PRINT ISSN 1119-8362
Electronic ISSN 2659-1499

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 28 (7) 2083-2094 July 2024

Optimization of Mechanical Characteristics of Low-priced Breadfruit Peel Waste by Impregnating Low Density Polyethylene for Production Printer Components

[1]*GOVERNMENT, RM; [2]AYUBA, S

*[*1]Department of Chemical Engineering, [2]Department of Agricultural Engineering, Federal University Wukari, Taraba State, Nigeria*

**Corresponding Author Email: govt_4real@yahoo.com*
**Tel: 07048059184*

Co-author Email: solos4life@gmail.com

ABSTRACT: The objective of this paper is the optimization of mechanical characteristics of low-priced breadfruit peel (BRP) waste by impregnating low density polyethylene (LPDE) for production printer components using appropriate standard procedure. The BRP at particle size (A) and fiber content (B) without modification was combined with LDPE melted and molded by injection molding machine. The characteristics of the BRP-LDPE composite that were evaluated are tensile strength (TS), tensile modulus (TSM), flexural strength (FS), flexural modulus (FM), Brinell's hardness (BH), impact strength (IM) and water absorption resistance (W_{AR}). The data obtained for the factors, A, B and the responses; TS, TSM, FS, FSM, BH, IS, and W_{AR} of BRP-LDPE composite, respectively were inserted into design of experiment software using central composite design (CCD) package of response surface methodology (RSM) models. The outcomes obtained at critical optimal situation noticeable to be; A, B, TS, TSM, FS, FSM, BH, IS, and W_{AR} were 180 µm (80 mesh), 14.39 wt%, 6.036284 MPa, 0.315798 GPa, 18.62651 MPa, 0.31388 GPa, 151.8932 Pa, 43.04614 KJ/m^2 and 4.830519 %, respectively. With deviation of errors between experimental and CCD models differs by 2.232%. The R^2>98.3, Ad.R^2>96.9 and Pr.R^2>98.3 with errors of the entire process to be below 10 %. This is a confirmed indication that RSM models are very good for prediction of the characteristics of BRP-LDPE composite for primer components.

DOI: https://dx.doi.org/10.4314/jasem.v28i7.21

Cite this Article as: GOVERNMENT, R. M; AYUBA, S. (2024). Optimization of Mechanical Characteristics of Low-priced Breadfruit Peel Waste by Impregnating Low Density Polyethylene for Production Printer Components. *J. Appl. Sci. Environ. Manage.* 28 (7) 2083-2094

Dates: Received: 21 May 2024; Revised: 17 June 2024; Accepted: 23 June 2024 Published: 02 July 2024

Keywords: bread fruit peel waste; polyethylene composite; mechanical characteristics; optimization; printer parts production

The involvement of plant comprises of non-edible fiber in polymer-agro-dependent fiber composite has reduced the cost of material in both cars and other manufacturing ventures (Supri and Lim, 2009; Obasi, 2012; Dungani *et al.*, 2016; Obasi, 2015; Government, 2019(a); Government *et al.*, 2019(b-e); Government *et al.*, 2018(a-b); Government *et al.*, 2021(a-b): Joseph *et al.*, 2002; Lou *et al.*, 2007; Kord, 2011; Salmah, *et al.* 2013; Okeke, *et al*, 2023; Government and Okeke, 2023; Government and Okeke, 2024; Government and Ngabea, 2023(a-d)). Some of engineering manufacturing products derived from biomass-fiber-polymer composite includes printers components, boats, refrigerator components, lap top computer parts, television parts, etc (Blezki and Gassan, 1999; Ochi, 2008; Lee *et al.*, 2009; Kannappan and Dhuri, 2012; Atuanya *et al.*, 2014; Obasi, 2015; Government, 2019(a); Government *et al.*, 2019(b-e); Yakubu *et al.*, 2013). Therefore, most investors have taking this opportunity for cost effectiveness posses by biomass-fiber (Bawon *et al.*, 2019; Yakubu *et al.*, 2013; Orji and McDonald, 2020; Rajak *et al.*, 2019; Sood and Dwivedi, 2018). This is generally due to the enormous merits they have (Government and Onukwuli, 2016a;

**Corresponding Author Email: govt_4real@yahoo.com*
**Tel: 07048059184*

Government *et al*, 2016(b); Government, 2019(b-d); Dungani *et al*, 2016; Obasi, 2015; Government, 2019(a); Government *et al*, 2018(a-b): Government *et al.*, 2021(a-b)). This can be enumerated as: minimization of energy cost, light weight, easily accessibility, etc (Government and Onukwuli, 2016a; Government *et al.*, 2016b; Government *et al.*, 2018(a-b); Thakore *et al.*, 1999; Ahmed *et al.*, 1996; Obasi, 2012).

Biomass as fiber acts as additive which aid to amplify the characteristics of biomass-fiber-polymer composite (Government *et al.*, 2019 (b-e); Obasi, 2015; André *et al.*, 2018; Verma *et al.*, 2019; Zakaria *et al.*, 2018)). Most probably, the properties are strength, flexural, modulus, impact strength, etc (Haristov and Vasileva, 2003; Nunes *et al.*, 2002; André *et al.*, 2018; Fortunati *et al.*., 2019; Obasi and Onuegbu, 2013; Reddy *et al.*, 2013; Azeez *et al.*, 2019; Azeez *et al.*, 2013; Azeez *et al.*, 2018; Government *et al.*, 2019(b-d); Government *et al.*, 2022; Homkhiew *et al.*, 2014; Laadila *et al.*, 2017). The biomass is also does not affect the injection molding machine in contrast to non-metal fiber such as, Cao, $CaCo_3$, Mgo, etc (Nachtigall *et al.*, 2007; Aimi *et al.*, 2014; Rashid *et al.*, 2016 Government *et al.*, 2019(b-d); Homkhiew *et al.*, 2014; Feldmann *et al.*, 2016; Government *et al.*, 2022; Hakeem *et al.*, 2015; Zhang *et al.*, 2020). Most importantly, it also minimizes material cost (Supri and Lim, 2009; Obasi, 2012; Netra *et al.*, 2012).

