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Predictive Modelling of the physical and mechanical properties of Natural fibre reinforced polymer composites

E.N. Ikezue [1] and J.O. Okoye [2]

[1] *Department Of Chemical Engineering Chukwuemeka Odumegwu Ojukwu University, Uli Anambra State, Nigeria*

Email: en.ikezue@coou.edu.ng

[2] *Department Of Chemical Engineering Enugu State University of Science and Technology Agbani campus-Enugu state, Nigeria*

Abstract

Polymeric composite substances which are based completely on virgin polymer resins are not completely biodegradable and are structurally so bulky for industrial use or application, hence polymer composites which are biodegradable with enhanced or improved mechanical and physical properties fabricated using natural fibres (biomaterials)such as okro (hibiscus esculentus) plantain (musa paradisiaca) and okro (cissus populnea) and a blend of high density polyethylene (HDPE) polymer resins is much desirable and a better alternative to the use of pure polymer resins for industrial and household applications. The work consist of fabricating a polymer composite specimen using the mentioned natural fibres and then testing for the physical and mechanical properties such as thickness swelling (%)water absorption capacity (%) and density (kg/m3) and then tensile strength ,tensile modulus (MPa), flexural strength (MPa) flexural modulus (GPa) elongation at break (%) The fabricated polymer composite specimens exhibited good qualities of high tensile strength of 44.13MPa,58.85MP and 36.80MPa for hibiscus esculentus, cissus populnea and musa paradisiaca respectively with corresponding densities of 0.65kg/m3,0.70kg /m3and 0.82kg/m3,The scenario show that cissus populnea fibre reinforced composite had the highest tensile strength, lower water absorption capacity and lower density .

Keywords: Hydrophilic fibre, hydrophobic polymere fibre reinforcement, mercerization, polymer composites

1. INTRODUCTION

The thermosets and thermoplastic material can be reinforced and made into polymer composite structures. Thermosets were the first to be introduced as matrix to be reinforced with natural fibres (Bledzki et al 2008). Recently developments shifted to thermoplastic matrix composites, this is because thermoplastics are more easily molded in manufacturing technologies (eg injection moulding, extraction, etc.) than reinforced thermosets (Ander, 2006), Another reason for thermoplastics being used as matrix is that they often need the additional strength or additional stiffness gained from reinforcement (Gassan, 1999) (Bledzki et al 2007) compared some common type of thermoplastics with different, properties used as matrix in natural fibre reinforced composites. They concluded that polyethylene (HDPE) were suitable to be matrix in natural fibre reinforced composites because they had lower characteristic temperatures and higher mold shrinkage although their mechanical properties were relatively low. PP and PE is alkyl and hydrogen group. PP has been studied as a matrix in fibre reinforced composites by many researchers because of its low cost and good thermal stability (Bo masden and Hans 2003). other thermoplastics such as polyester amide (PEA), poly (3-hydrobuty rate - co- b hydrovalerate) PHBV polylactic acid [PLA] polyphenylene sulphide (PPS) polyetherether ketone (PEEk) polycarbonate [PC] polyamide 6(PA-6) polybutylene terephthalate has better mechanical properties than PP and PE but also more costly were chosen as matrix for fabricating composite reinforced with natural fibres (water loving characteristics) hence the hydrophobic (water hating) matrix have mould shrinkage which is the amount of shrinking (%)when a polymer is cooled down(Ander,2001) mold shrinkage occur in

all thermoplast materials due to thermal and other contractions in the molecules. rystalline polymers exhibit the worst problems [shrinkage[1-4%] for nylon, HDPE, pp. etc. while amorphous polymer (PC Polystyrene etc.) have less mold shrinkage(Alakali,2009) by introducing natural fibres into polymer matrix, mold shrinkage of composites are all reduced. HDPE and LLDPE have greater stiffness or strength than LDPE. HDPE also has good chemical resistance and excellent stiffness from room temperature to the boiling point of water (1000) the mechanical properties are influenced by the individual mechanical properties of both polymer matrix and fibre reinforcement.

