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Improving the Unsaturated Polyester Matrix Through Commingled With Chemically Treated Cissus Populnea Fibers

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Abstract

The extent of improvement of chemically treated Cissus populnea fiber on morphology, mechanical, adhesion, and water sorption behaviors in Cissus populnea fiber/UPE composites was aimed to be investigated. Fibers were treated with sodium hydroxide (NaOH) and sodium lauryl sulphate (SLS), respectively. The composites were prepared by hand laying techniques of treated and untreated fibers with unsaturated polyester matrix (UPE) using response surface methodology with central composites design of DoE software. The mechanical properties (tensile strength, tensile modulus, flexural strength, flexural modulus, hardness and impact strength) were optimized. The interfacial shear stress (IFSS) using fiber pull-out method, scanning electron microscopy (SEM), density, and water sorption behavior using power law with Fickian diffusion law were studied at optimum level. The optimization of mechanical properties as dependent with factors (weight fraction of the fiber and weight fraction of the matrix) using RSM with CCD technique was done to avoid waste of materials and confusion on properties of the composites. Treatment of Cissus populnea fiber with NaOH and SLS, respectively, improved the tensile and flexural properties of the composites. NaOH treatment gave the best tensile strength while best flexural properties was achieved with SLS treatment. SEM images revealed the morphological changes caused by NaOH and SLS, respectively, at optimal composites production to corroborate interfacial adhesive between Cissus populnea fiber and UPE matrix on composite properties. NaOH and SLS treatments, respectively, reduced the water saturation point with less Fickian behaviour and increased water diffusion coefficient of the composite.

Keywords: Cissus populnea fiber, unsaturated polyester, mechanical properties, density, water sorption behavior.

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Introduction

Cissus populnea (C. populnea) known as food gum is a woody climber found abundantly in forests of western Nigeria. There are wide ranges of possible application of C. populnea. The gum is used for soup thickener, used as medicine for the treatment of venereal diseases, indigestion, as drug binder and treatment of male infertility (Alakali *et al.*, 2009). Lignocellulosic fibers are natural polymer composed of crystalline cellulose microfibril-reinforced aromatic lignin and hemicelluloses matrix, as well as non - structural phytochemicals or extractives which influences their utilization (Agu *et al.*, 2012). Azeez and Onukwuli reported that C. populnea fibers contains moisture content, water soluble, ash, wax, pectin, lignin, hemicelluloses and cellulose with composition of 3.94, 2.33, 1.59, 2.94, 1.14, 11.52, 14.74 and 61.8 %, respectively. The physical, mechanical and microstructural properties of unmodified and modified C. populnea fibers have been studied but its applications in composites are limited. The various applications of lignocellulosic materials depend on their chemical composition and physical properties (Agu *et al.*, 2012). One of the major concerns that has prevented the application of the natural fibers in making composites is poor adhesion to most polymeric matrices. The natural fibers (hydrophilic materials) adversely affects interfacial adhesion to a hydrophobic matrix which may cause a loss of tensile properties, flexural properties, hardness, impact strength and durability through water absorption. The use of fiber surface modifications has been employed to promote adhesion (Herrera-Franco & Valadez-Gonza ´lez, 2005) but differed in fiber – to – fiber due to their source, composition, types and processing techniques. Researchers have reported several methods to modify the natural fiber surface such as: improvement in mechanical properties of treated banana, coconut and dolichopetalum fibers with NaOH (Azeez *et al.*, 2016, Azwin *et al.*, 2009, Walter *et al.*, 2016, Adekunle, 2015), H_2O_2, NaOCl, and NaOCl/NaOH, respectively, improved the coconut fiber surface and morphology (Brígida *et al.*, 2010) and sodium lauryl sulphate (Thiruchitrambalam *et al.*, 2012). Researchers have reported the improvement in mechanical properties of unsaturated polyester composites when raffia palm fiber (Anike *et al.*, 2014), cotton fabric (Achukwu *et al.*, 2015), hybrid of bamboo/glass fibers (Bai & Rao, 2014) and hybrid of banana/kenaf fiber (Thiruchitrambalam *et al.*, 2009) treated with 10% NaOH, and alfa fiber treated with 7% NaOH (Benyahia *et al.*, 2013). It has also been reported that 10% sodium lauryl sulphate (SLS) treatment of hybrid banana/kenaf fiber improved the unsaturated polyester composites (Thiruchitrambalam *et al.*, 2009). More so, NaOH treatment of the fiber improved the mechanical properties of flax fiber – polylactic acid bio - composites due to increased fiber–matrix adhesion (Raj *et al.*, 2011). The implication is that, mechanical properties of a fiber-reinforced polymer composite did not only on the properties of the constituents, but also on the interfacial properties since stress transfer from the matrix to the fiber takes place at such interphase. Therefore, it is important to characterize its properties to better understand the performance of the composite. In this paper, the characterization of improvement in mechanical properties of unsaturated polyester (UPE) matrix reinforced C. populnea fibers treated by NaOH and SLS treatments at optimal production of composites with physical properties (density and water absorption behavior) was aimed to be investigated.

Materials and Methods

White C. populnea fibers obtained from Gbana village, Ogbomoso, Oyo state, Nigeria was used and modified using analytical grade chemicals of sodium hydroxide and sodium lauryl sulphate obtained from Rovert scientific limited, Benin city in Edo state, Nigeria. Unsaturated polyester resin (thermoset), cobalt octnoate and the catalyst methyl ethyl ketone peroxide (MEKP) were obtained from polychem resin International Ind, LLC, Dubai, United Arab Emirates. The chosen chemicals.

Modifications of Cissus Populnea Fiber

The procedure described by Thiruchitrambalam *et al.* (2009) was employed. C. populnea fibers were cut into 120 mm length, modified using NaOH and SLS, respectively, at optimal level of 15 % for 49.68 mins and 4.45 % for 20.09 mins at room temperature. The unmodified and modified C. populnea fibers were washed severally with deionized water until neutral pH of 7 was obtained. The fibers was finally dried in an air oven at 60^0C for 2 hours.

Composite Preparation

The composites were prepared using hand laying technique with composition of 1% cobalt octnoate (accelerator), 1% methyl ethyl ketone peroxide (MEKP) called butanox HBO - 50 (Catalyst), C. populnea fiber range of 1.7574 – 10.2526% and UPE range of 89.7476 – 98.2426% using Design of Experiment (DoE) software version 6.0.8 (2002 East Hennepin ave., Suite 480 Minneapolis, MN 55413, stat Ease, Inc.) for two factors (weight fraction of fiber and matrix) with six responses (tensile strength and modulus, flexural strength and modulus, hardness and impact strength) as presented in Table 1-3. The second order polynomial model of the form equation (1) was used to model central composites design (CCD) model of response surface methodology (RSM).

$$Y_i = \beta_0 + \beta_1 W_f + \beta_2 W_m + \beta_3 W_f^2 + \beta_4 W_m^2 + \beta_5 W_f W_m \quad (1)$$

Mechanical Properties

Tensile test on a 100mm (span) x 25mm (width) x 3mm (thickness), 3 - point flexural test on a 80mm (span) x 25mm (width) x 3mm (thickness) and impact strength by using equation (2) were determined on a dumb bell shape of C. populnea fiber/UPE composites using tenstometer machine Model: M500-25KN, OL11 1NR with a constant rate of transverse of the moving grip of 40 mm /min. A standard Rockwell tester (model Testor HT 1a, Otto Wolpert-Werke) was used with steel indenter to measure the hardness property of the test specimen according to ASTM E – 18. Load of 150kgf was applied for each measurement on the specimen with parallel flat surfaces of the avail of the apparatus and minor load (15kgf) was applied by lowering the steel ball onto the surface of the specimen. The dial was adjusted to zero on the scale under minor load and the major load (150kgf) was immediately applied by releasing the trip lever. After 15 second the major load was removed and Rockwell hardness was recorded.

$$I_s = \frac{E}{A} \quad (2)$$

Where E is the energy absorbed (J) which is equivalent to energy to break and A is the area of cross section of the specimen below the notch (mm^2). Impact strength I is measured in J/mm^2.