The polymeric material is the major components material in composite production. It serves as a binder which forms a strong bond holding the biomass and other components of the composite (Salmal *et al.*, 2013; Blezki and Gassan, 1999; Ochi, 2008; Kannappan and Dhuri, 2012). The nature of polymer introduces in the production process depends on the specific qualities. High structural materials involve high density polymeric material, while low density application requires low density polymers (Laadila *et al.*, 2017; Turku *et al.*, 2018).. Also, the characteristics of biomass waste polymer composite is proportional to the nature of polymers, kind of biomass, age of the biomass waste, cellulosic' components, particle size, fiber components, etc (Chanda, 2015; Najafi *et al.*, 2013; Turku *et al.*, 2018; Government *et al.*, 2021(a); Government *et al.*, 2022) . Optimization of research work is pertinent to ensure efficiently use of raw materials during design of experimental work and cost implications are paramount (Chanda, 2015; Harun and Geok, 2016; Laadila *et al.*, 2017; Najafi *et al.*., 2013; Turku *et al.*, 2018; Government *et al.*, 2021(a); Government *et al.*, 2022). This enables researchers and industry to optimal obtains the cost of raw materials with right the process variables for production of a specific products. This process minimizes cost of raw, increase profitability and removal of non-significant variables out of the process system(Chanda, 2015; Harun and Geok, 2016; Laadila *et al.*, 2017; Najafi *et al.*, 2013; Turku *et al.*, 2018; Government *et al.*, 2021(a); Obasi, 2015; Government *et al.*, 2022). The commonly utilize software is design expert to achieve this process (Myers *et al.*, 2002; Myers, 2004; Montgomery, 2001; Government *et al.*, 2018(a); Government *et al.*, 2019(b); Kandar and Akil, 2016; Rostamiyan *et al.*, 2014: Government *et al.*, 2022; Government and Ngabea, 2023(a-c)). Meanwhile, several authors utilize many biomass fiber in polymeric fiber composite for engineering output for industrial commercialization. These biomass fibers are enumerated: date palm (Atuanya *et al.*, 2014; Government *et al.*, 2021(a)), groundnut shell (Obasi, 2015; Government *et al.*, 2022), flame of forest pod (Government *et al.*, 2019(c)), avocado wood flour (Government and Onukwuli, 2016a; Government *et al*, 2016(b); Government *et al.*, 2019(b, d); Government *et al.*, 2018(a-b)), mango seed shell (Government *et al.*, 2019(e)),etc. Hence, the focus of this paper is the optimization of mechanical characteristics of low-priced breadfruit peel waste by impregnating low density polyethylene for production printer components.

MATERIALS AND METHODS

Collection of breadfruit peel and preparation: The BRP was source in a local market, New Market at Enugu statate metropolis. The BRP was subjected to sunlight exposure for 480 mins daily for 14 day interval. The BRF was ground to a particle of 150-850 µm (100-20 mesh).

BRP-LDPE composite production: The BRP with fiber content of 5-25 wt% was compounded with LDPE supplied by Exxon Mobil, Saudi Arabia 95-75 wt%. The unified component of BRP and LDPE was injected in injection molding machine where the mixture was allowed to melt and blended properly to form the BRP-LDPE composite..

BRP-LDPE composite mechanical testing: The tensile, flexural and hardness test were evaluated using houisefield tensile machine BSS1610, model no. 8889, made in England. Based on ASTM standard the samples were sized, tensile test (ASTM D638) comprised tensile strength and modulus; flexural test (ASTM D790) involving flexural strength and modulus, hardness analysis; Brinell hardness analysis (ASTM E103) for the sample of BRF-LDPE composite (ASTM, 1990). The tensile strength, young modulus, flexural strength, flexural modus and Brinell's hardness were determined Eq. (1-6), respectively. These equations were stated below:

The following formulae were used for estimation of tensile strength, tensile modulus, flexural modulus, Brinell hard- ness, as stated in Equations (1) to (6), respectively.

$$\boldsymbol{\sigma_T} = \frac{\boldsymbol{f_m}}{\boldsymbol{A_1}} \quad (1)$$

$$\boldsymbol{E_M} = \frac{\Delta\boldsymbol{\sigma}}{\Delta\boldsymbol{\varepsilon}} \quad (2)$$

$$\sigma = \frac{3FL}{2bd^2} \quad (3)$$

$$E_{BD} = \frac{L^3 m}{4Wb^3} \quad (4)$$

$$m = \frac{\Delta F}{\Delta e} \quad (5)$$

$$BH = \frac{2f}{\pi D\left[D - \sqrt{D^2 - d^2}\right]} \quad (6)$$

The variables σ_T, f_m, A_1, E_M, $\Delta\sigma$, $\Delta\varepsilon$, σ, f, d, l, b, denotes ultimate strength, force at tensile mode, crossectional area of the material, bending modulus, change in stress and strain, flexural strength, force at bending, sample width, length and thickness of sample, respectively. Also E_{BD}, m, ΔF, Δe, BH, D, d and f represent the bending modulus, slope of load deflection, change in flexural force, difference in extension, Brinell's hardness, bulb diameter, indentation height and the force exerted at hardness test, respectively.

Furthermore, impact analysis was estimated by simple Charpy impact tester model no. 17562 made by German company. The sample of BRP-LDPE composite was sized to ASTM standard (ASTM D610-02 M). The impact strength was calculated applying Eq. (7).

$$IS = \frac{E_b}{A_1} \quad (7)$$

The IS, E_b and A_1 are the Charpy impact strength, energy gained during impact and the cross-sectional area of BRP-LDPE composite specimen, respectively.

Water absorption Analysis: The specimen of BRP-LDPE composite was tested for water absorption analysis based ASTM D 570. The sample was tested for this analysis implementing Eq. (8).

$$W_{AR\%} = \frac{D_{2-}D_1}{D_1} \times \frac{100}{1} \quad (8)$$

The water sorption percentage, initial weight and final weight after water sorption are $W_{\%}$, P_1 and P_2, respectively.

The $W_{AR\%}$, D_1, D_2 stands for the water absorption resistance, initial mass of sample, final mass after immersion in water.

Design of experiment for the preparation of BRP-LDPE composite: The software used for this study was Design Expert 7.0. The BRP particle size ranged from (A)(100-20 mesh (150-850 µm)) and BRP content (B) (5-25 wt%) were potential variables slotted in the RSM of CCD applying face cubic centre design of experiment with factor ranged low, lower, middle, high, highest. and also for the output factors, TS, TSM, FS, FSM, BH,IS, and W_{AR}, respectively. These variables for input facts (A and B) and output factors (responses (characteristics of the composite) were slotted in the software to obtain models and other parameters corresponding to the optimization process.

RESULTS AND DISCUSSION

From Table 1 which demonstrates design matrix of BRP-LDPE composite, the factors A and B of the BRP-LDPE composite combined to connect response (TS, TSM, FS, FSM, BH,IS, and W_{AR}) which was inputted on RSM model.