The bonding strength between fibre and polymer matrix in the composite is considered a major factor in order to get a superior fiber reinforcement in composites properties. Because of the pendant hydroxyl and polar group in fibre this leads to extreme high moisture absorption resulting in weak interfacial bonding between the fibre and the hydrophobic polymer matrix. To develop composite with good mechanical properties, chemical modification of the natural fibre (a process called mercerization) is carried out to reduce the hydrophilic behavior of fibre, increase the cellulose content (hence the mechanical properties) and then reduce the moisture absorption capability (Hashim et al,2012). The different surface chemical treatment of natural fibres include but not limited to the following

i. Alkaline treatment

Alkaline treatment is also known as mercerization is one of the most used chemical treatments for natural fibres when used to reinforce thermoplastics and thermo sets (Ikezue, 2016). Addition of aqueous sodium hydroxides (NaoH) to natural fibre promotes the ionization of the hydroxyl group to the alkoxide Fe-oH+ NaoH→ Fibre-O-Na+H2O

This increases the cellulose and hemicelluloses content of fibre there by improving the physical and mechanical properties of fabricated composite.

ii. Silane Treatment

Silane is a chemical compound with chemical formula SiH4. Silane coupling agent may reduce the number of cellulose hydroxyl groups in the fiber-matrix interface. In the presence of moisture hydrolysable alkoxy group leads to the formation of silanol. The silanol then reacts with the hydroxyl group of the fiber forming stable covalent bonds to the cell wall that are chemisorbed onto the fibre surface. This increases the interfacial strength of the fiber.

iii. Acrylation Treatment.

Acrylic acid (CH2=CHCOOH) is also used in graft polymerization to modify fiber surface (Okoye, 2023). The reaction is initated. By free radicals of the cellose molecule.

iv. Permangate Treatment

Permangate is a compound that contains permangate group,MnO4

The permangate treatment leads to the formation of cellulose radical through MnO ion formation. Most treatment are done through potassium permanganate (KMnO4) solution in acetone.

This decreases the hydrophilic tendency of fibre.

2. MATERIALS AND METHODS

2.1 MATERIALS

The three natural fibres, okro, (Hibiscus Esculentus) plantain (musa paradisiaca) and okoho (cissus populnea) were sourced and extracted from a farm land Amechi, Enugu South Local Government Area, Enugu state located at 6.4o North of latitude, 9.52o East of longitude and 197m or 646.33ft of elevation above sea level.

The thermoplastic polymers ie (HDPE) used in the work were supplied by Centre for Composite Research and Development (CCRD) JUNENG Nigeria Ltd. The other materials include sundry chemicals-methanol, glacial acetic acid, triethoxyvinyl silane coupling agent, benzoyl chloride, methylethyl ketone, NaoH pellets, sulphuric acid, acetic anhydride, benzene solution, toluene solution, Ca(oH)2 pellets, peroxide (catalyst), mould release agents, Accelerator (helps in solidification and curing), metal cutter, metal hammer, filling machine (composite cutter) digital weight balance, plastic drum, masking tape, Hounsfield Digital Tensometer, Buck 530 Fourier Transform in fra spectroscopic analyser.

2.2 EXTRACTION OF THE FIBRES

The okro stem fibres were retted in water for 12 days in a mud tank, plaintain pseudo stem fibre were mechanically extracted while okoho bast fibre was retted in water for 21 days in a mud tank. Each of these fibres were dried in air until a constant weight and then subjected to hot KOH treatment and also dried to obtain the single fibre.

2.3 THE MOULDING PROCESS

The ground blend from the compound process were gradually poured into specially made moulds. The surface of the moulds were coated with oleic acid to avoid adhesion of the mixture and for easy removal of the polymer composites. The mixture was then spread equally on the surface of the moulds and allowed to stand for 24hrs at temperatures at ambient condition.

2.4 DETERMINING THE MECHANICAL AND PHYSICAL PROPERTIES OF THE COMPOSITES

The mechanical - Tensile strength, Tensile modulus, flexural strength, flexural modulus and elongation at break were determined using the hounsfied digital tensometer according to ASTM 190-03 and the result were presented in the tables 1.0 for Cissus Populnea, Table 3.0 for Hibiscus Esculentus, and tables 5.0 for Musa paradisiaca fiber. The water absorption capacity and thickness swelling were done according to ASTM D570, the composite samples were immersed in distilled water for 24 hrs at ambient condition and then dried in an oven at 50oc for 24 hrs, stored in a desiccator, the moisture uptake and thickness swelling were determined and presented in table 2.0.