Interfacial Shear Strength

The interfacial behavior of fiber and unsaturated polyester matrix was examined using pull-out test performed under 40mm/min of cross-head speed. Interfacial shear strength was evaluated by the equation (3) as given by Raj *et al.* (2011),

$$\tau = \frac{P}{\pi dl} \quad (3)$$

Where τ is the interfacial shear strength between the fiber and matrix, P is the maximum pull-out load at debonding measured in Newton, d is the diameter of fiber measured in mm and l is the length of the fiber embedded in the matrix.

Scanning Electron Microscope Analysis

High resolution scanning electron microscope (SEM) of ASPEX 3020 model was used to study the morphology of surfaces of the C. populnea fiber/UPE at optimal conditions. The surfaces of the fiber was examined directly by scanning electron microscope (SEM) ASPEX 3020 model at 20 KeV and 5.0 $x10^{-5}$ torr. C. populnea fiber/UPE composites sample was mounted on stubs with silver paste. To enhance the conductivity of the C. populnea fiber/UPE composites, a thin film of platinum is vacuum-evaporated before the photomicrographs or spectrum were taken.

Physical Properties

Density of C. Populnea Fiber/UPE Composites

C. populnea fiber/UPE samples were selected and bound into a bundle and its mass measured on a digital weighing balance with resolution 0.001 g. The volume of this fixed mass of C. populnea fiber/UPE composites. The density was calculated using equation (4),

$$\rho_f = \frac{M}{V} \quad (4)$$

Where ρ_f is density of C. populnea fiber/UPE composites measured in grams per cubic centimeters, M is the C. populnea fiber/UPE composites quantity immersed in deionized water in grams and V is the volume water displaced by the composites.

Water Absorption of C. Populnea Fiber/UPE Composites

The test was carried out in accordance with ASTM D – 570. Prior to testing, the C. populnea fiber/UPE composites were dried in an oven at 60^0C for 24 hours. The fibers were then soaked in deionized water for 24 hours at room temperature. The fibers were removed, rid of surface water and immediately weighed. The process was continued until equilibrium was attained. The water absorption was determined by percentage mass gain using equation (5) as given by Isa *et al.* (2014) and Singha & Rana (2012),

$$\text{Water absorption } (\%) = \frac{M_t - M_0}{M_0} x100\% \quad (5)$$

Where M_t is the mass of the sample after conditioning in grams (wet weight), M_0 is the mass of the sample before conditioning in grams (dry weight).

Kinetics of Water Absorption and Diffusion Behaviors of Composites

The water diffusion phenomenon was studied through water absorption method. The kinetics of water absorption and water diffusion coefficient D_{WC}, respectively, using power law expression of equation (6) and Fickian diffusion model of equation (7) were evaluated as reported by Gierszewska-Drużyńska & Ostrowska-Czubenko (2012),

$$\frac{M_t}{M_m} = kt^n \quad (6)$$

$$D_{WC} = \pi \left[\frac{h}{4M_m}\right]^2 [S]^2 \quad (7)$$

Where M_t, and M_m are the water content at specific time t and the maximum or equilibrium water content (EMC), k and n, respectively, are intercept and slope of Ln (M_t/M_m) versus Ln (t) plot. Where$S = \frac{M_2 - M_1}{\sqrt{t_2} - \sqrt{t_1}}$, h is the fiber thickness, $M_1$and M_2 are percentage of water content at respective time t_1 and t_2 selected in the linear portion of the plot of water sorption (M_t) versus$\sqrt{t}$. S was evaluated as gradient plot of M_t against$\sqrt{t}$.

Results and Discussion

Result

The mechanical properties as responses (tensile strength, tensile modulus, flexural strength, flexural modulus, hardness and impact strength) based on weight fraction of fibers and matrix for untreated, NaOH and SLS treated C. populnea fiber/UPE composites were obtained as presented in Table 1 – 3, respectively.

Table 1: Experiment CCD matrix of untreated C. populnea fiber/UPE composites

W_f (%)	W_p (%)	T_s (MPa)	T_m (MPa)	F_s (MPa)	F_m (MPa)	H (HR)	I_s (J/mm^2)
3	91	16.309	434.13	24.815	813.57	27	0.006371594
3	97	12.266	587.25	23.804	846.66	26	0.008621652
6	89.7574	20.134	653.73	38.113	1371.62	29	0.043217544
1.7574	94	8.74569	613.73	16.417	700.53	27	0.004937237
10.2426	94	6.4736	314.72	28.12	1172.4	33	0.001109028
9	97	11.003	201.63	28.137	983.74	30	0.004256738
6	98.2426	17.946	524.16	36.012	1185.42	28	0.054567384
6	94	18.354	590.43	37.929	1223.5	28	0.050824777
9	91	2.9096	221.55	27.754	1103	31	0.001020089
6	94	18.354	590.43	37.929	1223.5	28	0.0508248
6	94	18.354	590.43	37.929	1223.5	28	0.0508248
6	94	18.354	590.43	37.929	1223.5	28	0.0508248
6	94	18.354	590.43	37.929	1223.5	28	0.0508248

W_f, W_p, T_s, T_m, F_s, F_m, H and I_s represent fiber weight fraction, polymer weight fraction, tensile strength, tensile modulus, flexural strength, flexural modulus, hardness and impact strength, respectively.

Table 2: Experiment CCD matrix of NaOH treated C. populnea fiber/UPE composites

W_f (%)	W_p (%)	T_s (MPa)	T_m (MPa)	F_s (MPa)	F_m (MPa)	H (HR)	I_s (J/mm^2)
9	91	20.067	724.3	50.746	2210.7	32	0.031896205
6	94	20.885	630.43	6.92	1586.5	30	0.042670759
6	94	20.885	630.43	6.92	1586.5	30	0.0426708
6	94	20.885	630.43	6.92	1586.5	30	0.0426708
6	98.2426	20.035	601.25	40.173	1682.1	30	0.03815923
6	94	20.885	630.43	6.92	1586.5	30	0.0426708
6	94	20.885	630.43	6.92	1586.5	30	0.0426708
10.2426	94	20.136	731.61	51.143	2247.6	35	0.033098342
6	89.7574	21.934	513.43	15.092	1601.7	31	0.07745678
1.7574	94	13.021	610.27	29.384	1125.8	29	0.07856734
9	97	19.239	641.03	47.286	2163.7	31	0.05327843
3	91	18.062	522.18	44.07	1600.8	33	0.083420096
3	97	16.873	598.13	48.68	1724	33	0.120390625

W_f, W_p, T_s, T_m, F_s, F_m, H and I_s represent fiber weight fraction, polymer weight fraction, tensile strength, tensile modulus, flexural strength, flexural modulus, hardness and impact strength, respectively.

