

# Influence of Fiber Surface Modifications on Fiber-Matrix Interaction in Plant and Waste Fiber Reinforced Thermoplastic Composites

Haydar U. Zaman\*<sup>1</sup>, Ruhul A. Khan<sup>2</sup>

<sup>1</sup>Department of Physics, National University of Bangladesh and Senior Researcher of Institute of Radiation and Polymer Technology, Bangladesh Atomic Energy Commission, P.O. Box-3787, Savar, Dhaka, Bangladesh

<sup>2</sup>Institute of Radiation and Polymer Technology, Bangladesh Atomic Energy Commission, P.O. Box-3787, Savar, Dhaka, Bangladesh

**ABSTRACT:** In the last century, polymers have appeared as one of the best essential materials used in daily life, polypropylene (PP) being one such instance. Until lately, synthetic filler ingredients were the desired choice for improving the strength of PP. Nevertheless, natural filler/fiber ingredients are developing as appropriate substitutes to synthetic ingredients for strengthening polymers such as PP due to their environment friendship, high richness, renewability, and cost efficacy. Numerous study endeavors have been made to study the effect of plant and waste fiber (abaca fiber, AF) based ingredients on the physicomechanical and biodegradation behavior of PP composites, mainly focusing on the fibers and their weight percentages within the composites. AFs were treated with ultraviolet (UV) light at varying intensities and then composites were fabricated by compression molding. The mechanical features of the irradiated AF/PP composites were considerably enhanced compared to the untreated ones. To enhance these features, irradiated AFs were grafted with 2-hydroxyethyl methacrylate (HEMA) by photocuring under UV light. The number of UV passes and therefore the HEMA concentration were optimized along with the quantity of grafting of HEMA, tensile, and impact features. Again, the irradiated AFs were treated with alkaline solutions of varying concentrations at varying temperatures. The optimized alkali-treated AFs were grafted with the optimized HEMA by photocured with the same UV-pass and their composite specimens rendered the best mechanical features. Scanning electron microscopy (SEM) studies exhibited that the optimized alkali with optimized HEMA treated composite had better dispersion than the optimized HEMA treated composite. Moisture absorption and weathering effect of the composites were also investigated.

**KEYWORDS:** Abaca fiber, polypropylene, composite, alkali-treatment and mechanical properties.

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## INTRODUCTION

The increasing ecological consciousness knowledgeable in current decades has promoted industrial interest in the use of natural fibers (NFs) as strengthening ingredients in polymer composites [1-3]. The benefits of NF are low cost, low-density, acceptable specific energy, good thermal insulation features, low equipment wear, low skin and respiratory irritation; they deliver a renewable resource and can be recycled without ecological loss. Moreover, they are often decomposable [4, 5]. NFs consist of cellulose, hemicellulose, and lignin. Additional constituents, generally considered surface impurities, are pectin and waxy ingredients.

Resins will be most suitable for reinforcement as higher cellulose content tends towards higher stiffness. One of the best significant chemical components of NF, especially in composites, is cellulose [6]. The chemical structure of cellulose comprises three -OH groups, which form hydrogen bonds to form macromolecular cellulose. Two of these -OH groups form intermolecular bonds, while the third forms intermolecular hydrogen bonds [7]. Cellulose based fibers are being used to create innovative ingredients for structural and nonstructural applications by attaching them to reinforced plastics. But researchers have found some weaknesses in NF. The barriers of most