The density were measured using a precision balance (Metlter Toledo model XP 5035, CCRD Nsukka) as seen in table 2.0

3. RESULTS AND DISCUSSION

3.1 RESULTS

The mechanical properties as well as the physical properties of virgin high density polyethylene (HDPE) were shown in Table 4.0, it shows the density g/cm^3 water absorption capacity (%), the flexural modulus (GPa). The tensile strength and the mold shrinkage (%). The physical properties data for the treated and untreated natural fibres of the three plants are presented in Tables 4 and table 2 it is observed that there is tremendous improvement of the physical properties i.e. thickness swelling (%), water absorption capacity (%) and density (Kg/m^3). Also the data on the Tensile Strength (MPa), flexural modulus (GPa) and Elongation at break (%) for the fabricated polymer composites from the three natural fibres are presented in table 1.0 (Cissus populnea fibre), Table 3.0 (Hibiscus Esculentus fiber) and Table 5.0 (Musa Paradisiaca fibre) these data on the three respective Table 1, 3 and 5 were compared with those of the virgin polymer resin Table 4.0 it was observed that there were improvements on the determined mechanical properties.

Table 1: Effect of process variables on the Mechanical Properties of Composites Produced from Treated and Untreated Cissus populnea fibre

Sample	Tensile Strength (Mpa)	Tensile Modulus (Mpa)	Flexural Strength (Mpa)	Flexural Modulus (Gpa)	Elongation@ Break (%)
1	35.53±51^{r}	36.81±.52^{b-e}	20.60±51de	159.47±35^{a}	4.35± 56^{j}
2	39±00^{lm}	36.03±05^{b-g}	21.17±06^{c-e}	142.23±23^{a}	5.04±05^{l}
3	43.6±86^{lm}	27.50±17.32^{i}	20.56±50de	158.04±05^{a}	4.52±02^{j}
4	38.99±84^{lm}	36.23±23^{b-f}	21.20±26^{c-e}	156.10±10^{a}	5.20±10^{hi}
5	53.91±16^{ef}	35.13±05^{i-h}	20.48±46de	145.20±26^{a}	6.03±05^{fg}
6	53.62±03^{f}	36.73±63^{b-e}	22.03±05^{c-e}	130.20±26^{ab}	4.02±01^{jk}
7	37.78±58no	30.66±76^{g-i}	25.20±26^{b-e}	150.40±60^{a}	8.27±23^{b}
8	58.04±91^{a}	37.06±05^{b-e}	21.03±05^{c-e}	155.26±20^{a}	9.00±00^{a}
9	50.72±32^{g}	40.00±05^{abc}	25.73±55^{a-d}	159.10±09^{a}	3.13±05^{l}
10	42.45±55^{j}	40.83±66^{ab}	20.43±51de	155.07±05^{a}	4.10±00^{jk}
11	39.18±94^{lm}	38.06±05^{bcd}	21.13±05^{c-e}	156.26±37^{a}	4.07±05^{jk}
12	31.12±64^{q}	36.16±20^{b-f}	20.36±55de	160.533±45^{a}	5.33±28^{hi}
13	56±85^{bc}	40.40±51^{abc}	22.16±11^{c-e}	158.20±49^{a}	6.20±62^{ef}
14	56.12±64^{bc}	41.23±23^{ab}	23.73±64^{c-e}	158.43±49^{a}	3.20±34^{l}
15	55.34±33^{cd}	45.36±55^{a}	21.13±11^{c-e}	161.37±54^{a}	4.07±05^{jk}
16	37.84±64no	44.03±05^{a}	20.50±00de	160.80±51^{a}	5.33±57^{hi}
17	56.13±11^{bc}	40.00±00^{abc}	21.33±57^{c-e}	155.70±61^{a}	4.10±00^{jk}
18	45.63± 40^{h}	40.84±75^{ab}	30.20±25^{ab}	155.06±05^{a}	5.60±05^{gh}
19	38.1± 01no	38.33±29b^{cd}	31.20±26^{a}	148.33±28^{a}	6.03±05^{fg}
20	56.24± 99^{b}	31.18±23^{f-j}	27.00±00^{abc}	145.40±51^{a}	6.53±05de
21	30.59± 08^{q}	36.78±57^{b-}e	20.60±51de	159.47±35^{a}	4.35±56^{j}
22	30.9±52^{qh}	30.67±58^{g-i}	20.53±57de	153.33±57^{a}	6.80±17^{cd}
23	54.61±5.0^{de}	40.76±66^{ab}	21.86±16.34^{c-e}	160.37±55^{a}	6.30±43^{ef}
24	55.4±00^{bcd}	40.76±66^{ab}	30.90±72^{ab}	155.53±45^{a}	6.03±05i
25	40.81±01^{k}	33.03±05^{d-h}	27.03±05^{abc}	105.53±78.40^{b}	7.13±05^{i}