The following models which described the both A and B co-related to each of the mechanical characteristics of the BRP-LDPE composite was generated through regression analysis by quadratic equation of RSM in the CCD. These models created by the characteristics of BRP-LDPE composite by varying A and B through RSM estimated experimental values of the composite material. These are models that were produced from CCD of RSM to illustrate the TS, TSM, FS, FSM, BH,IS, and W_{AR} of BRP-LDPE composite as represented in Eq. 9-15, respectively.

$$TS = +6.77120 + 0.040766A - 0.062312B - 2.79104x10^{-4}A^2 - 2.47258x10^{-3}B^2 \quad (9)$$

$$TSM = +0.19458 + 1.43985x10^{-3}A + 4.30453x10^{-3}B - 9.70271x10^{-6}A^2 - 4.62465x10^{-5}B^2 \quad (10)$$

$$FS = +15.13490 + 0.059918A + 0.11698B - 4.57163x10^{-4}A^2 - 1.42878x10^{-3}B^2 \quad (11)$$

$$FM = +0.027382 + 1.92681x10^{-3}A + 0.019055B - 1.3531x10^{-5}A^2 - 4.1891x10^{-4}B^2 \quad (12)$$

$$BH = -22.66478 + 1.60518A + 8.38833B - 9.93657x10^{-3}A^2 - 0.15587B^2 \quad (13)$$

$$IS = +41.88854 + 0.098379A - 0.027030B - 7.31639x10^{-4}A^2 - 3.88959x10^{-3}B^2 \quad (14)$$

$$W_{AR} = +3.69027 - 0.010733A + 0.12511B + 6.71536x10^{-5}A^2 - 2.10202x10^{-3}B^2 \quad (15)$$

Table 1: Design matrix and response of.BRP-LDPE composite

	Factors		Responses							
	mesh	%	MPa	GPa	MPa	GPa	KJ/m^2	Pa	%
Run	A	B	TM	TSM	FS	FM	IS	BH	W_{AR}
1	1.000	-1.000	7.65	0.258	16.98	0.165	78	43.91	3.82
2	0.000	1.000	4.75	0.333	19.19	0.315	163	41.61	5.07
3	-1.000	-1.000	7.29	0.24	16.64	0.147	52	43.21	4.05
4	-1.000	1.000	4.29	0.3	18.08	0.276	120	40.3	5.29
5	0.000	0.000	6.67	0.301	18.43	0.289	132	43.8	4.65
6	0.000	0.000	6.67	0.301	18.43	0.289	132	43.8	4.65
7	1.000	0.000	6.49	0.297	17.58	0.285	137	42.8	4.67
8	1.000	1.000	4.57	0.32	18.29	0.301	152	40.93	4.99
9	0.000	0.000	6.67	0.301	18.43	0.289	132	43.8	4.65
10	0.000	-1	7.89	0.259	17.42	0.14	51	45.29	3.59
11	0.000	0.000	6.67	0.301	18.43	0.289	132	43.8	4.65
12	0.000	0.000	6.67	0.301	18.43	0.289	132	43.8	4.65
13	-1.000	0.000	5.51	0.26	17.14	0.235	76	41.59	5.01

Table 2(a-g) illustrates ANOVA for the TS, TSM, FS, FSM, BH, IS, and W_{AR} of BRP-LDPE composite, respectively. As traceable from Table 2, the models of TS, TSM, FS, FSM, BH, IS, and W_{AR} with their probability values (P- value) < 0.000 l of BRP-LDPE composite, respectively. The factors A and B for all the models were significantly < 0.0071. The multiple terms AB were entirely insignificant for all the characteristics of BRP-LDPE composite. This means that the insignificant term of AB had to be eliminated the models of BRP-LDPE composite properties. Also, A^2 and B^2 variables exposed highly great values of p-values with its significance of TS, TSM, FS, FSM, BH, IS, and W_{AR} < 0.02. Finally, R^2, Ad. R^2 and Pr. R^2 yielded brilliant significant results > 98.2%, >96.9 and > 86.7% for TS, TSM, FS, FSM, BH, IS, and W_{AR} of BRP-LDPE composite, respectively. With differences of R^2, Ad. R^2 and Pr. R^2 < 10% for models of the mechanical-characteristic of the BRP-LDPE composite. Moreover, these show highly significant and correlation of the models to predict the experimental values of qualities of BRP-LDPE composite. The research outcome of this study was near equals to the previous scholarly works (Khuri *et al.*, 1987; Government *et al.*, 2019(c-d); Kandar and Akil, 2016; Peng *et al.*, 2015; Rostamiyan *et al.*, 2014; Rostamiyan *et al.*, 2015(a); Rostamiyan *et al.*., 2015(b); Government *et al.*, 2018(a-b)).

Table 2a: ANOVA for the TS of BRP-LDPE composite.

Source	SS	df	MS	F-Value	p-value	Prob > F
TS	15.87	5	3.17	91.34	< 0.0001	Significant
A	0.49	1	0.49	14.13	0.0071	
B	14.03	1	14.03	403.87	< 0.0001	
A^2	1.03	1	1.03	29.59	0.0010	
B^2	0.32	1	0.32	9.07	0.0196	
R^2	0.9849					
Ad R^2	0.9741					
Pr R^2	0.8881					

Table 2b: ANOVA for the TSM of BRP-LDPE composite

Source	SS	df	MS	F Value	p-valuev Prob > F	
TSM	0.008809	5	0.001762	156.6094	< 0.0001	Significant
A	0.000999	1	0.000999	88.81821	< 0.0001	
B	0.006456	1	0.006456	573.8878	< 0.0001	
A^2	0.001243	1	0.001243	110.4506	< 0.0001	
B^2	0.00011	1	0.00011	9.801659	0.0166	
R^2	0.99114					
Ad R^2	0.984811					
Pr. R^2	0.935283					

Table 2c: ANOVA for the FS of BRP-LDPE composite

Source	SS	df	MS	F Value	p-value Prob > F	
FS	6.494859	5	1.298972	159.4302	< 0.0001	Significant
A	0.170101	1	0.170101	20.87742	0.0026	
B	3.456862	1	3.456862	424.2804	< 0.0001	
A^2	2.758424	1	2.758424	338.5572	< 0.0001	
B^2	0.105247	1	0.105247	12.91763	0.0088	
R^2	0.991295					
Ad R^2	0.985077					
Pr. R^2	0.938125					

Table 2d: ANOVA for the FM of BRP-LDPE composite

Source	SS	df	MS	F Value	p-value Prob > F	
FM	0.0459	5	0.00918	198.6311	< 0.0001	Significant
A	0.001569	1	0.001569	33.94086	0.0006	
B	0.032855	1	0.032855	710.8946	< 0.0001	
A^2	0.002416	1	0.002416	52.28583	0.0002	
B^2	0.009048	1	0.009048	195.7692	< 0.0001	
R^2	0.993001					
Ad R^2	0.988002					
Pr. R^2	0.949207					

Table 2e: ANOVA for the BH of BRP-LDPE composite

Source	SS	df	MS	F Value	p-value Prob > F	
BH	16281.4	5	3256.28	76.53367	< 0.0001	Significant
A	2538.347	1	2538.347	59.6598	0.0001	
B	11178.33	1	11178.33	262.7287	< 0.0001	
A^2	1303.14	1	1303.14	30.62822	0.0009	
B^2	1252.588	1	1252.588	29.44008	0.0010	
R^2	0.982036					
Ad R^2	0.969205					
Pr. R^2	0.866527					

