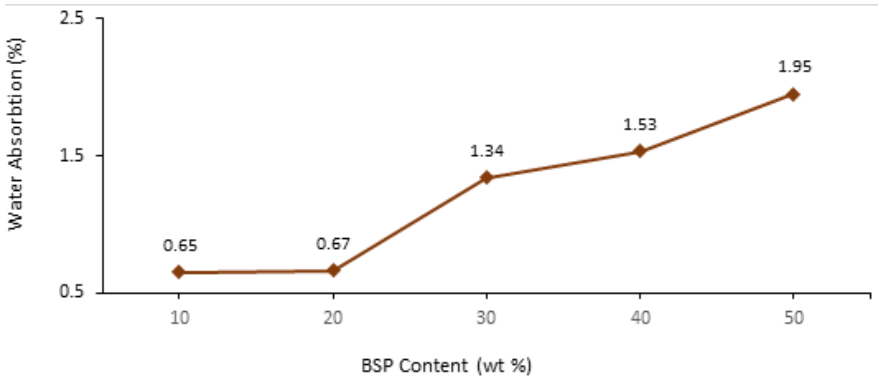

Fig. 12. Water absorption vs BSP content (wt. %)

Table 10. ANOVA for water absorption

	Sum of Sqrt	df	Mean Sqrt	F	Sig.
Between Groups	7.890	4	1.972	5.207	.016
Within Groups	3.788	10	.379		
Total	11.678	14			

The ANOVA result on water absorption shows that, there was a statistically significant effect of the composition of particulate on the amount of water absorption of the composites at the p <0.05 level for the five compositions [F (2, 10) = 5.207, p=0.016].

Density

Fig. 13 presents a graph of density vs Bambaranut shell particles content. The density ranges from 0.1044 to 0.1129 $\frac{g}{cm^3}$. From the graph it was observed that there was a minimal decrease in density as the Bambaranut shell particles increases (which the statistical analysis proved non-significant). This could be due to the fact that the Bambaranut shell has lower density.

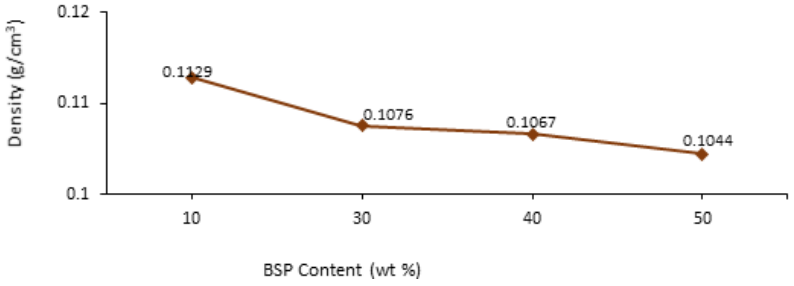

Fig.13. Density vs BSP content (wt. %)

Table 11. ANOVA for density

	Sum of sqrt	Df	Mean Sqrt	F	Sig.
Between Groups	.000	4	.000	2.834	.083
Within Groups	.000	10	.000		
Total	.000	14			

One – way ANOVA of density in gram per centimeter cube (table 11) revealed a statistically non-significant effect [F (4,10) = 2.834, p = 0.083] indicating that some of the means

are equal. Similar result was found in [18]. The result shows that as the Bambaranut shell fibre increases the density of the composite produced decreases.

Conclusions

The following conclusions can be drawn from the research work:

The incorporation of the Bambaranut shell particles in the polymer matrix as reinforcement increases the hardness value from 7.7 HRB to 9.7 HRB for all particle contents of the developed composites.

Increasing the Bambaranut shell particle content reduces the tensile strength from 20.90 MPa to 15.62 MPa of the developed composites.

Addition of Bambaranut shell particle content as reinforcement in polymer matrix slightly decreases tensile modulus from 4.61 MPa to 2.93 MPa, flexural strength from 53.09 MPa to 29.96 MPa and flexural modulus from 3668.40 MPa to 2283.72 MPa.

Percentage elongation was found to have increased from 12.95 % to 15.24 % with increase in Bambaranut shell particle content.

The bending (flexural) test shows that the developed composite has a better bending strength and elastic modulus when compared with existing particle board. Therefore, it could be used in structural application.

The percentage water absorption of the developed composite increases from 0.65 % to 1.95 % on addition of the Bambaranut shell particles from 10 to 50%.