26	53.16±10^{f}	32.00±00^{e-l}	26.06±05^{a-d}	154.10±10^{a}	3.20±26^{i}
27	41.25±01^{k}	32.40±5.1^{e-l}	27.06±05^{abc}	154.16±15^{a}	5.40±34^{hi}
28	54.55±50de	30.02±02^{b-i}	22.50±00^{c-e}	140.50±60^{a}	4.50±00^{j}
29	54.65±38de	30.02±02^{hi}	21.10±00^{c-e}	140.87±57^{a}	6.26±28^{ef}
30	31.35±04^{q}	30.10±00^{hi}	22.03±05^{c-e}	155.20±17^{a}	7.06±05^{c}
31	39.35±21^{lm}	36.20±26^{b-f}	21.20±26^{c-e}	160.53±45^{a}	3.76±6^{k}
32	58.37±11^{a}	35.20±26^{c-h}	8.03±10.45^{f}	162.86±77^{a}	4.16±28^{jk}
33	56.1±09^{dc}	32.20±26^{c-h}	22.36±55^{c-e}	158.03±05^{a}	5.10±10^{i}
34	44.2±11^{j}	36.70±60^{b-e}	26.10±10^{a-d}	155.10±10^{a}	3.13±05^{l}
35	39.5±43^{l}	40.13±15^{abc}	20.43±51de	143.10±00^{a}	8.16±20^{h}
36	38.52±45^{mn}	36.66±57^{b-e}	22.03±05^{c-e}	130.20±26^{ab}	4.35±56^{j}
37	39.23±11^{lm}	35.08±06^{c-h}	25.03±05^{b-e}	105.36±78.17^{b}	6.06±05^{efg}
38	37.33±31^{o}	36.00±00^{d-g}	19.00±00^{e}	160.67±58a	5.04±06^{i}
39	37.68±27no	40.04±05^{abc}	25.70±61^{a-d}	159.00±00^{a}	3.00±00^{l}
40	37.3±20^{o}	40.83±66^{ab}	20.10±00de	155.07±05^{a}	4.10±00^{jk}

Tensile Strength (Mpa) of Cissus populnea fibre reinforced composite
Tensile Modulus (Mpa) of Cissus populnea fibre reinforced composite
Flexural Strength (Mpa) of Cissus populnea fibre reinforced composite
Flexural Modulus (Gpa) of Cissus populnea fibre reinforced composite
Elongation @ Break (%) of Cissus populnea fibre reinforced composite

Table 2: Physical properties of composites produced from treated and untreated fibres of the three plants