Table 3: Experiment CCD matrix of SLS treated C. populnea fiber/UPE composites

W_f (%)	W_p (%)	T_s (MPa)	T_m (MPa)	F_s (MPa)	F_m (MPa)	H(HR)	I_s (J/mm^2)
1.7574	94	17.2615	817.23	29.785	1045.3	31	0.009731427
9	97	9.6375	825.34	40.136	1913.4	33	0.031005672
6	94	19.911	380.84	45.436	1652.6	33	0.040205357
6	94	19.911	380.84	45.436	1652.6	33	0.0402054
3	97	19.104	550.61	38.661	1355.2	34	0.026987723
3	91	18.724	561.97	37.624	1411.7	34	0.01345926
9	91	10.186	672.96	32.174	1869.5	32	0.001939616
10.2426	94	6.1245	1021.7	38.729	1934.1	36	0.002178691
6	94	19.911	380.84	45.436	1652.6	33	0.0402054
6	94	19.911	380.84	45.436	1652.6	33	0.0402054
6	94	19.911	380.84	45.436	1652.6	33	0.0402054
6	89.7574	20.974	796.18	45.967	2143.7	34	0.04756932
6	98.2426	17.2615	363.91	43.15	1539.1	32	0.03017865

W_f, W_p, T_s, T_m, F_s, F_m, H and I_s represent fiber weight fraction, polymer weight fraction, tensile strength, tensile modulus, flexural strength, flexural modulus, hardness and impact strength, respectively.

The ANOVA for response surface quadratic models for tensile strength, tensile modulus, flexural strength, flexural modulus, hardness and impact strength are presented in Table 4 – 9, respectively.

Table 4: ANOVA for response surface quadratic model of tensile strength of C. populnea fiber/UPE composites

Source	Model Coefficient	Sum of Squares	DF	Mean Square	F Value	Prob > F	R^2	Adj R^2	Adeq Precision
UPE+D									
Model	407.1044768	294.65	5.00	58.9297	50.5436	< 0.0001	0.9768	0.9575	19.7948
W_f	-22.6505504	5.55	1.00	5.5498	4.7600	0.0719			
W_m	-6.78394795	0.11	1.00	0.1143	0.0980	0.7648			
W_f^2	-0.85951253	251.82	1.00	251.8188	215.9830	< 0.0001			
W_m^2	0.025537511	0.34	1.00	0.3427	0.2939	0.6073			
W_fW_m	0.337122222	36.82	1.00	36.8231	31.5828	0.0014			
$UPE+D_{NaOH}$									
Model	27.05547899	63.33	5.00	12.6667	21.0990	0.0004	0.9378	0.8933	14.7967
W_f	2.603519285	26.04	1.00	26.0394	43.3742	0.0003			
W_m	-0.13991354	2.76	1.00	2.7643	4.6045	0.0690			
W_f^2	-0.24539583	34.50	1.00	34.4968	57.4618	0.0001			
W_m^2	-0.00061806	0.00	1.00	0.0002	0.0004	0.9854			
W_fW_m	0.010027778	0.03	1.00	0.0326	0.0543	0.8225			
$UPE+D_{SLS}$									
Model	-615.403066	278.42	5.00	55.6830	66.8183	< 0.0001	0.9795	0.9648	23.6726
W_f	6.827475148	142.42	1.00	142.4216	170.9025	< 0.0001			
W_m	13.39707912	3.67	1.00	3.6704	4.4044	0.0740			
W_f^2	-0.484125	129.22	1.00	129.2158	155.0559	< 0.0001			
W_m^2	-0.07163889	2.89	1.00	2.8918	3.4701	0.1048			
W_fW_m	-0.02579167	0.22	1.00	0.2155	0.2586	0.6267			

D is the food gum fiber

Table 5: ANOVA for response surface quadratic model of tensile modulus of food gum fiber - UPR composites

Source	Model Coefficient	Sum of Squares	DF	Mean Square	F Value	Prob > F	R^2	Adj R^2	Adeq Precision
UPR+D									
Model	-3268.60137	230592.34	5.00	46118.47	18.4227	0.0031	0.9485	0.8970	11.7913
W_f	706.7066667	89460.81	1.00	89460.81	35.7364	0.0019			
W_m	42.26501453	313.00	1.00	313.00	0.1250	0.7381			
W_f^2	-25.3941667	133329.67	1.00	133329.67	53.2605	0.0008			
W_m^2	-0.0825	3.15	1.00	3.15	0.0013	0.9731			
W_fW_m	-4.80666667	7485.71	1.00	7485.71	2.9903	0.1443			
UPR+D with NaOH									
Model	-36432.3349	43139.58	5.00	8627.92	20.5317	0.0005	0.9362	0.8906	17.0136
W_f	403.6703058	21696.60	1.00	21696.60	51.6310	0.0002			
W_m	756.8253987	1707.51	1.00	1707.51	4.0633	0.0837			
W_f^2	2.4525	5008.17	1.00	5008.17	11.9178	0.0107			
W_m^2	-3.85861111	8389.56	1.00	8389.56	19.9645	0.0029			
W_fW_m	-4.42277778	6337.75	1.00	6337.75	15.0818	0.0060			
UPR+D with SLS									
Model	113153.7167	585832.71	5.00	117166.54	26.0483	0.0005	0.9560	0.9193	12.4001
W_f	-1854.38582	62504.02	1.00	62504.02	13.8958	0.0098			
W_m	-2244.97909	21934.01	1.00	21934.01	4.8763	0.0693			
W_f^2	30.09170798	401485.54	1.00	401485.54	89.2575	< 0.0001			
W_m^2	11.23504132	50127.89	1.00	50127.89	11.1443	0.0156			
W_fW_m	16.0023875	49781.25	1.00	49781.25	11.0673	0.0159			

D is the food gum fiber

Table 6: ANOVA for response surface quadratic model of flexural strength of W_m, composites

Source	Model Coefficient	Sum of Squares	DF	Mean Square	F Value	Prob > F	R^2	Adj R^2	Adeq Precision
UPR+D									
Model	-704.447886	599.80	5.00	119.9604	159.6049	< 0.0001	0.9938	0.9875	35.2975
W_f	19.45078658	268.44	1.00	268.4406	357.1547	< 0.0001			
W_m	14.804716	47.88	1.00	47.8794	63.7026	0.0005			
W_f^2	-1.07191172	279.67	1.00	279.6709	372.0964	< 0.0001			
W_m^2	-0.07837605	3.38	1.00	3.3835	4.5016	0.0873			
W_fW_m	-0.06179345	0.43	1.00	0.4278	0.5692	0.4846			
UPR+D with NaOH									
Model	13350.26674	4042.33	5.00	808.4663	9.3320	0.0053	0.8695	0.7764	7.3680
W_f	-4.23758863	162.49	1.00	162.4852	1.8755	0.2132			
W_m	-285.252227	167.63	1.00	167.6270	1.9349	0.2068			
W_f^2	2.234291667	2372.46	1.00	2372.4577	27.3849	0.0012			
W_m^2	1.532569444	1323.48	1.00	1323.4803	15.2767	0.0058			
W_fW_m	-0.22416667	16.28	1.00	16.2812	0.1879	0.6777			
UPR+D with SLS									
Model	-238.680936	265.53	5.00	53.1059	88.5026	< 0.0001	0.9866	0.9755	28.3021
W_f	23.5817694	48.25	1.00	48.2542	80.4171	0.0001			
W_m	4.810233141	8.21	1.00	8.2077	13.6784	0.0101			
W_f^2	-0.59435517	202.94	1.00	202.9426	338.2096	< 0.0001			
W_m^2	-0.02204962	0.80	1.00	0.8043	1.3404	0.2910			
W_fW_m	-0.16544042	5.32	1.00	5.3208	8.8673	0.0247			