Table 2f: ANOVA for the IM of BRP-LDPE composite

Source	SS	df	MS	F Value	p-value Prob > F	
IS	24.42653	5	4.885305	82.42175	< 0.0001	Significant
A	1.136842	1	1.136842	19.18008	0.0032	
B	15.44349	1	15.44349	260.5526	< 0.0001	
A^2	7.06499	1	7.06499	119.196	< 0.0001	
B^2	0.779984	1	0.779984	13.15938	0.0084	
R^2	0.983298					
Ad R^2	0.971368					
Pr. R^2	0.881012					

Table 2g: ANOVA for the W_{AR} of BRP-LDPE composite

Source	SS	df	MS	F Value	p-value Prob > F	
W_{AR}	2.96318	5	0.592636	1935.377	< 0.0001	Significant
A	0.12802	1	0.12802	418.0763	< 0.0001	
B	2.546616	1	2.546616	8316.507	< 0.0001	
A^2	0.059519	1	0.059519	194.3726	< 0.0001	
B^2	0.227799	1	0.227799	743.9262	< 0.0001	
R^2	0.999277					
Ad R^2	0.998761					
Pr. R^2	0.994803					

The trend has been reported previously (Soury *et al.*, 2009; Hadi, 2011; Patpen *et al.*, 2015; Government, 2021(a); Government *et al.*, 2022; Homkhiew *et al.*, 2014; Government, 2019(a); Government *et al.*, 2019(b-e); Peng *et al.*, 2015; Rostamiyan, *et al.* 2015(b); Government and Okeke, 2023: Government and Ngabea, 2023(a-c))..

Figure 1(a-g) demonstrates 3-D graph for factors A and B forming quadratics model on the TS, TSM, FS, FSM, BH, IS, and W_{AR} of BRP-LDPE composite, respectively. During the variation of the factors A and B in the LDPE polymeric matrix, the composition of the LDPE and BRP changes. This is leads to composition of contents and particle size of BRP to varies. This escalates making A and B which generates more interactions for the characteristic of BRP-LDPE composite. After sometime, as A and B continue to make reasonable impact on the interactions of TS, TSM, FS, FSM, BH, IS, and W_{AR} of BRP-LDPE composite, respectively. There are focal points where the interactions between A and B matched on the composition of BRP and LDPE content led to the BRP-LDPE composite attaining the desire apex. At this apex, A and B had specific values leading to the mechanical-characteristics of BRP-LDPE composite achieved its corresponding values at that point. This is the ultimate condition of the composite for ideal predictions with RSM model of A, B which maintained and yielded corresponding values of TS, TSM, FS, FSM, BH, IS, and W_{AR} of BRP-LDPE composite, respectively.

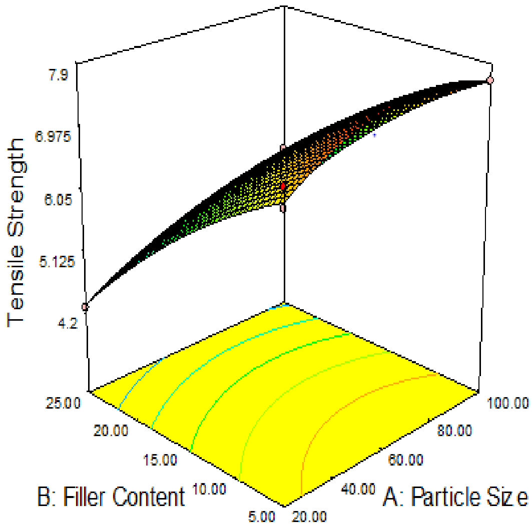

Fig 1a: 3D Surface plots for the BRP-LDPE unmodified composite of TS as dependent on Particle size (A) and Filler content (B)

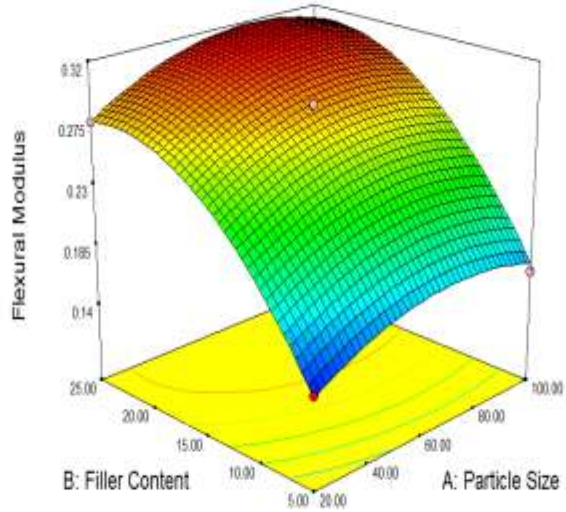

Fig 1d: 3D Surface plots for the BRP-LDPE unmodified composite of FM as dependent on Particle size (A) and Filler content (B)

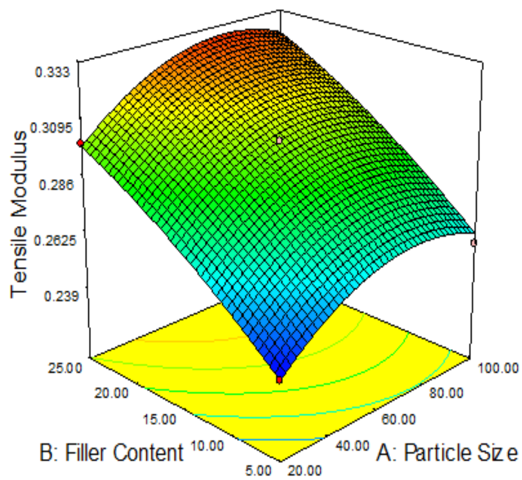

Fig 1b: 3D Surface plots for the BRP-LDPE unmodified composite of TSM as dependent on Particle size (A) and Filler content (B)

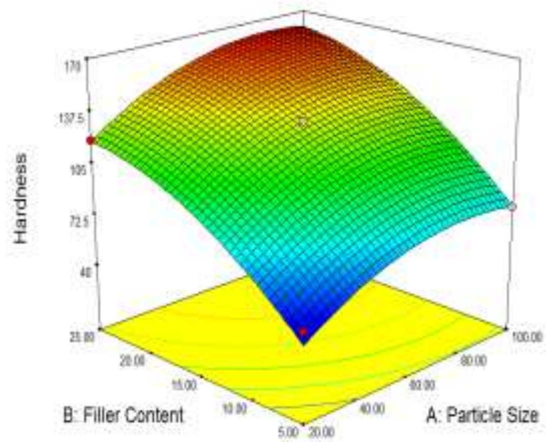

Fig 1e: 3D Surface plots for the BRP-LDPE unmodified composite of BH as dependent on Particle size (A) and Filler content (B)