S/N	Sample	Thickness Swelling (%)	Water Absorption Capacity (%)	Density (kg/m^3)
1.	Polymer resin	0.00^{f}	0.00^{f}	0.93^{f}±0.10
2.	Composite produced with untreated CP	3.30^{a}±0.21	1.83^{c}±0.06	0.76^{b}±0.25
3.	Composite produced with CP fibre treated with KOH	2.43^{bc}±0.21	1.83^{c}±0.06	0.76^{b}±02.5
4.	Composite produced with CP fibre with Acetic Anhydride	2.70^{b}±0.26	2.17^{b}±0.21	0.74^{c}±0.15
5.	Composite produced with CP fibre treated with Nitric Acid	3.20^{a}±0.20	2.33^{b}±0.21	0.71^{d}±0.020
6.	Composite produced with untreated HE fibre	2.17^{c}±0.15	1.77^{c}±0.25	0.68^{d}±0.23
7.	Composite produced with HE fibre treated with KOH	1.37^{de}±0.32	1.30^{d}±0.10	0.65^{d}±0.10
8.	Composite produced with HE fibre treated with Acetic Anhydride	1.63^{d}±0.21	1.23^{d}±0.21	0.64^{e}±0.20
9.	Composite produced with HE fibre treated with Nitric Acid	2.20^{c}±0.020	1.63^{c}±0.15	0.66^{d}±0.25
10	Composite produced with untreated MP fibre	1.57^{de}±0.49	0.80^{e}±0.20	0.63^{e}±0.10
11	Composite produced with MP fibre treated with KOH	1.17^{e}±0.15	0.30^{f}±0.10	0.82^{f}±0.15
12	Composite produced with MP fibre treated with Acetic Anhydride	1.50^{de}±0.10	0.30^{f}±0.10	0.80^{f}±0.24
13	Composite produced with MP fibre treated with Nitric Acid	1.70^{d}±0.10	0.73^{e}±0.32	0.78^{f}±0.20

CP=*Cissus populnea,* HE=*Hibiscus esculentus,* MP=*Musa paradisiaca*

Table 3: Effect of process variables on the Mechanical Properties of Composites Produced from Treated and Untreated *Hibiscus esculentus* fibre