D is the food gum fiber

Table 7: ANOVA for response surface quadratic model of flexural modulus of C. populnea fiber/UPE composites

Source	Model Coefficient	Sum of Squares	DF	Mean Square	F Value	Prob > F	R^2	Pred R^2	Adeq Precision
UPR+D									
Model	2493.140706	462909.47	5.00	92581.89	29.2712	0.0004	0.9606	0.9278	18.2801
W_f	1634.614285	171811.83	1.00	171811.83	54.3210	0.0003			
W_m	-105.38226	39543.31	1.00	39543.31	12.5022	0.0123			
W_f^2	-18.1408993	210915.21	1.00	210915.21	66.6841	0.0002			
W_m^2	0.862156294	181.94	1.00	181.94	0.0575	0.8184			
W_fW_m	-14.4261252	40457.18	1.00	40457.18	12.7912	0.0117			
UPR+D with NaOH									
Model	52932.1834	775244.33	5.00	155048.87	25.3224	0.0006	0.9548	0.9171	14.0618
W_f	215.130633	515498.08	1.00	515498.08	84.1904	< 0.0001			
W_m	-1118.85824	4507.88	1.00	4507.88	0.7362	0.4238			
W_f^2	25.31139892	228160.72	1.00	228160.72	37.2629	0.0009			
W_m^2	6.144348507	19835.64	1.00	19835.64	3.2395	0.1220			
W_fW_m	-4.72777778	7242.01	1.00	7242.01	1.1828	0.3185			
UPR+D with SLS									
Model	101126.1618	806665.04	5.00	161333.01	110.2094	< 0.0001	0.9910	0.9820	37.6692
W_f	1878.47014	535123.58	1.00	535123.58	365.5523	< 0.0001			
W_m	-2177.40069	160240.98	1.00	160240.98	109.4634	0.0001			
W_f^2	5.662015844	4729.41	1.00	4729.41	3.2307	0.1322			
W_m^2	11.82332393	65916.96	1.00	65916.96	45.0290	0.0011			
W_fW_m	-19.0486543	40654.11	1.00	40654.11	27.7715	0.0033			

D is the food gum fiber

Table 8: ANOVA for response surface quadratic model of hardness of C. populnea fiber/UPE composites

Source	Model Coefficient	Sum of Squares	DF	Mean Square	F Value	Prob > F	R^2	Adj R^2	Adeq Precision
UPR+D									
Model	101.8621272	40.0334	5.00	8.0067	46.8098	< 0.0001	0.9710	0.9502	21.8942
W_f	-0.396446609	33.9706	1.00	33.9706	198.6034	< 0.0001			
W_m	-1.447814454	1.4571	1.00	1.4571	8.5187	0.0224			
W_f^2	0.090277778	4.5786	1.00	4.5786	26.7680	0.0013			
W_m^2	0.006944444	0.0272	1.00	0.0272	0.1589	0.7021			
W_fW_m	4.34221E-15	0.0000	1.00	0.0000	0.0000	1.0000			
UPR+D with NaOH									
Model	111.7158751	28.8131	5.00	5.7626	24.0630	0.0007	0.9525	0.9129	13.2453
W_f	-0.911491903	0.9095	1.00	0.9095	3.7976	0.0992			
W_m	-1.569072673	0.7286	1.00	0.7286	3.0422	0.1317			
W_f^2	0.279462783	26.8854	1.00	26.8854	112.2650	< 0.0001			
W_m^2	0.008697591	0.0397	1.00	0.0397	0.1660	0.6979			
W_fW_m	-0.027777778	0.2500	1.00	0.2500	1.0439	0.3463			
UPR+D with SLS									
Model	177.9617905	22.2227	5.00	4.4445	12.2171	0.0024	0.8972	0.8238	11.8141
W_f	-8.684334416	2.2500	1.00	2.2500	6.1848	0.0418			
W_m	-2.256740019	5.8284	1.00	5.8284	16.0211	0.0052			
W_f^2	-0.131944444	10.1171	1.00	10.1171	27.8097	0.0012			
W_m^2	0.006944444	0.0272	1.00	0.0272	0.0747	0.7925			
W_fW_m	0.111111111	4.0000	1.00	4.0000	10.9952	0.0128			

D is the food gum fiber

Table 9: ANOVA for response surface quadratic model of impact strength of food gum - UPR composites

Source	Mode Coefficient	Sum of Squares	DF	Mean Square	F Value	Prob > F	R^2	Adj R^2	Adeq Precision
UPR+D									
Model	-1.14094137	0.00529	5.00	0.001057764	379.1055	< 0.0001	0.9974	0.9947	42.9620
W_f	0.056335683	0.00002	1.00	2.36022E-05	8.4591	0.0335			
W_m	0.020915107	0.00006	1.00	5.79846E-05	20.7818	0.0061			
W_f^2	-0.00497679	0.00520	1.00	0.005201658	1864.2876	< 0.0001			
W_m^2	-0.000107352	0.00001	1.00	5.33415E-06	1.9118	0.2253			
W_fW_m	2.74053E-05	0.00000	1.00	2.4334E-07	0.0872	0.7796			
$UPR+D_{NaOH}$									
Model	24.33458919	0.00744	5.00	0.001487743	22.3923	0.0008	0.9491	0.9067	15.9858
W_f	0.025353166	0.00418	1.00	0.004183333	62.9641	0.0002			
W_m	-0.522473447	0.00016	1.00	0.000157406	2.3692	0.1747			
W_f^2	0.000643931	0.00033	1.00	0.000331135	4.9840	0.0670			
W_m^2	0.002816829	0.00271	1.00	0.002706091	40.7299	0.0007			
W_fW_m	-0.000433008	0.00006	1.00	6.07488E-05	0.9143	0.3759			
$UPR+D_{SLS}$									
Model	-8.531317214	0.00254	5.00	0.00050729	36.8441	0.0002	0.9685	0.9422	15.0263
W_f	-0.020230209	0.00004	1.00	4.13271E-05	3.0016	0.1339			
W_m	0.180776612	0.00039	1.00	0.000394523	28.6540	0.0017			
W_f^2	-0.001758149	0.00173	1.00	0.001726102	125.3658	< 0.0001			
W_m^2	-0.000959736	0.00031	1.00	0.000314141	22.8159	0.0031			
W_fW_m	0.0004316	0.00006	1.00	6.03542E-05	4.3835	0.0812			

D is the food gum fiber

Discussion

The tensile strength models for untreated, NaOH and SLS treated C. populnea fiber/UPE composites are represented by equations (8) – (10), respectively. The ANOVA results are presented in Table 4. It can be observed that models were significant for design applications since $p < 0.05$. The results for untreated, NaOH and SLS C. populnea fiber/UPE composites, respectively, with coefficient of determination (R^2) of 0.9768, 0.9378 and 0.9795 explain 97.68, 93.78 and 97.95% of the observed variability in tensile strength as a result of

weight fraction of food gum fiber and matrix. This shows that 2.32, 6.22 and 2.05%, respectively, represent residue of untreated, NaOH and SLS C. populnea fiber/UPE composites which cannot be explain but may be due to uncontrollable factors that did put into consideration for composites production. Moreover, the closeness of R^2 and Adj R^2 shows the fitness of variables with tensile strength. Notwithstanding, adequacy precision > 4 judged the fitness of the model and indicated that the model can be used for design applications. The tensile strength of UPE composites with C. populnea fiber: untreated (W_f, W_f^2 and W_fW_f), treated with NaOH (W_f and W_f^2) and treated with SLS (W_f and W_f^2) were significant since $p < 0.05$.