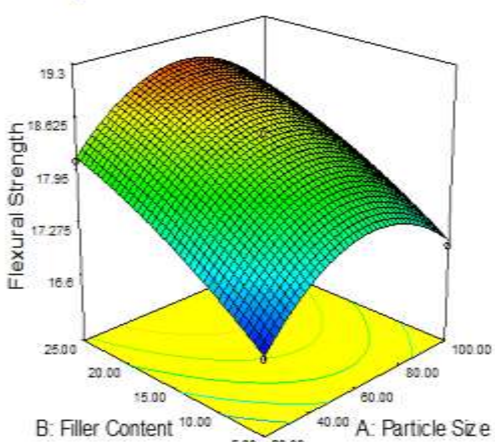

Fig 1c: 3D Surface plots for the BRP-LDPE unmodified composite of FS as dependent on Particle size (A) and Filler content (B)

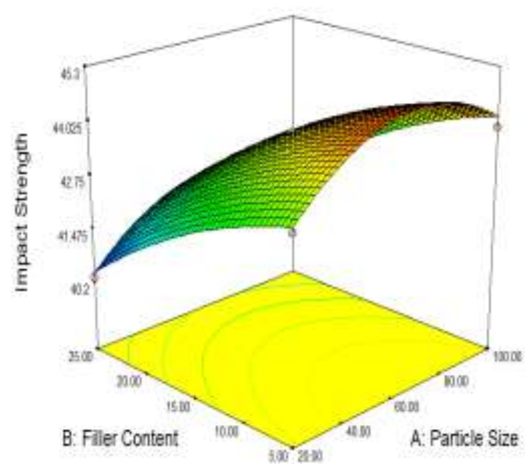

Fig 1f: 3D Surface plots for the BRP-LDPE unmodified composite of IM as dependent on Particle size (A) and Filler content (B)

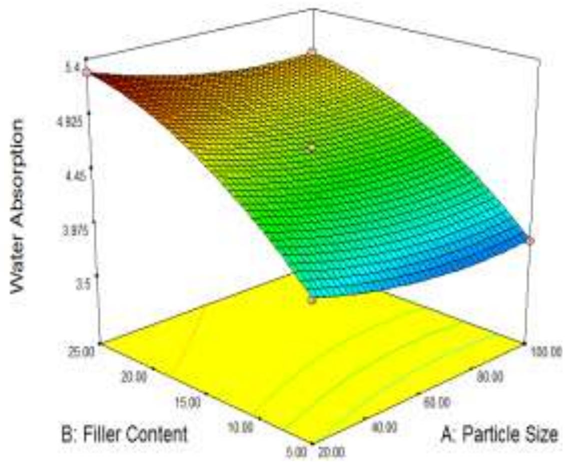

Fig 1g: 3D Surface plots for the BRP-LDPE unmodified composite of W_{AR} as dependent on Particle size (A) and Filler content (B)

From Figure 1 at optimal situation, the A and B were 80 mesh (180 µm) and 19.39 wt % which corresponded to TS, TSM, FS, FSM, BH, IS, and W_{AR} of BRP-LDPE composite, respectively at this state. Similar height was recorded by past results (Government *et al.,* 2022; Brent *et al.*, 2014; Homkhiew *et al.*, 2014; Government, *et al.* 2019(b-d); Nwanenyi *et al.,*2013; Government and Okeke, 2023: Government and Ngabea, 2023(a-c))

Table 3 presents results of experimental data and that of the predicted value using CCD of RSM at ultimate condition. As can be seen in Table 3, when A and B were 80 mesh (180 µm) and 19.39 wt% at optimal moment; the experimental data were 5.943266 MPa, 0.312324 GPa, 18.53303 MPa, 0.30684 GPa, 147.1384 Pa, 42.79402 KJ/m^2 and 4.842398 % for TS, TSM, FS, FSM, B, IS, and W_{AR} of BRP-LDPE composite, respectively. For RSM predicted value at this state, the TS, TSM, FS, FSM, BH, IS, and W_{AR} of BRP-LDPE composite were 6.036284 MPa, 0.315798 GPa, 18.62651 MPa, 0.31388 GPa, 151.8932 Pa, 43.04614 KJ/m^2 and 4.830519 %, respectively. Furthermore, the relative error between the predicted RSM values and the one derived from the experiment of the entire process were <3.232%. This is an indication that the RSM model was highly commendable for predication of characteristics of BRP-LDPE composite for the printer parts production. Similar process is displayed by later scholars(Government *et al.*, 2022; Homkhiew *et al.*, 2014; Government, *et al.* 2019 (b-d); (Yang, *et al.* 2004; Rahman *et al.*2010; Government *et al.*, 2022; Homkhiew *et al.*, 2014; Government *et al.,*2019 (a-e)).: Government and Ngabea, 2023(a-c)).

Table 3: Variance of experimental and RSM of characteristics of BRP-LDPE composite at optimal state

Characteristic	(mesh) A	(µm) A	(%) B	Pr. V.	Exp. V.	Error (%)
TS (MPa)	80	180	19.39	6.036284	5.943266	1.565101
TSM (GPa)	80	180	19.39	0.315798	0.312324	1.112092
FS (MPa)	80	180	19.39	18.62651	18.53303	0.504367
FM (GPa)	80	180	19.39	0.31388	0.30684	2.294368
BH (Pa)	80	180	19.39	151.8932	147.1384	3.231523
IS (KJ/m2)	80	180	19.39	43.04614	42.79402	0.589143
W_{AR} (%)	80	180	19.39	4.830519	4.842398	0.24531

Conclusion: This work studied on optimization of unmodified BRP waste by impregnation of LDPE matrix for engineering parts had been carried out. The parameter A, B had significant role in determining characteristics of BRP-LDPE composite. The CCD of RSM was able to give good prediction of TS, TSM, FS, FSM, BH, IS, and W_{AR} of BRP-LDPE composite. Also, the relative deviational errors between the experimental data and the models generated by RSM were minimal. A better correlation exists between the factors A, B and the mechanical characteristics of the BRP-LDPE composite. From this reasonable outcome of this work, the RSM give an insight for immense predictor for characteristics of BRP-LDPE composite making it to be utilized as novel engineering material for printer parts production.

Abbreviation
A = Particle size
B = Filler content
BRP = breadfruit peel
LPDE = low density polyethylene
TS = tensile strength
TSM = tensile modulus
FS = flexural strength
FM = flexural modulus
BH = Brinell's hardness
IS = impact strength
W_{AR} = water absorption resistance
CCD = central composite design
RSM = response surface methodology

Declaration of Conflict of Interest: The authors declare no conflict of interest.

Data Availability Statement: Data are available upon request from the corresponding author.

REFERENCE

Ahmed, NT; Singal, RS; Kulkarni, PR; Kale, P; Pal, M; (1996). Studies on chenopodium quinoa and armaranthus paniculatas starch as biodegradability filler in LDPE films. *Carb. Polym.* 31: 157-160.