Sample	Tensile Strength (Mpa)	Tensile Modulus (Mpa)	Flexural strength (Mpa)	Flexural modulus (Mpa)	Elongation @ break (%)
1	33.08±.80^{cd}	48.20±.17^{cd}	25.16±.05^{im}	150.40±.51^{i}	5.40±.51^{jkl}
2	39.68±.50^{ab}	46.70±.60^{e-h}	25.90±.34^{jkl}	155.53±.45^{fg}	5.70±.34^{h-l}
3	31.87±.00^{cd}	42.21±.25^{n}	26.11±.02^{ijk}	156.10±.00^{ef}	6.10±.01^{g-l}
4	34.03±.02^{cd}	44.33±.20^{m}	27.75±.65^{fg}	160.20±.26^{d}	6.45±.56^{e-j}
5	42.61±.01^{a}	45.67±.58^{h-l}	28.16±.05^{fgh}	160.90±.72^{cd}	6.48±.41^{e-j}
6	42.61±.01^{a}	48.17±.06^{cd}	30.10±.00^{e}	175.36±.63^{a}	7.80±.17^{a-f}
7	40.65±.48^{ab}	53.86±.2.8^{a}	28.40±.51^{fg}	165.70±.60^{b}	7.5±.00^{a-g}
8	31.77±.00de	56.20±.2^{b}	25.04±.05^{mn}	160.17±.06^{d}	8.07±.05^{abc}
9	26±.00^{fg}	58.03±.05^{a}	28.09±.02^{fgh}	161.47±1.17^{cd}	8.08±.07^{a-e}
10	42.16±.00^{ab}	45.04±.05^{u-m}	26.20±.26^{ujk}	162.43±.67^{c}	9.03±.02^{a}
11	32.53±.37^{cd}	40.51±.00^{op}	26.36±.23^{ijk}	155.20±.00^{fgh}	9.05±.00^{a}
12	40.7±.17^{ab}	45.70±.25^{h-l}	26.20±.26^{ijk}	156.10±.00^{ef}	8.16±.28^{a-d}
13	42.07±.06^{ab}	45.25±.26^{i-m}	26.45±.56^{ij}	155.10±.10^{fgh}	8.41±.36^{abc}
14	40.82±.02^{ab}	46.20±.26^{f-j}	26.43±.49^{ij}	145.16±.28j	7.40±.34^{a-g}
15	31.24±.64^{e}	46.20±.26^{d-g}	26.66±.57^{l}	150.36±.55^{i}	7.50±.00^{a-g}
16	42.55±.04^{a}	47.21±.29^{d-g}	20.11±.02^{q}	150.16±.28^{j}	7.00±.00^{c-j}
17	13.11±17.32^{h}	40.44±.000^{op}	20.26±.21^{q}	158.06±.05^{e}	6.50±.00^{d-j}
18	44.19±.00^{a}	44.67±.28^{v-m}	24.38±.33no	156.57±.80^{ef}	6.1±.28^{f-j}
19	32.82±.71^{cd}	41.53±2.57^{no}	24.06±.05^{op}	155.86±.32^{fg}	7.54±.03^{a-g}
20	34.01±.01^{cd}	40.66±.05^{p}	25.03±.05^{mn}	150.83±.28^{i}	7.54±.03^{a-g}
21	30.97±.84^{ef}	47.73±.63^{kde}	30.36±.55^{e}	145.10±.00^{j}	6.26±.28^{f-j}
22	30.43±.75^{def}	48.16±.28^{cd}	30.07±.64^{e}	145.17±.28^{j}	7.00±.00^{c-j}
23	41.22±.29^{ab}	49.20±.17^{cb}	32.06±.05^{c}	156.33±.57^{ef}	4.51±3.43^{kl}
24	32.15±.99^{cd}	49.1±.22^{cb}	31.16±1.25^{d}	156.67±.58^{ef}	7.25±.61^{b-h}
25	37.01±.91^{bc}	49.50±.00^{b}	35.00±.00^{b}	157.00±.50^{ef}	7.70±.00^{a-g}
26	34.24±.21^{cd}	48.23±.32^{cd}	36.17±.28^{a}	140.48±.50^{k}	4.53±3.45^{kl}
27	31.46±.40de	48.40±.34^{cbd}	35.00±.00^{b}	140.96±.83^{k}	6.54±.55^{d-j}
28	25.18±.30^{fg}	46.00±.00^{g-k}	30.38±.24^{e}	140.83±.76^{k}	6.39±.33^{f-j}
29	32.2±.6^{cd}	45.71±.60^{h-l}	30.51±.02^{e}	150.85±.56^{l}	7.11±.02^{b-i}
30	32.3±.20^{cd}	45.0±.00^{j-m}	35.00±.00^{b}	153.46±.05^{h}	7.75±.56^{a-g}
31	31.03±.04^{def}	44.50±.00^{i-m}	26.20±.00^{ijk}	146.50±.00^{j}	4.51±.01^{kl}
32	41.76±.25^{ab}	45.17±.28^{i-m}	25.37±.63^{lm}	145.00±.00^{j}	4.57±.06^{kl}
33	40.22±.20^{ab}	46.01±.01^{g-k}	26.70±.52^{i}	140.33±.57^{k}	5.46±.40^{i-j}
34	29.5±.00^{fg}	45.33±.57^{i-m}	26.67±.58^{j}	140.68±.59^{k}	6.75±.21^{d-j}
35	33.12±.02^{cd}	45.34±.58^{i-m}	7.67±.57^{h}	140.38±.58^{k}	6.73±.25^{d-j}
36	33.28±.24^{cd}	45.34±.58^{i-m}	28.50±.00^{f}	146.00±.86^{j}	8.48±.45^{abc}
37	25.29±.49^{fg}	47.36±.63^{def}	26.37±.23^{ijk}	145.87±.80^{j}	8.71±.25^{ab}
38	26.36±.22^{fg}	48.03±.05^{cd}	25.67±.58^{klm}	154.07±6.02^{gh}	8.73±.55^{ab}
39	40.21±.02^{ab}	46.50±.00^{e-i}	23.40±.00^{p}	158.11±.01^{e}	4.00±.86^{l}
40	43.28±.40^{a}	46.58±.00^{e-i}	23.67±.58^{p}	158.10±.08^{e}	5.53±.50^{i-k}

Tensile Strength (Mpa) of *Musa paradisiaca* fibre reinforced composite
Tensile Modulus (Mpa) of *Musa paradisiaca* fibre reinforced composite
Flexural Strength (Mpa) of *Musa paradisiaca* fibre reinforced composite
Flexural modulus (Gpa) of *Musa paradisiaca* fibre reinforced composite
Elongation @ Break (%) of *Musa paradisiaca* fibre reinforced composite