$$T_s = 407.1045 - 22.651W_f + 6.7839W_m - 0.8595W_f^2 - 0.0255W_m^2 + 0.33712W_fW_m \quad (8)$$

$$T_s = 27.055 + 2.6035W_f - 0.13991W_m - 0.2454W_f^2 - 0.0006181W_m^2 - 0.010028W_fW_m \quad (9)$$

$$T_s = -615.4 + 6.8275W_f + 13.397W_m - 0.48413W_f^2 - 0.071639W_m^2 - 0.025972W_fW_m \quad (10)$$

The quadratic models obtained for tensile modulus of untreated, NaOH and SLS C. populnea fiber/UPE composites are represented by equations (11) – (13), respectively. The statistical analysis using ANOVA for response models of tensile modulus of untreated, NaOH and SLS treated C. populnea fiber/UPE composites are presented in Table 5. It revealed that the tensile modulus for both untreated and treated C. populnea fiber/UPE composites were significant and adequate for design applications since $p < 0.05$ and adequate precision > 4.

The result of the experimental data for untreated, NaOH and SLS C. populnea fiber/UPE composites, respectively, with R^2 of 0.9485, 0.9362 and 0.9560 explain 94.85, 93.62 and 95.60% of the observed variability in tensile modulus as an effect of weight fraction of C. populnea fiber in UPE matrix. This indicated that 5.15, 6.38 and 4.40 % represent the residue of untreated, NaOH and SLS C. populnea fiber/UPE composites, respectively, which cannot be explained. The tensile modulus variables of UPE composites with C. populnea fiber: untreated (W_f and W_f^2), treated with NaOH (W_f, W_f^2, W_m^2 and W_fW_m) and treated with SLS (W_f, W_f^2, W_m^2 and W_fW_m) were significant since $p < 0.05$.

$$T_m = -3268.601 + 706.707W_f + 42.265W_m - 25.394W_f^2 - 0.0825W_m^2 - 4.8067W_fW_m \quad (11)$$

$$T_m = -36432 + 403.67W_f + 756.83W_m + 2.4525W_f^2 - 3.8586W_m^2 - 4.4228W_fW_m \quad (12)$$

$$T_m = 113153.72 - 1854.39W_f - 2244.98W_m + 30.0917W_f^2 + 11.24W_m^2 + 416.002W_fW_m \quad (13)$$

The flexural strength models for untreated, NaOH and SLS treated C. populnea fiber/UPE composites are represented by equations (14) - (15), respectively. The statistical analysis using ANOVA for flexural strength response models of untreated and treated C. populnea fiber/UPE composites are presented in Table 6. It can be deduced that the flexural strength of untreated, NaOH and SLS C. populnea fiber/UPE composites, respectively, were significant and adequate for design applications since $p < 0.05$ and adequate precision > 4.

$$F_s = -704.447 + 19.4508W_f + 14.805W_m - 1.0719W_f^2 - 0.0784W_m^2 + 0.0618W_fW_m \quad (14)$$

$$F_s = 13350 - 4.2376W_f - 285.25W_m + 2.2343W_f^2 + 1.5326W_m^2 - 0.22417W_fW_m \quad (15)$$

$$F_s = -238.681 - 23.582W_f + 4.8102W_m - 0.5944W_f^2 - 0.022W_m^2 + 0.1654W_fW_m \quad (16)$$

The results of the experimental data for flexural strength of untreated, NaOH and SLS C. populnea fiber/UPE composites, respectively, with R^2 of 0.9938, 0.8695 and 0.9866 explain 99.38, 86.95 and 98.66% of the observed variability in flexural strength as an effect of weight fraction of C. populnea fiber in UPE matrix. This might be due to good intermolecular structure and interfacial adhesion bond between food gum fiber and UPE matrix in the composites. This is in agreement with the report of Herrera-Franco & Valadez-Gonza ´lez (2005).

The flexural strength of UPE composites with C. populnea fiber: untreated (W_f, W_m and W_f^2), treated with NaOH (W_f^2 and W_m^2) and treated with SLS (W_f, W_m, W_f^2 and W_fW_m) were significant since $p < 0.05$.

$$F_m = 2493.14 + 1634.61W_f - 105.38226W_m - 18.1409W_f^2 - 0.862W_m^2 - 14.426W_fW_m \quad (17)$$

$$F_m = 52932 + 215.1306W_f - 1118.858W_m + 25.3114W_f^2 + 106.1443W_m^2 - 4.7278W_fW_m \quad (18)$$

$$F_m = 101126.16 + 1878.47W_f - 2177.4W_m + 5.662W_f^2 + 11.8233W_m^2 - 19.0489W_fW_m \quad (19)$$

The ANOVA results of experimental data for flexural modulus of C. populnea fiber/UPE composites are presented in Table 7. The flexural modulus models for untreated, NaOH and SLS C. populnea fiber/UPE composites are represented by equations (17) - (19), respectively, were significant and adequate for design applications since $p < 0.05$ and adequate precision > 4. The results of the experimental data for untreated, NaOH and SLS C. populnea fiber/UPE composites, respectively, were significant and adequate for composites production. The flexural modulus of UPE composites with C. populnea fiber: untreated (W_f, W_m, W_f^2 and W_fW_m), treated with NaOH (W_f and W_f^2) and treated with SLS (W_f, W_m, W_m^2 and W_fW_m) were significant since $p < 0.05$.

Moreover, the ANOVA results of experimental data for hardness response models are presented in Table 8. The hardness models for untreated, NaOH and SLS treated C. populnea fiber/UPE composites are represented by

equations (20) - (22), respectively. The hardness models for untreated, NaOH and SLS treated C. populnea fiber/UPE composites were significant and adequate for design applications since $p < 0.05$ and adequacy precision > 4. The high value of coefficient of determination (R^2) for hardness of untreated, NaOH and SLS treated C. populnea fiber/UPE composites, respectively, shows that the models are fit and justified with magnitude of adequacy precision > 4 which indicated that the models can be used for design applications.

$$H = 101.86 - 0.39645W_f - 1.4478W_m + 0.090278W_f^2 + 0.00694 + 4.322x10^{-15}W_fW_m \quad (20)$$

$$H = 111.716 - 0.9115W_f - 1.569W_m + 0..279W_f^2 + 0.0087W_m^2 - 0.027778W_fW_m \quad (21)$$

$$H = 177.962 - 8.6843W_f - 2.2567W_m + 0.1319W_f^2 + 0.0069W_m^2 + 0.1111W_fW_m \quad (22)$$

The hardness variables of UPE composites with C. populnea fiber: untreated (W_f, W_m and W_f^2), treated with NaOH (W_f and W_m^2) and treated with SLS (W_f, W_m, W_f^2 and W_m^2) and treated with EDTA (W_f^2) were significant since $p < 0.05$. The ANOVA results for impact strength of UPE composites are presented in Table 9. The impact strength models for untreated, NaOH and SLS treated C. populnea fiber/UPE composites are represented by equations (23) - (25), respectively, were significant and adequate for design applications since $p < 0.05$ and adequate precision > 4.