Aimi, NN; Anuar, H; Manshor, MR; Nazri, WBW.;Sapuan, SM (2014). Optimizing the parameters in durian skin fiber reinforced polypropylene composites by response surface methodology. *Ind. Crops Prod*. *54*: 291–295. https://doi.org/10.1016/j.indcrop.2014.01.016

Atuanya, CU; Government, MR., Nwobi-Okoye, CC; Onukwuli, OD (2014). Predicting the mechanical properties of date palm wood fibre-recycled low density polyethylene composite using artificial neural network. *Int. J. Mech. Mater. Eng*. *9*(1): 1–20. https://doi.org/10.1186/s40712-014-0007-6

Azeez, TO(2019). Thermoplastic recycling: properties, modifications, and applications. in *polymer recycling* (pp. 1–19). Rijeka, Croatia: InTech Open. https://doi.org/http://dx.doi.org/10.5772/intechopen.81614

Azeez, TO.; Government, RM; Eze, IO; Iwuji, SC (2021). Modifications and Physicomechanical Behaviors of Roselle Fiber-HDPE Biocomposites for Biomedical Uses. *Roselle*, 89–102. https://doi.org/10.1016/b978-0-323-85213-5.00013-5

Azeez, TO; Olaitan, SA; Atuanya, CU; Chukwudi, DO; Akagu, C; Menkiti, MC (2013). Effect of filler weight fraction on the mechanical properties of bambara groundnut (Okpa) husk polyethylene composite. *Int. J. Cur. Res. Rev*. *5*(7): 1714–1717

Azeez, TO., Onukwuli, OD.; Walter, PE., Menkiti, MC. (2018). Influence of chemical surface modifications on mechanical properties of combretum dolichopetalum fiber-high density polyethylene (HDPE) composites. *Pakistan J. Sci. Ind. Res. Ser. A Phys. Sci.*. *61A*(1): 28–34

ASTM, (1990). Annual book of ASTM standard, Vol.8.Philadelphia, PA; *American Society for Testing and Materials*.

Bawon, P; Lee, SH; Osman, NF; Mohd, MS; Ashaari, Z (2019). A preliminary study on physical and mechanical properties of particleboard made from palm oil-treated rubberwood particles. *J. Indian Acad. Wood Sci.* https://doi.org/10.1007/s13196-019-00231-2

Bhandari, NL; Thomas, S; Das, CK; Adhikari, R (2013). Analysis of Morphological and Mechanical Behaviors of Bamboo Flour Reinforced Polypropylene Composites. *Nepal J. Sci. Technol.* *13*(1): 95–100. https://doi.org/10.3126/njst.v13i1.7447

Bledzki, AK; Gassan, J (1999). .Composites reinforced with cellulose based fibres. *Prog. Polym. Sci*. 24; 221-274.

Brent, T; Louis, R; David, G; Gowrishanker S (2014).Effect of particle size, coupling agent and DDGS additions on paulownia wood polypropylene composites. *J. Reinf. Plast. Compos.* 33(14); 1279-1293.

Catto, AL; Santana, RMC (2018). Influence of coupling agent in polyolefinic composites from post-consumer waste with Eucalyptus *Grandis* flour. *J. Mater. Sci. Eng. B*, *3*(10): 641–652. https://doi.org/10.17265/2161-6221/2013.10.003

Chanda, B; Kumar. R; Kumar K. (2015). Optimization of the mechanical properties of wood dust-reinforced epoxy composite using grey relational analysis. *Proceed. fourth int. conf. soft comput. Prob. solv.*

Dungani, R; Karina, M; Subyakto, SA; Hermawan, D; Hadiyane, A (2016.) Agricultural waste fibers towards sustainability and advanced utilization: A review. *Asian J. Plant Sci*. *15*(1–2): 42–55. https://doi.org/10.3923/ajps.2016.42.55

Fortunati, E; Kenny, J. M; Torre, L (2019). Lignocellulosic materials as reinforcements in sustainable packaging systems: Processing, properties, and applications. *Biom. Biopolym.Mater. Bioen. Construct,, Biomed., Indust. Appl.* 87–102. https://doi.org/10.1016/B978-0-08-102426-3.00005-9

Government, RM; Onukwuli, OD (2016(a). Effect of chemical treatment of avocado wood flour (AWF) on the properties of high density polyethylene (HDPE) for the production of natural filler composites. *Int. J. Innov. Sci. Eng. Technol*. 3 (2): 627-643.

Government, RM; Onukwuli,OD; Onoh. IM (2016(b)). Response surface methodology for the optimization of Avocado wood filler (AWF) -high density polyethylene (HDPE) composites using surface modification. *Int. J. Sci. Eng, Res*. 7(2): 750-761.

Government, RM (2019(a)). The comparative studies on the use of some agricultural wastes as fillers for polyethylene composites. Nnamdi Azikiwe University: PhD Thesis, Unpublished.

Government, RM; Ngabea, SA (2023(a)). Effect of particle size and filler content on mechanical properties of avocado wood flour-low density polyethylene composite. *J. Appl. Sci. Environ. Manag.* 27 (10): 2303-2313.

Government, RM; Ngabea, SA (2023(b)). Optimization of tensile, hardness and water absorption characteristics of pre-treated APWF-LDPE composite using central composite design. *J. Eng. Dev.* 15(3): 36-55.

Government, RM; Ngabea, SA (2023(c)). Optimization of process parameters on the flexural and impact properties of GSF-R-LDPE composite for television appliance parts. *J. Eng. Dev.* 15(3): 56-74.

Government, RM; Ngabea, SA (2023(d)). Comparative study on the mechanical properties of fillers-recycled low- density polyethylene for printers and car parts production.
UNIZIK J. Eng. Appl. Sci. 2(3): 376-387.

Government, M R; Onukwuli, OD; Odera, RS (2018(a)). Optimization of avocado wood flour polymer Composite. *J. Eng. Appl. Sci*. 13: 99-109.

Government RM; Onukwuli OD; Ani, AK (2018(b)). Chemically treated avocado wood flour -LLDPE Composite. *Usak Univ. J. Mater. Sci. 6*(1–2): 27–40. https://doi.org/10.12748/uujms.2018.44

Government, RM; Okeke, ET; Thaddaeus, J; Ani, AK; Onukwuli, OD (2021(a)). Optimization of flexural and impact properties of r-LDPE-DPWF composite for printer parts production. *Mater. Test.* 63(4): 373-376

Government, RM; Ani, AK; Onukwuli, OD(2021(b)). Effect of using different chemically modified breadfruit peel fiber in the reinforcement of LDPE composite. *Mater. Test.* 63: 286–292.

Government, RM; Ani, KA; Azeez, TO; Onukwuli, DO (2019(b)). Effects of the chemical treatment of avocado pear wood filler on the properties of LDPE composites. *Mater. Test. 61*(12): 1209–1214.

Government, RM; Agu, OS; Olowokere, JA (2019(c)). The use of flame of forest pod flour in high density. *Act. Tech. Corv. – Bull. Eng.* (8889), 12(1): 11–14.