\*Corresponding Author: haydarzaman07@gmail.com

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anxiety were poor fiber matrix bond, inconsistency with some polymeric matrices, and moisture absorption by the fibers [8]. AF (hydrophilic nature) and PP matrix (hydrophobic nature) contribute to the weak mechanical features of AF reinforced composites. To increase the AF-PP bond, it is necessary to include a pretreatment or surface modifier on the fiber surface during processing. Various methods, such as chemical treatment [9], photochemical treatment [10, 11] have been improved to modify fiber surfaces. Chemical treatments are required to optimize fiber interfaces. Chemicals can effectively interlock with cellulose by activating the -OH groups and persuade preferred features to the polymer. Moreover, the possible use of NFs as strengthening of polymer matrices is considerably hindered by their hydrophilic character, high capacity for moisture, and weak bond between fibers and matrix. As an outcome, significant attempt is presently being directed towards improving the quality of the interfacial bond between the polymer and the fiber through surface treatment of lignocellulosic fibers. Certain additives or coupling agents are often used to increase the interaction and bond between the fibers and the polymer matrix. Alkali treatment is a method to improve mechanical features. This method changes the state of hydrophilic to hydrophobic substances in crude fibers such as lignin, hemi-cellulose and pectin. A large loss of hemi-cellulose causes the fibers to lose their reinforcing capacity and thus they isolated from each other, creating them finer [12]. Irradiation is a very suitable technique for graft initiation. Benefits of ultraviolet (UV) radiation treatment of polymer ingredients are space reduction, ubiquitous growth, rapid cure at ambient temperature, solvent emission or low flash point, rapid processing, excellent film features, etc. Numerous researches have reported improving the physicomachanical features of NF using dissimilar impregnating solutions under UV irradiation [13,14]. In fiber strengthened composites, the matrix transfers load onto the fibers through shear stress [15]. Therefore, better bonding between the polymeric matrix and the fiber will improve the compatibility between the fiber and the polymer matrix. Earlier studies have shown that NF treatment significantly enhanced the mechanical features of NF strengthened composites [16, 17].

Amid all NF strengthening ingredients, abaca seems to be a favorable ingredient as it is

comparatively economical and widely available. AF, a bast fiber, a cellulosic fiber obtained from the pseudo-stem of the abaca plant (Musaceae family) [18]. AF is currently a discarded product of abaca cultivation and AF can be achieved for industrial purposes without more investment. AF is deliberated an operative restorative ingredient due to its good compatibility and bonding with the resin matrix [19]. Currently, AFs are used to make handbags, ropes, table mats and fancy accessories. Several papers have been published on AFs where abaca was used as a strengthening agent in thermoplastics such as PE and PP [20-23]. As a matrix ingredient, PP was used in the present research as it has some outstanding characters for making composites. PP is a thermoplastic polymer and it has some essential and useful features like clearness, dimensional stability, fire resistance, high heat distortion temperature and high impact strength and these broaden its application. PP is likewise very appropriate for filling, strengthening and mixing. PP with fibrous NFs is one of the possible ways to make natural synthetic polymer composites. Abaca fiber-reinforced composites are attractive of growing attention nowadays due to the development of automobile dashboard/mudguard applications. It can also expand into biomedical, electronics and sports goods manufacturing. It can also be used in marine products due to abaca's excellent resistance to salt water damage and tensile strength when wet. In this present research, unidirectional AF/PP composites were arranged and the physico-mechanical features were investigated. To increase the mechanical features of the composites, AFs were modified with monomer (HEMA) under UV irradiation before and after treatment with alkali.

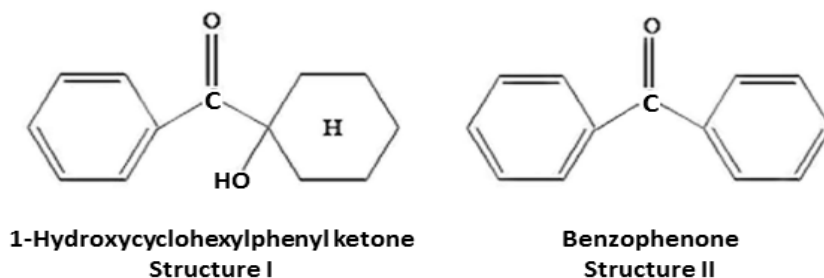
## EXPERIMENTAL

### Materials

The thermoplastic polymer PP, used as the matrix ingredient, was supplied by BASF-YPC Co., Ltd., China in the form of homopolymer pellets. It had grade of G452, density of  $0.90 \text{ g cm}^{-3}$ , melt flow index of 45 g/10 min. AFs were found from abaca-plants collected from a rural area of Bangladesh and used as fillers. The abaca comprises of 68.50% cellulose, 54.50% alpha cellulose, 8.70% lignin, and 28.70% residual cellulose [24]. The bulk monomer, 2-hydroxyethyl methacrylate (HEMA) was procured from Sigma-Aldrich, USA and swelling solvent methanol (MeOH) was purchased from Sigma-Aldrich, India. Photoinitiator, Irgacure-

500 [1-hydroxycyclohexylphenyl ketone (structure I) and benzophenone (structure II)] [Scheme 1] procured from E. Merck Germany, was used to initiate the photo polymerization of the chemically unsaturated system. A reagent grade chemical, namely sodium hydroxide (NaOH), acetone (CH<sub>3</sub>COCH<sub>3</sub>) was used to modify the surface of the fibers.