$$I_s = -1.1409 + 0.0563W_f + 0.0209W_m - 0.00497W_f^2 - 0.0001W_m^2 + 2.74x10^{-5}W_fW_m \quad (23)$$

$$I_s = 24.3346 - 0.0254W_f + 0.5225W_f^2 + 0.0064W_m^2 + 0.0028W_m^2 - 0.000433W_fW_m \quad (24)$$

$$I_s = -8.531 - 0.0202W_f + 0.1808W_m - 0.0018W_f^2 - 0.00096W_m^2 - 0.000432W_fW_m \quad (25)$$

The ANOVA results for impact strength of untreated, NaOH and SLS treated C. populnea fiber/UPE composites, respectively, with R^2 of 0.9974, 0.9491 and 0.9685 explain 99.74, 94.91 and 96.85 % of the observed variability in impact strength as an effect of weight fraction of food gum fiber in matrix. The impact strength model terms of UPE composites with C. populnea fiber: untreated (W_f, W_m and W_f^2), treated with NaOH (W_f and W_m^2) and treated with SLS (W_m, W_f^2 and W_m^2) were significant since $p < 0.05$. The choice of optimal values of mechanical properties for models with factors (weight fraction of fiber and matrix) were based on high desirability. The optimal values for weight fraction of C. populnea fiber and UPE matrix with the mechanical properties of predicted and experimental values are presented in Table 10. It can be observed that the model predicted values for most mechanical properties are close to the experimental values at optimal production. It can also be observed that untreated C. populnea fiber increased the tensile strength, flexural strength, flexural modulus and impact strength of UPE matrix, respectively, by 244.42, 45.38, 112.99 and 1639.56% but reduced the tensile modulus and hardness of UPE matrix by 5.27 and 13.64%, respectively. The increase in tensile strength indicated that C. populnea fiber reinforced UPE matrix and it may be attributed to compatibility of the C. populnea fiber and UPE matrix as well as some mechanical properties of the composites. This is in agreement with the report of Luyt *et al.,* (2009). Moreover, the improved tensile strength of UPE matrix using C. populnea fiber is more than that of 138 % improvement of bagasse fiber as reported by Aramide *et al*. (2009) as well as that of raffia palm fiber reported by Anike *et al*. (2014). The reduction in hardness may be attributed to pores formation in the composites. NaOH and SLS treatment of C. populnea fiber, respectively, improved the tensile strength by 13.06 and 8.37% of untreated C. populnea fiber/UPE composites. The reason may be attributed to the better bonding of C. populnea fiber with UPE due to improved fiber surface (Benyahia *et al*., 2013, Dhawan *et al*, 2013). The improvement in tensile strength of C. populnea fiber/UPE composites for NaOH and SLS treatments, respectively, more than 4.48% improvement in tensile strength of 5% NaOH treated Typha angustifolia fiber/polyester composites reported by Dedeepya *et al*. (2012), although lower compared with 43.65% improvement when 10% NaOH treated Alfa fiber/polyester composites reported by Benyahia *et al* (2013). More so, NaOH and SLS treated C. populnea fiber, respectively, improved the flexural strength, flexural modulus and hardness of composites with reduced impact strength. This may be due to removal of surface impurity such as hemicellulose, lignin, wax and pectins as reported by Thiruchitrambalam *et al*. (2009). The increase in flexural strength is more than the 14.33 % improvement of polyester based composites by coconut coir filler as reported by Dhawan *et al* (2013). The SLS treatment of C. populnea fiber reinforced UPE composites improved flexural strength and hardness better when compared with NaOH treatment but vice versa in the case of flexural modulus. SLS treated C. populnea fiber improved the hardness and it is also greater than 0.91% improvement in hardness when rice husk filler was used for reinforced polyester composites by Dhawan *et al* (2013). This indicated that SLS modified C. populnea fiber may be better for improving the flexural strength of the polyester based composites. The reduction in impact strength may be due to pores formation in the composites, although, the increase in impact strength of the UPE matrix obtained when untreated C. populnea fiber was used is far greater compared with coconut coir filler reported by Benyahia *et al* (2013). It can also be observed that NaOH treatment improved the ductility of the composites due to increase in tensile modulus while SLS treatments improved the brittleness of the composites due to reduction in tensile modulus.

Table 10: Optimal data of mechanical properties of C. populnea fiber - UPE composites

Property	UPE	UPE + D	UPE + D_{NaOH}	UPE + D_{SLS}
W_f (%)	0	5.79	9	5.98
W_m (%)	100	97	91	91.61
T_{sa} (MPa)	5.3694	18.4934	20.9726*	20.0405
T_{sp} (MPa)	5.3694	18.4182	20.9628	20.0693
T_{ma} (MPa)	629.55	596.392	695.048*	532.104
T_{mp} (MPa)	629.55	595.223	695.923	533.3
F_{sa} (MPa)	26.217	38.1133	42.7685	46.0932*
F_{sp} (MPa)	26.217	38.1447	42.2711	46.0658
F_{ma} (MPa)	747.67	1319.48	2110.7*	1884.04
F_{mp} (MPa)	747.67	1322.9	2111.78	1880.39
H_a (HR)	33*	28.5	32	33*
H_p (HR)	31	28.4805	32.6381	33.7208
I_a (J/mm^2)	0.002712	0.047177*	0.0413702	0.0277682
I_p (J/mm^2)	0.002712	0.0471465	0.0405541	0.0277588

Superscript (*) indicates maximum value, subscript (a) and (p),respectively, refers to experimental data and predicted data from obtained from DoE for tensile strength, tensile modulus, flexural strength, flexural modulus, hardness and impact strength, respectively.

From Table 11, it can be observed that treatment of C. populnea fiber with NaOH and SLS, respectively, reduced the diameter of the fibers which causes an increased in interfacial adhesion between the C. populnea fiber and UPR matrix. The reduction in diameter of the fiber may be attributed to removal of hemicellulose, lignin and other impurities on fiber surfaces. This is in agreement with the report of researchers (Mohammed & Dauda, 2014, Phong *et al*, 2012, Thiruchitrambalam *et al*., 2009). The decrease in debonding force may be due to intermolecular relation, hydrophilicity of fibers and void formation in the composites.

Table 11: Evaluated interfacial shear stress of fiber -UPR composites

Composite Sample	F (N)	d_f (mm)	IFSS (N/mm^2)
UPE + D	1644.50	0.110	475.6818
UPE + D_{NaOH}	1828.50	0.088	661.1312
UPE + D_{SLS}	1784.00	0.095	597.5120

Figure 1 shows the morphology of UPE matrix and C. populnea fiber/UPE composites at fracture surface of tensile test. It can be observed that there pores formation in UPE matrix as shown in Figure 1 (a). From Figure 1 (b), fiber breakage with debonding was observed. This shows interaction between the fibers and UPE matrix, hence influenced the mechanical properties of the composites. Fiber agglomerate, tearing and breakage characterized the NaOH treated C. populnea fiber/UPE as observed in Figure 1 (c). This may be attributed to improve in mechanical properties of the composites. Fiber breakage, tearing and debonding was observed in Figure 1 (d). The fiber tearing indicated improvement in interfacial adhesion between the C. populnea fiber and UPE matrix caused by NaOH and SLS treatment. The failure of the composites by fiber tearing at the fracture surface indicated that fibers are not pulled out directly from the matrix, thereby, required more energy for composites to break. This is also indicated that there is better compatibility between the fibers with the matrix.