Increasing the Bambaranut shell particle content from 10 to 50 % results in reduction of the density from 0.1129 g/cm^3 to 0.1044 g/cm^3 for all particle contents of the developed composites.

References

[1] J. Sharma, S. Ahmad, B. Unis, and S. Singh., *An Approach to use Agricultural Wastes Fiber in Polymer for Bio-composite Application.* **Material Science and Engineering International Journal**, 2, 5, 2018, p. 149-157

[2] P. J. Schaffer, S. Ashok, D. A. Stephen, H. S. Tomas, P. W. Steven, **The Science and Design of Engineering Materials** (2nd edition), Richard D Irwin, New York,1995, p. 595-597

[3] O.O. Isiaka, F.O. Taiwo, and A.A. Adeolu *Polymer- Based Composites, An Indispensable Material for Present and Future Application.* **Hindawi International Journal of Polymer Science,** 2020, pp. 1-12.

[4] B.B. Hassan, and O.O Owopetu, *Production and Characterization of Particle Board from Agro Wastes in Nigeria***. International journal of Innovative Science and Research Technology**, **4**, 2019, pp. 1-6

[5] Harshavardha and L. Muruganandam. *Preparation and Characteristics Study of Particle Board from Solid Wastes*. **Material Science and Engineering, 263,** 2017, pp. 32-35.

[6] Y. Isheni., B.S. Yahaya, M.A Mbishida, F. Achema, and F. KarfeGayus. Production of Agro Wastes Composite Ceiling Board. **Journal of Scientific and Engineering Research,** 4, 2017, pp. 212-217.

[7] Oluwole, F. A., Abdulrahim, A. T., and Oumarou, M. B. *Development and Performance Evaluation of Impact Bambaranut Sheller*. **International journal of Agrophysics**, 21,2007, pp. 269-274

[8] M. I Ezue,. *Cultivation and Utilization of minor Food Legumes in Nigeria*. **Tropical Grain Legumes Bulletin: 10,** 19**7**7, pp. 7-12.

[9] A.A. Atiku, (2000). *Bambaranut processing and storage practices in North Eastern Nigeria*.

Post graduate seminar paper, Department of Agric Engineering University of Maiduguri, Nigeria.

[10] R. J. Hillocks, C. Bennett, O. M. Mponda 2012. *A review of utilization, market potential and crop improvement.* **African Crop Science journal:** 20, 1, pp. 1-16.

[11] S. Jayabal, S. Sathiyamurthy, K.T. Loganathan, S. Kalyanasundarama. *Effect of Soaking Time and Concentration of NaOH Solution on Mechanical Properties of Coir-Polyester Composite***. Bulletin of Material Science: 35,4,** 2012, pp. 567-574.

[12] M.F. Hossain, M.K. Islam, M.A. Islam. *Effect of chemical treatment on the mechanical and physical properties of wood saw dust particles reinforced polymer matrix composites*. ***Procedia Engineering*:90**, 2014, pp. 39-45.

[13] K. Hardinnawirda, I. SitiRabiatull Aisha. *Effect of rice husks as filler in polymer matrix composites*. **Journal of Mechanical Engineering and Sciences: 2**, 2012, pp. 181-186.

[14] J. M. Joao Bessa. *Influence of surface treatments on the mechanical properties of fibre reinforced thermoplastic composites*. **Procedia Engineering:200,** 2017, pp. 465-471.

[15] Uygunoglu, T., Ibrahi, G., and Witold, B., (2015). Physical and Mechanical Properties of Polymer Composites with High Content of Wastes Including Boron. **Material Research**: **18**, pp. 1188-1196

[16] M. H. Goh Chee Keong, (2017). *A Study on Mechanical Properties and Leaching Behaviour of Municipal Solid Waste (MSW) Incineration Ash/Epoxy Composites***. Energy Procedia: 43**, pp. 448-453.

[17] A. Gopinath, M. Senthil Kumar, A. Elayaperumal,. *Experimental Investigations on Mechanical Properties Of Jute Fiber Reinforced Composites with Polyester and Epoxy Resin Matrices.* **Procedia Engineering**: 97, 2014, pp. 2052–2063.

[18] Rachchh, N. V, Ujeniya, P. S., & Misra, R. K. (2014). *Mechanical characterisation of rattan fibre polyester composite.* **Procedia Materials Science***:* **6**, 1396–1404. doi:10.1016/j.mspro.2014.07.119.

Received: January 08, 2022
Accepted: February 15, 2022