General properties of Exchange Bias system (Section 2), the various theoretical models developed (Section 3), some techniques used (Section 4), exchange bias on different materials (Section 5), applications (Section 6) several interesting open issues (Section 7) and future scope (Section 8).



**Scheme 1: Structure of 1-hydroxycyclohexylphenyl ketone and benzophenone.**

## METHODS

### Fiber Surface Treatments

#### Modification of AFs with UV Light

AFs were cut to the identical length (15 cm) and then soaked in acetone for half an hour at room temperature to eliminate unnecessary ingredient. Cleaned and dehydrated AFs were irradiated under UV light (UV curing machine; IST Technik, Germany) with dissimilar intensities of 254–313 nm wavelength and 2 kW power at 50 amps current. The UV light source has a conveyor belt, which rotates around the mercury lamp and once it reaches the lamp, it is deliberated a pass and the conveyor speed is 4 m/min. Carrier length is 1 meter. The specimens were positioned on the conveyor and passed through the UV light. AFs were photocured under UV light and the number of UV passes was totaled. Specimens were examined after 24 h of irradiation.

#### Modification of AFs with HEMA

A set of formulations was arranged using dissimilar contents of HEMA in MeOH with 2% Irgacure-500. MeOH was mixed with HEMA to swell the cellulose surface for better pregnancy. The formulations are shown in Table 1. Irradiated AFs were soaked in these formulations and photocured under UV light at various intensities. The photocured specimens were extracted in hot benzene for 48 h to quantify the grafting of HEMA. Grafting percentage was calculated by equation (1):

$$\% \text{ grafting} = [(W_1 - W_2) / W_1] \times 100 \quad (1)$$

where  $W_1$  and  $W_2$  are the weights of cured AF before and after extraction in hot benzene.

**Table 1: Composition of dissimilar formulations based on HEMA**

Ingredients	Formulations (w/w %)			
	H <sub>1</sub>	H <sub>2</sub>	H <sub>3</sub>	H <sub>4</sub>
HEMA	5	10	15	20
Methanol	93	88	83	78
Photoinitiator	2	2	2	2

#### Modification of AFs with Alkali

The alkali solution was adjusted using 5-25% NaOH in water. Cleaned and dehydrated AFs

were soaked in these solutions for 30 min at a temperature range of 15 to 45°C to activate the -OH groups of cellulose and lignin. AFs were then taken out and thoroughly cleaned with distilled

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water for numerous times to eliminate any traces of NaOH on the AF. Nevertheless, a last laundry with 2% acetic acid was performed to neutralize the last traces of NaOH. Lastly, the AFs were cleaned again in fresh water and dried in an oven at 80°C to a constant weight. Final pH measurement was 7. For better comparison, optimized alkaline AF was grafted with optimized HEMA solution and permitted to view for 5 min. The grafted specimens were then photocured under UV light with the same UV pass.

### **Fabrication of Composites**

PP sheet (0.25-0.30 mm thickness) was cut into desired pieces ((15 × 12 cm<sup>2</sup>). First, the AFs were arranged on the PP sheet along the fiber winding direction by manual winding method. The PP sheet layers were stacked alternately AF layers; the outer layer was composed of two layers of PP sheet. These stacks were formed by pressing (Kao Tieh Go Tech Compression Machine) the composites at 190°C for 5 min at a pressure of 10 MPa and then cooled at the same pressure for 5 min before demolding.

### **Determination of the Mechanical Properties**

Tensile tests were performed using Shimadzu Universal Testing Machine (Model AG-1, Japan) according to ASTM-D 638-03, standard [25]. The test was conducted at a crosshead speed of 10 mm/min and a gauge length of 50 mm. Five specimens were examined in each set and the mean value is reported. The Izod impact strength of the specimen with dimensions of 63.5 × 12.7 × 3 mm<sup>3</sup> was carried out in an Izod impact machine (Toyo Seiki Co., Japan) according to ASTM-D 256. A minimum of four specimens were tested in each case and the mean value is reported.

### **Scanning Electron Microscopy (SEM)**

Scanning electron microscopic (SEM) studies of the unmodified and surface modified AF/PP composites were carried out in a scanning electron microscope (JEOL 6400 SEM) at an operation voltage of up to 15 keV. The scanning was synchronized with the microscopic beam to keep up a small size at a great distance comparative to the sample. The ensuing images had depth of field. A notable three-dimensional countenance is obtained with high resolution.