Table 4: Properties of PE polymers

Thermal and Mechanical Properties	LDPE	PE HDPE	LLDPE
Density (g/cm^3)	0.910-0.925	0.935-0.1	0.918-0 0.940
W_{24h}(%)*	<0.015	<0.01-0.20	
Tg(^{0}C)**	-20-125	-20-110	-120
Tm(^{0}C)***	105-16	120-140	
Tp(^{0}C)****	150-230	150-290	
Mold shrink(%)	1.5-5.0	1.5-5.0	
Specific heat (kJ/kg^{0}C)	1.901-1.989	1.566-2.281	
Tensile strength (MPa)	10-12	14.5-38.0	15-32
Youngs modulus (GPa)	0.055-0.380	0.413-1.490	
Flexural modulus (GPa)		0.41-1.07	
Ultimate tensile strain(%)	90-800	12-1000	

*W_{24h}: Water absorption
**Tg: Glass transition temperature
***Tm: Melt point
****Tp: Process temperature

Table 5: Effect of process variables on the Mechanical Properties of Composites Produced from Treated and Untreated *Musa paradisiaca fibre*

Sample	Tensile Strength (Mpa)	Tensile Modulus (Mpa)	Flexural Strength (Mpa)	Flexural Modulus (Gpa)	Elongation @ Break (%)
1	25.36±55^{op}	45.13±05^{ij}	21.20±00^{d-n}	160.83±05^{f}	5.40±51^{j-l}
2	34.61±01^{d-g}	45.36±23^{hi}	21.55±39^{c-h}	155.50±00^{kl}	5.70±34^{h-k}
3	35.17±28^{cde}	46.20±26^{gh}	20.63±32^{e-h}	155.03±05^{l}	6.10±01^{g-k}
4	26.51±00^{mn}	46.13±98^{gh}	23.33±29^{a-f}	155.67±58^{kl}	6.45±56^{e-j}
5	20.42±01^{s}	46.20±52^{gh}	24.55±00^{a-d}	156.33±57^{jk}	6.48±41^{e-j}
6	20.81±00^{s}	46.80±00^{g}	20.42±03^{c-h}	156.83±76^{hij}	7.80±17^{a-f}
7	33.63±03^{hi}	45.10±00^{ij}	21.44±03^{c-h}	157.67±58^{h}	7.50±00^{a-g}
8	26.22±0^{1mn}	46.13±51^{gh}	22.48±01^{a-g}	159.17±28^{g}	8.07±05^{a-e}
9	35.13±00^{c-f}	45.00±00^{ijk}	20.44±00^{f-h}	160.83±29^{f}	8.08±07^{a-e}
10	25.73±57^{hop}	44.34±57^{jk}	21.45±01^{c-h}	160.70±75^{f}	9.03±02^{a}
11	33.53±40^{l}	44.67±28^{ijk}	25.05±05^{ab}	154.13±63^{m}	9.05±00^{b}
12	26±00^{mno}	45.36±31^{hi}	24.00±00^{a-e}	155.63±77^{kl}	8.16±28^{a-d}
13	25.24±22^{op}	48.17±28^{f}	24.57±06^{a-d}	156.133±98^{jk}	8.41±36^{a-c}
14	33.53±40^{l}	49.54±03^{e}	25.33±57^{a}	156.76±55^{hij}	7.40±34^{a-g}
15	26.67±28^{n}	55.92±88^{bcd}	25.37±54^{a}	156.34±58^{jk}	7.50±00^{a-g}
16	24.33±49^{q}	55.33±29^{d}	24.71±61^{abc}	160.70±75^{f}	7.00±00^{c-j}
17	34.34±56^{ghi}	56.54±45^{b}	25.01±00^{ab}	165.40±10^{fg}	6.50±005^{d-j}
18	34.7±17d-^{g}	56.20±53^{bc}	20.74±56^{e-h}	166.05±52^{d}	6.16±28^{f-j}
19	25.84±.58^{m-p}	55.43±.50^{cd}	21.67±.28^{b-h}	167.75±.30^{c}	7.54±.03^{a-g}
20	27.5±.00^{l}	58.78±.57^{a}	20±.55^{e-h}	148.40±.34^{p}	5.70±.25^{h-k}
21	25.82±.64^{m-p}	44.90±.81^{ijk}	19.00±.00^{gh}	165.33±.57de	6.26±.28^{f-j}
22	27.49±.44^{l}	46.33±.28^{g}	19.67±.28^{gh}	164.86±.80^{e}	7.00±.00^{c-j}
23	26.34±.29^{m-n}	44.70±.51^{hi}	21.10±.77^{d-h}	170.60±.34^{b}	451±.3.43^{kl}
24	20.83±.62^{s}	45.40±.51^{hi}	21.28±.55^{c-h}	175.18±.16^{a}	7.25±.61^{b-h}
25	34.38±.54^{e-h}	44.86±.70^{ijk}	19.70±.61^{gh}	170.79±.44^{b}	7.70±.00^{a-g}
26	35.4±.60^{cd}	46.57±.55^{g}	20.41±.50^{f-h}	165.00±.00^{e}	4.53±.3.45^{kl}
27	20.59±.45^{s}	40.40±.60^{n}	21.03±.05^{e-h}	160.18±.27^{f}	6.54±.55^{d-j}
28	31.03±.89^{j}	44.13±.11^{k}	20.34±.56^{f-h}	160.41±.60^{f}	6.39±.33^{f-j}
29	34.05±.05^{ghi}	40.61±.01^{m}	20.33±.57^{f-h}	170.80±.61^{b}	7.11±.02^{b-j}
30	23.11±.84^{r}	40.61±.01^{m}	19.43±.02^{gh}	170.85±.56^{b}	7.75±.56^{a-g}
31	35.2±.27^{cd}	44.43±.05^{ijk}	20.34±.57^{f-h}	157.36±.63^{hi}	4.51±.01^{kl}
32	27.6±.55^{l}	44.53±.55^{ijk}	20.47±.45^{e-h}	156.50±.50^{ijk}	4.57±.0.6^{KL}
33	36.48±.49^{a}	45.37±.54^{hi}	21.44±.53^{c-h}	156.10±.1.00^{jk}	5.46±.40^{j-k}