Government, RM; Okeke, ET (2023). Elastic-characteristics of recycled low-density-polyethylene-date palmwood composite by response surface methodology optimization process for structural application. *UNIZIK J. Eng. Appli. Sci.* 2(2): 358-368.

Government, RM; Okeke, ET (2024). Effect of particle size on the properties of avocado pear wood fiber/low-density polyethylene composite enhanced by pretreatment. *Mater. Test.*. 66(1): 22–35.. https://doi.org/10.1515/mt-2023-0223

Government, RM; Onukwuli, OD; Azeez TO (2019 (d)). Optimization and characterization of the properties of treated avocado wood flour-linear low density polyethylene composites. *Alexandria Eng. J. 58*(3): 891–899. https://doi.org/10.1016/j.aej.2019.08.004

Government, RM., Okeke, ET; Ibrahim, IA; Onukwuli, OD (2022). Modeling and simulation of tensile properties of r-LDPE/GSF composite using the response surface methododology. *Mater. Test. 64*(3): 446–454 https://doi.org/10.1515/mt-2021-2109.

Government, R; Olowokere, J; Odineze, C; Anidobu, C; Yerima, E; Nnaemeka, B (2019 (e)). Influence of soaking time and sodium hydroxide concentration on the chemical composition of treated mango seed shell flour for composite application. *J Appl. Sci. Env. Manag. 23*(1): 21-28. https://doi.org/10.4314/jasem.v23i1.3

Hadi AE (2011). Characterisation and optimization of mechanical, physical and thermal properties of short abaca (Musa TextileNee) fibre reinforced high impact polystryrene composites. Ph.D.thesis, University Putral Malaysia.

Haristov, V; Vasileva, S (2003). Dynamic mechanical and thermal properties of modified polypropylene composites, wood fibre composites. *Macromol. Mater. Eng.* 288: 798-806.

Harun, S; Geok, SK (2016). Effect of sodium hydroxide pretreatment on rice straw composition. *Indian J. Sci. Technol.9*(21): 1-9 https://doi.org/10.17485/ijst/2016/v9i21/95245

Homkhiew, C; Ratanawilai, T; Thongruang, W (2014). Optimizing the formulation of polypropylene and rubberwood flour composites for moisture resistance by mixture design. *J. Reinf. Plast. Comp.* *33*(9): 810–823. https://doi.org/10.1177/0731684413518362

Joseph, PV; Rabello, MS; Mattoso, LHC (2002). Environmental effect on the degradation of sisal fiber reinforced polypropylene composites. *Comp. Sci. Technol.* 66: 1357-1372.

Laadila, MA; Hegde, K; Rouissi, T;, Brar, SK; Galvez, R; Sorelli, L; Cheikh, RB; Paiva, M.; Abokitse, K (2017). Green synthesis of novel biocomposites from treated cellulosic fibers and recycled bio-plastic polylactic acid. *J. Clean. Prod.*, *164*: 575–586. https://doi.org/10.1016/j.jclepro.2017.06.235

Lee, S; Lee BH; Kim, HJ; Kim; S; Eom, YG (2009). Properties evaluation of bio-composite by content and particle size of bamboo flour. *Mokch. Kongh.*, 37(4): 310-319.

Lou, CW; Lin, CW; Lei, CH; Su, KH; Hsu, CH; Liu, ZH; Lin, JH (2007). PET/PP blend with bamboo charcoal to produce functional composites, *J. Mater. Proc. Technol.*, 192-193: 428-433.

Kannappan, S; Dhurai, B (2012). Investigation and optimization the process variables related to the tensile properties of short jute fibre reinforced with polypropylene composite board. *J Eng. Fib. fab.* 7 (4): 28-34.

Kandar, MIM; Akil, HM (2016). Application of Design of Experiment (DoE) for Parameters Optimization in Compression Moulding for Flax Reinforced Biocomposites. *Proc. Chem.* 19: 433–440. https://doi.org/10.1016/j.proche.2016.03.035

Khuri, AI; Cornell, JA (1987). Dekker M. Response surfaces: design and analysis. New York: Dekker.

Kord, B (2011). Influence of maleic anhydride on the flexural, tensile and impact characteristics of sawdust flour reinforced polypropylene composite. *World Appl. Sci. J.* 12 (7): 1014-1016.

Mengeloğlu, F; Karakuš, K (2008). Some properties of eucalyptus wood flour filled recycled high density polyethylene polymer-composites. *Turkish J. Agric. For.* *32*(6): 537–546. https://doi.org/10.3906/tar-0801-7

Montgomery, DC (2001). Design and Analysis of Experiment.5th ed., John Wiley and Sons, New York.

Myers, RH; Montgomery, DC (2002). Response Surface Methodology, John Wiley & Sons, Inc., USA.

Mayers R; Montgomery; D; Vinning; G; Borror CM; Kowalski, SM (2004). Response surface methodology: A prospective and a literature survey. *J, Qual. Technol.* 36: 53-77.

Myers, RH; Montgomery, DC; Anderson-Cook, CM (2009). Response surface methodology-process and product optimization using design experiment. 3rd edition, Ney Jersey: John Wiley and Son Inc.

Nachtigall, SMB; Cerveria, GS; Rosa, SML (2007). New polymeric-coupling agent for polypropylene/wood flour composites. *Polym. Test.* 26: 619-628.

Najafi, SK; Sharifi, F; Mohebby, B (2013). Improvement of some physical and mechanical properties of sawdust / recycled polypropylene composites using nanoclay, 25–27.

Netral, B; Sabu, T; Chapal, KD; Rameshwar, A (2012**).** Analysis of morphology and mechanical behaviours of bamboo flour reinforced polypropylene composites. *Nep. J. Sci. Technol*. 13 (1): 95-100.

Ng, MH; Verma, D; Sabu, T ; Goh, K.(2019). Characteristics of johorean elaeis guineensis oil palm kernel shells: Elasticity, Thermal stability, and biochemical composition. *Biom. Biopolym.Mater. Bioen. Constr. Biomed. Indust. Appl.* Elsevier Ltd. https://doi.org/10.1016/B978-0-08-102426-3.00004-7

Nourbakhsh, A; Karegarfard, A; Ashori, A; Nourbakhsh, A (2010). Effects of particle size and coupling agent concentration on mechanical properties of particulate-filled polymer composites. *Journal of Thermoplastic Composite Materials*, *23*(2): 169–174. https://doi.org/10.1177/0892705709340962

Nwanonenyi, SC; Obidiegwu, MU; Onuegbu, GG (2013). Effect of particle size, filler content and compactibilization on the properties of linear low density polypropylene filled periwinkle shell powder. *Int. J. Eng. Sci.* 2(2); 1-8.

Nunez, AJ; Kenny, JM; Reboredo, MM; Aranguren, MI; Marcovich, NE (2002). Thermal and dynamic mechanical characterization of polypropylene-wood flour composites. *Polym. Eng. Sci.*42: 733-742.