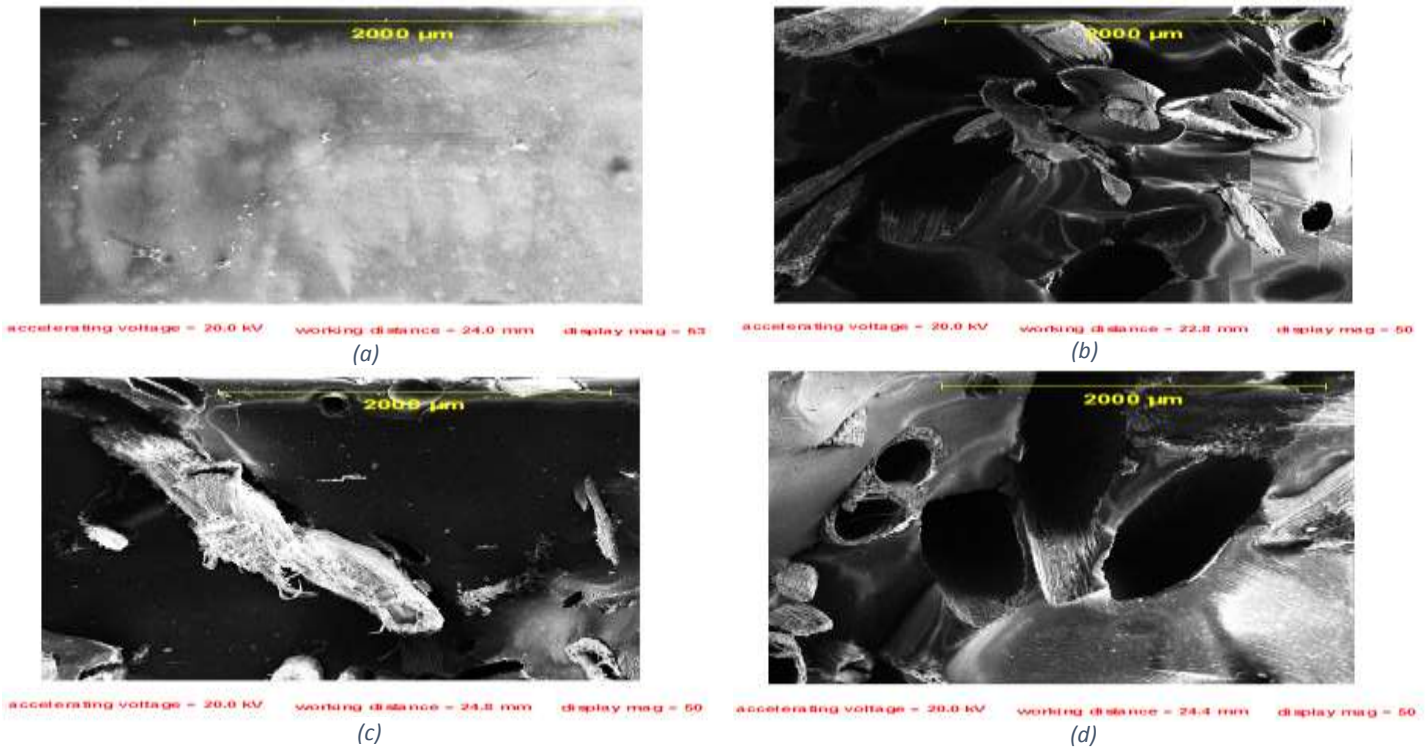

Figure 1: SEM analysis for (a) UPE matrix (b) Untreated C. populnea fiber/UPE (c) NaOH treated C. populnea fiber/UPE (d) SLS treated C. populnea fiber/UPE composite

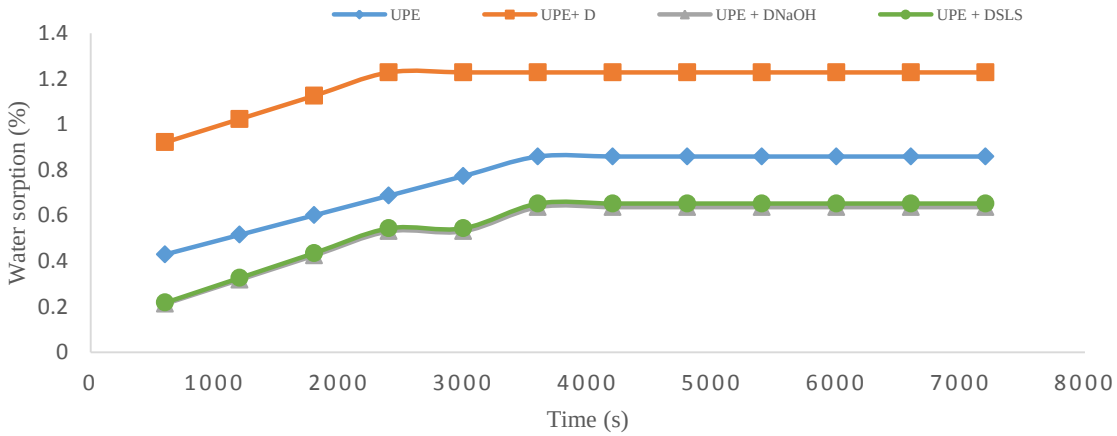

Figure 2: Water sorption of cissus populnea fiber/UPE composites

Figure 2 shows the water sorption with increased time. The rate of approach to saturation point is longer for the UPE matrix and treated C. populnea fiber/UPE composites than untreated C. populnea fiber/UPE composites. The water saturation time of UPE matrix, NaOH and SLS treated C. populnea fiber/UPE composites obtained to be 3600s while that of untreated C. populnea fiber/UPE composites is found to be 2400s. The reduction in sorption period of untreated fiber/UPE composites may be attributed to the high constituents of lignin and hemicellulose in the composites. This is supported by the report of Kalia *et al*, (2009). Treatment of C. populnea fiber with NaOH and SLS seem to decelerate the water sorption behaviour of the composites. This is due to improvement in hydrophobicity of the fiber and interfacial adhesion between the fiber and matrix.

Table 12 shows the density and water absorption parameter of UPE matrix and C. populnea fiber/UPE composites for both untreated and treated C. populnea fiber. It can be deduced that the density of untreated C. populnea fiber/UPE composites reduced by 4.94% of UPE matrix. This may be due to weight saving nature of C. populnea fiber. This makes the C. populnea fiber/UPE composites to be lighter than UPE matrix. The treatment of

C. populnea fiber with NaOH increased the density of the composites by 2.06% but less than the density of UPE matrix. This may be attributed to substitution of hydroxyl groups of fiber with sodium ions with high molecular weight treated fiber. This is similar to the report of (Salim & Sorya, 2015). It can also be observed that SLS treatment of C. populnea fiber reduced the density of composites reduced by 1.17 % of untreated C. populnea fiber/UPE composites which may be due to removal of lignin, hemicellulose and other impurities as reported by (Thiruchitrambalam *et al.*, 2009). Thus, makes the composites to be lighter.