34	28.56±.38^{k}	46.35±.56^{g}	19.88±.11^{f-h}	158.60±.55^{g}	6.75±.21^{d-j}
35	35.54±.42^{bc}	44.53±.54^{ijk}	18.57±.97^{h}	149.47±.55^{o}	6.73±.25^{d-j}
36	27.44±.48^{l}	45.34±.58^{hi}	19.03±.02^{gh}	150.54±.58^{n}	8.48±.45^{a-c}
37	25.13±.22^{p}	46.80±.17^{g}	19.20±.26^{gh}	150.86±.72^{n}	8.71±.25^{b}
38	26.51±.5^{mn}	46.83±.14^{g}	21.77±.82^{b-h}	148.19±.07^{p}	8.73±.55^{ab}
39	25.84±.03^{m-p}	48.00±.00^{f}	22.22±.32^{a-g}	149.47±.45^{o}	4.00±.86^{l}
40	36.17±1.20	42.66±.28^{l}	14.58±10.92^{l}	147.33±.58^{q}	5.53±.50^{i-l}

Tensile Strength (Mpa) of *Musa paradisiaca* fibre reinforced composite
Tensile Modulus (Mpa) of *Musa paradisiaca* fibre reinforced composite
Flexural Strength (Mpa) of *Musa paradisiaca* fibre reinforced composite
Flexural modulus (Gpa) of *Musa paradisiaca* fibre reinforced composite
Elongation @ Break (%) of *Musa paradisiaca* fibre reinforced composite

4. CONCLUSION

4.1 Conclusion

From the data on the mechanical properties it was observed that adding fibre to a polymer matrix influenced the properties by improving them ie Tensile Strength, Tensile modulus, flexural strength, flexural modulus and elongation at break. It also lowered the water absorption capacity and the thickness swelling as well as the mold shrinkage. Among the three natural fibre Cissus populnea fibre reinforced polymer composite had the highest mechanical properties improvement. Also the water absorption capacity, thickness swelling properties of the fabricated polymer composites showed that the composite with Hibiscus Esculentus fibre had the least (better) property. The chemical treatments of the three natural fibres helped in increasing the mechanical properties of the produced polymer composites and reducing the moisture uptake or water absorption capacity as well as the thickness swelling of the composites by increasing the cellulose, hemicelluloses content of each of the fibres. These two components of the individual fibres are responsible for the structural strength and mechanical properties.

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