### **Moisture Absorption Properties**

As both treated and untreated fibers are tend to decompose NF due to absorption of moisture. Moisture absorption studies were performed following ASTM D 570 standards. The moisture absorption of both treated and virgin specimens was measured after 5, 10, 15, 20, 25, and 30 days immersion in water at room temperature. At the end of the immersion time, the samples were removed from the water and the surface water was removed using a cloth. The weight of the sample was measured at dissimilar time intervals during prolonged immersion.

### **Weather Experiment**

Both unmodified and modified composite samples were conducted by weathering tester (model Q-U-V, Q-Panel Company, USA). Throughout the treatment, the temperature varied between 65 ± 2°C (sunshine) and 45 ± 2°C (condensation) for approximately 600 h alternating with 4 h of sunshine and 2 h of condensation. The samples were then dehydrated in an oven for 30 min and their tensile features were measured.

## **OUTCOMES AND DISCUSSION**

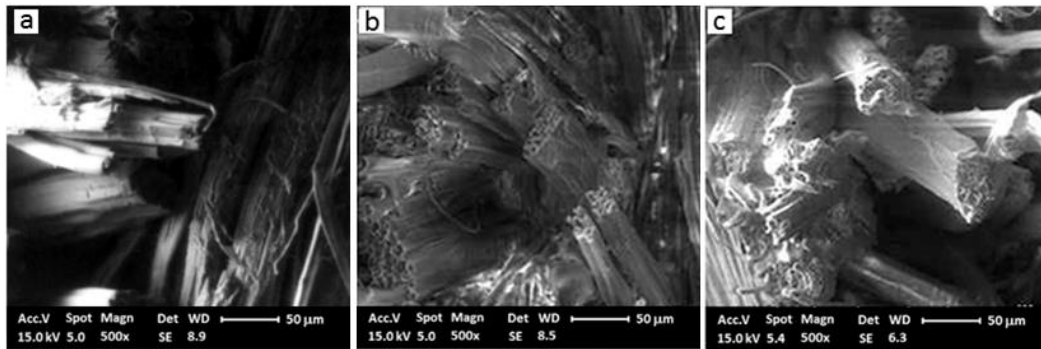
### **Interfacial Features**

Scanning electron microscopy (SEM) was used to study the interfacial features of untreated (AF/PP) and treated (optimized HEMA treated AF/PP and optimized alkali + optimized HEMA treated AF/PP) fiber based composites. Figures 1a, b, and c display the fracture surfaces of untreated AF/PP, optimized HEMA treated AF/PP, and optimized alkali treated + optimized HEMA treated AF/PP composites, respectively. Untreated composites exhibit higher levels of pull-out (Figure 1a). Due to hydrogen bonds formed between untreated AFs and the wide difference in chemical and physical character between untreated AF and the PP matrix, the AF aggregates into bundles and is unevenly distributed through the PP matrix. It can be seen that better bonding is observed for optimized alkali + optimized HEMA treated composite over optimized HEMA treated composite. While it was observed that fiber pull-out occurred in both cases, a substantial quantity of matrix residue on the fiber was found in the optimized alkali + optimized HEMA treated composite. After optimized HEMA treated AF/PP composites a tiny amount of fibers were found in the form of pullout bundles and well distributed through the PP matrix. However, a better dispersion and very lower fiber pull-out in the matrix was



observed when AFs were treated with optimized alkali + optimized HEMA solution. It revealed that the optimized alkali + optimized HEMA treated AF/PP composites were absolutely enclosed by the PP matrix signifying a better fiber-matrix bond (Figure 1c). Chemical modification of the fibers prevents hydrogen bonds from being formed and causes the

properties of the fiber surface and the matrix to become similar. NaOH treatment removed a portion of the lignin and hemi-cellulose from the cell wall of the fiber. Hemi-cellulose has an inferior molecular weight than cellulose. Reduction of hemi-cellulose content in fibers can lead to enhancement of mechanical features of composites.