More so, it can also be observed from Table 12 that maximum water sorption of untreated C. populnea fiber/UPE composites increased by 42.97% of UPE matrix while NaOH and SLS, respectively, treated C. populnea fiber/UPE composites reduced by 25.86 and 24.01% of UPE matrix. The lower and slower of the water sorption may reduce interfacial micro - cracks and decomposition of the composites, hence prolong the service life of the composites. Figure 3 evaluated the magnitude of water sorption parameters (n and k). It can be deduced that water sorption behavior of the UPE matrix, untreated and treated fiber/UPE composites were less Fickian since n < 0.5. This implies that water penetration rate is much less than relaxation rate of composites. This is in agreement with the report of Gierszewska-Drużyńska & Ostrowska-Czubenko (2012). It can be observed that the value of n for untreated C. populnea fiber/UPE composites is less than UPE matrix, but otherwise for the case of NaOH and SLS treated C. populnea fiber/UPE composites. The value of k for untreated C. populnea fiber/UPE composites seem to be higher than UPE matrix. This may be due to poor structural arrangement of the fiber in the matrix. In the case of NaOH and SLS treatments, respectively, C. populnea fiber/UPE composites were the same and lesser than that of UPE matrix. It is important to indicate that NaOH and SLS treatment, respectively, enhanced good cohesion and arrangement of fibers in the composites which be governed by the surface area, roughness and wettability. This is similar to the report of (Ghali, Msahli, Zidi, & Sakli, 2011). The value of S, diffusion parameter was evaluated from Figure 4 to determine the diffusion coefficient (D_{wc}). It can be observed that the diffusion coefficient for untreated C. populnea fiber/UPE composites is lesser than UPE matrix but vice versa for the case of NaOH and SLS treated C. populnea fiber/UPE composites. This may be attributed to high value of optimal weight fraction of the fiber.

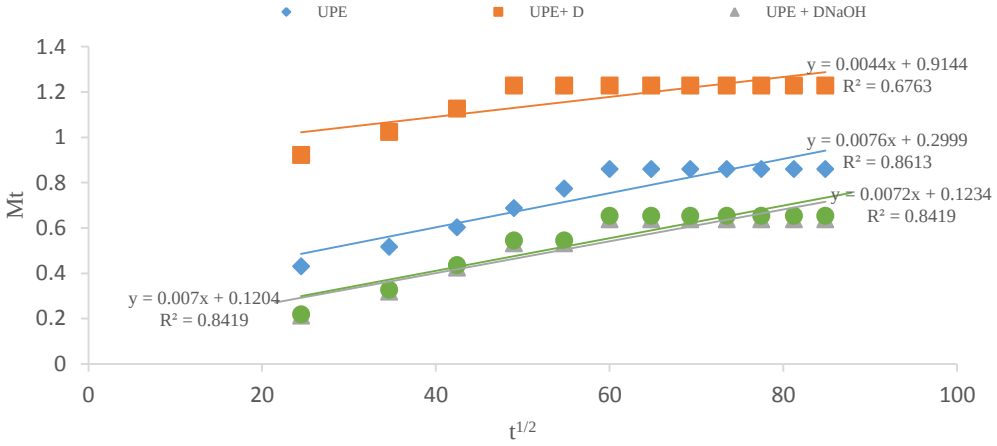

Figure 3: Estimation of S (min-1/2) for UPE matrix and Cissus populnea fiber/UPE composites

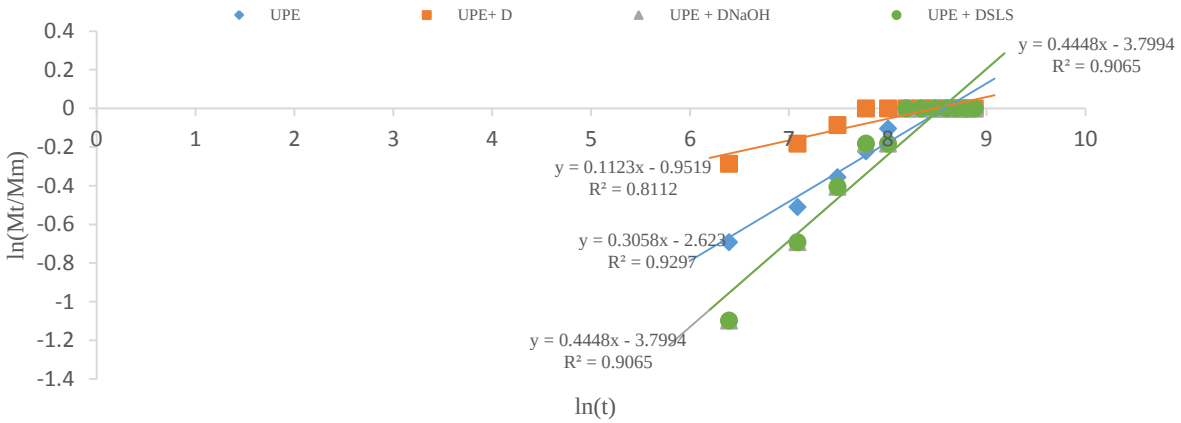

Figure 4: Evaluated n and k for C. populnea fiber/UPE

Table 12: Density, water sorption and diffusivity of the fiber - UPR composites at optimal conditions

Sample	W_f	W_m	ρ (g/cm^3)	h_c (mm)	n (s^{-1})	k	M_m (%)	S ($s^{-1/2}$)	D_{wc} (mm/s)
UPE	0	100	1.2383	6.4	0.3058	0.073	0.85911	0.0076	0.000629395
UPE + D	5.79	97	1.1771	6.4	0.1123	0.386	1.22825	0.0044	0.00010321
UPE + D_{NaOH}	9	91	1.2077	6.4	0.4448	0.022	0.63694*	0.007	0.000971371
UPE + D_{SLS}	5.98	91.61	1.1633	6.4	0.4448	0.022	0.65288*	0.0072	0.0009781

Superscript (*) represents low water sorption compared to matrix

Conclusions

In the present research, various characterization tests were conducted on UPE, untreated, NaOH and SLS treated C. populnea fiber/UPE composites. In general, the untreated and treated C. populnea fiber reinforced and reduced the weight of UPE matrix. The effect of chemically treated C. populnea fiber has been studied and the following conclusions can be drawn. The tensile strength of epoxy-based composites is better than that of polyester-based. The tensile strength of GFR-Epoxy composites with coconut coir as fillers is comparable to that of plain GFR-Epoxy composite and in case of polyester composites GFR-polyester with rice husk filler is comparable to that of plain GFR-Polyester laminate. The tensile properties of NaOH treated C. populnea fiber/UPE composites is better than tensile properties of SLS treated C. populnea fiber/UPE composites. The flexural strength of SLS treated C. populnea fiber/UPE composites is better than that of NaOH treated C. populnea fiber reinforced UPE composites but vice versa for flexural modulus. The hardness of SLS treated C. populnea fiber/UPE composites is more than untreated and NaOH treated C. populnea fiber/UPE composites and the same with UPE matrix. The impact strength of untreated C. populnea fiber/UPE composites is good compared with that of NaOH and SLS treatments, respectively. Although, NaOH treated C. populnea fiber/UPE composites is better than SLS treated UPE based C. populnea fiber composites. The interfacial adhesion between the fiber and UPE matrix is superior when C. populnea fiber treated with NaOH composites and revealed by fiber tearing and agglomerated fiber in the composites as observed in morphology of the composites. The density of SLS treated C. populnea fiber/UPE composites is less than that of NaOH treated C. populnea fiber/UPE composites. Water sorption of NaOH treated C. populnea fiber/UPE composites is lesser than SLS treated C. populnea fiber/UPE composites and the water sorption behaviour of UPE matrix and composites with C. populnea fibers were less Fickian in nature. Both treated C. populnea fiber/UPE composites possess high water diffusion coefficient.

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