Obasi, .H (2012). Studies on biodegradability and mechanical properties of high density polyethylene/corn cob flour based composites. *Int. J. Sci. Eng. Res.* 3: 8-17.

Obasi, HC; Onuegbu, GC (2013). Biodegradability and mechanical properties of low density polyethylene/waste maize cob flour blends. *Int. J. Appl. Sci. Engi. Res. 2*(3): 233–240. https://doi.org/10.6088/ijaser.020300006

Obasi, HC (2015). Peanut husk filled polyethylene composites: effects of filler content and compatibilizer on properties. *J. Polym. 2015*, 1–9. https://doi.org/10.1155/2015/189289

Ochi, O (2008). Mechanical properties of kenaf fibres and kenaf /PLA composites, *Mech. Mater*. 40 (4-5): 446-452.

Okeke, ET; Government, RM. Apake, DD; Ani, AK. 2023. Effects of sodium hydroxide on the compositions of shea butter bark wood fiber for polymeric composite production in structural application. *J. Appl. Sci.Environ. Manag.* 27 (1): 1423-1429

Onuegbu, GC; Nwanonenyi, SC; Obidiegwu, MU (2013). The effect of pulverised ground nut husk on some mechanical properties of polypropylene composites. *Int. J. Eng. Sci. Eng. 2*(6): 79–83.

Onuegbu, GC; Obasi, CH; Onuoha, FN (2014). Tensile behaviour of cocoa pod filled polypropylene composites. *Asian J. Bas. Appl. Sci. 1*(2): 1–7. Retrieved from www.multidisciplinaryjournals.com

Orji, BO; McDonald, AG (2020). Evaluation of the mechanical, thermal and rheological properties of recycled polyolefins rice-hull composites. *Mater., 13*(3):1-15. https://doi.org/10.3390/ma13030667

Patpeni. PR; Rusly AR; Rosnita, AT; Khalina. A (2015). Response surface methodology for the optimization of preparation of biocomposites based on poly(lactic acid) and duran peel cellulose. *Sci. World J.* 1-12.

Peng, CB; Mohamed, AH; Nasir, BR; Khan, A (2015). Optimization on wear performance of UHMWPE composites using response surface methodology. *Trib. Int. 88*: 252–262. https://doi.org/10.1016/j.triboint.2015.03.028

Rahman, MR; Islam, MN; Huque, MM; Hamdan, S; Ahmed, SA (2010). Effect of chemical treatment on rice husk reinforced polyethylene composites. *Biores.* 5(2): 854-869.

Rajak, DK; Pagar, DD; Menezes, PL; Linul, E (2019). Fiber-reinforced polymer composites: Manufacturing, properties, and applications. *Polym., 11*(10). https://doi.org/10.3390/polym11101667

Rashid, B; Leman, Z; Jawaid, M; Ghazali, MJ; Ishak, MR (2016). The mechanical performance of sugar palm fibres (ijuk) reinforced phenolic composites. *Int. J. Prec. Eng. Manuf. 17*(8): 1001–1008. https://doi.org/10.1007/s12541-016-0122-9

Reddy, KO; Reddy, KRN; Zhang, J; Varada, RA (2013). Effect of alkali treatment on the properties of century fiber. *J. Nat. Fib. 10*(3): 282–296. https://doi.org/10.1080/15440478.2013.800812

Rostamiyan, Y; Hamed MA; SalmanKhani, A (2014). Optimization of mechanical properties of epoxy-based hybrid nanocomposite: Effect of using nano silica and high-impact polystyrene by mixture design approach. *Mater. Des. 56*: 1068–1077. https://doi.org/10.1016/j.matdes.2013.11.060

Rostamiyan, Y; Fereidoon, A; Ghalebahman, AG; Mashhadzadeh, AH; Salmankhani, A (2015(a)). Experimental study and optimization of damping properties of epoxy-based nanocomposite : Effect of using nanosilica and high-impact polystyrene by mixture design approach. *J. Mater. Des.. 65:1236-1244*. https://doi.org/10.1016/j.matdes.2014.10.022

Rostamiyan, Y; Fereidoon, A; Mashhadzadeh, AH; Ashtiyani, MR; Salmankhani, A (2015(b)). Using response surface methodology for modeling and optimizing tensile and impact strength properties of fiber orientated quaternary hybrid nano composite. *Comp. Part B: Eng. 69*: 304–316. https://doi.org/10.1016/j.compositesb.2014.09.031

Salmah, H; Marliza, M; Teh, PL (2013). Treated coconut shell reinforced unsaturated polyester composites. *Int. J. Eng. Technol.* 13(2): 94-103.

Sood, M; Dwivedi, G (2018). Effect of fiber treatment on flexural properties of natural fiber reinforced composites: A review. *Egyptian J. Petr. 27*(4): 775–783. https://doi.org/10.1016/j.ejpe.2017.11.005

Soury, E.; Behravesh, AH; Roulani, EE; Zolfaghari, A (2009). Design, optimization and manufacturing of wood-plastic pallet. *Mater. Des.* 30: 4183-4191.

Supri, AG; Lim, BY (2009). Effect of treated and untreated filler loading on the mechanical, morphological, and water absorption properties of water hyacinth fibre low density polyethylene composites. *J. Phys. Sci.* 20(2): 85-96.

Thakore, IM; Iyers, S; Desai, A; Lele, A; Devi, S (1999). Morphology, thermochemical properties and biodegradability of LDPE/starch blends. *J. Polym. Sci.* 74: 2791-2802.

Tisserat, B; Reifschneider, L; Grewell, D; Srinivasan, G (2014). Effect of particle size, coupling agent and DDGS additions on Paulownia wood polypropylene composites. *J. Reinf. Plast. Comp. 33*(14): 1279–1293. https://doi.org/10.1177/0731684414521886

Turku, I; Kärki, T; Puurtinen, A (2018). Durability of wood plastic composites manufactured from recycled plastic. *Heliyon. 4*(3):1–20. https://doi.org/10.1016/j.heliyon.2018.e00559

Yang, HS; Kim, HJ; Son, J; Park, HJ; Lee, BJ; Hwang, TS (2004). Rice husk flour filled propropylene composites; mechanical and morphological study. *Comp. Struct.* 63: 305-312.

Yakubu, A; Olatunji, GA; Mohammed, C (2013). Acetylation of wood flour from four wood species grown in Nigeria using vinegar and acetic anhydride. *Acad. J. Interdiscip. Stud. 2*(10): 147–154. https://doi.org/10.5901/ajis.2013.v2n10p147

Zakaria, MS; Ghazali, CMR; Hussin, K; Wahab, MKA., Halim, KAA; Yevon, L (2018). Characteristic and morphology of palm waste filled thermoplastic composites. *Sol. State Phen.* 280: 415–421. https://doi.org/10.4028/www.scientific.net/SSP.280.415