**Figure 1: SEM images of the fracture surfaces of (a) untreated AF/PP, (b) optimized HEMA treated AF/PP, and (c) optimized alkali treated + optimized HEMA treated AF/PP composites.**

### ***Influence of UV Light on Mechanical Features of Composites***

Washed and dehydrated AFs were irradiated under UV light at dissimilar intensities and then composites were fabricated. Tensile strength, tensile modulus and impact strength values of AF/PP composite were found to be 38.4 MPa, 0.89 GPa and 12.1 kJ/m<sup>2</sup>, respectively. The influence of UV light on mechanical features such as tensile strength, tensile modulus and impact strength of irradiated AF/PP composites were assessed. The outcomes are given in Table 2. We observed that AFs underwent momentous changes in mechanical features after being pretreated by UV light. Increasing the UV light in AF also increases the tensile strength, tensile modulus and impact strength of the composites. The maximum tensile strength (45.3 MPa), tensile modulus (1.02 GPa) and impact strength (14.4 kJ/m<sup>2</sup>) of the composites were attained after passing 40 UV light, which were 18%, 15% and 19% greater than the untreated composite. The rise in mechanical features of the composites with growing UV light may be due to the cross-linking between neighboring cellulose molecules, thereby growing the strength of AFs. It has been perceived that the mechanical features rise with UV light up to a certain limit and then decline due to two opposite events, namely, photo cross-linking and photo degradation that occur instantaneously under UV light [26]. In low UV light, free radicals are

stable by a conjugation reaction, ensuing in photo-crosslinking or inter-crosslinking between bordering cellulose molecules. At high UV light, the key chain can break and the polymer can break into pieces. Consequently, the mechanical features drop with higher UV light. During photo degradation, strength will drop due to the breaking of primary bonds in cellulose components.

### ***Influence of HEMA Treatment on Mechanical Features***

The irradiated AFs were soaked in dissimilar concentrations of HEMA with MeOH for 10 min and photocured under UV light of dissimilar intensities. The outcomes of grafting values versus the number of UV passes as a function of HEMA concentration are depicted in Figure 2. The quantity of grafting ascertains the quantity of cross-linking between HEMA and AFs and it was observed that grafting rises with UV pass, reaches a highest value at a definite UV pass and then drops rapidly as the UV pass rises. All-out grafting was detected in virtually all cases by samples treated with 10% HEMA solution at the 50th UV pass of UV light. The maximum grafting value (6.7%) was given by 10% HEMA solution and followed by 15% HEMA solution. At concentrations above 10% of HEMA, the extent of grafting of AFs declines as the monomers promote rapid free-radical reactions with a photoinitiator leading to network polymer

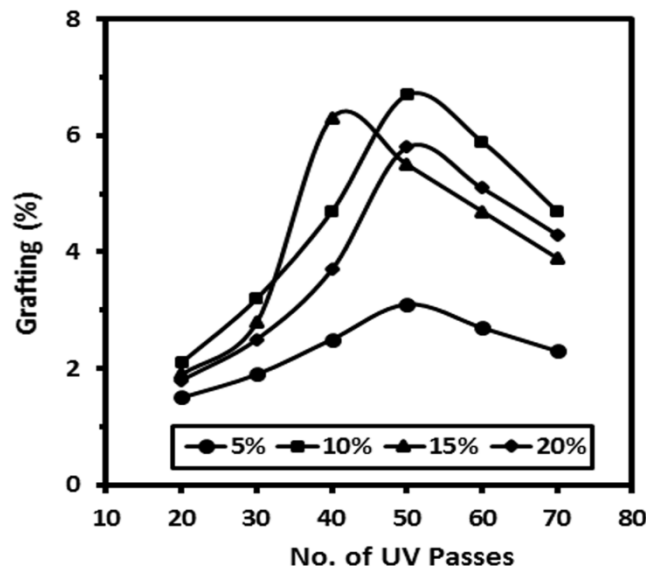
structures by grafting through double bonds [27]. As the HEMA concentration rises, the quantity of residual unsaturation also rises, ensuing in a faster rate of three-dimensional network formation ensuing in limited mobility at the initial stage. The decline in grafting with growing HEMA can be explicated by the fact that

at upper HEMA concentrations, a radical-radical recombination technique may dominate, creating further homopolymers rather than monomer + cellulose backbone reactions [28]. Minimum grafting value (3.1%) was obtained for 5% HEMA solution at 50th UV pass.

**Table 2: Mechanical features of irradiated AF/PP composites against dissimilar UV light**

Ingredients	No. of UV pass	Features		
		TS (MPa)	TM (MPa)	IS (kJ/m <sup>2</sup> )
Irradiated AF/PP composites	0	38.4 ± 0.9	0.89 ± 0.03	12.1 ± 0.6
	20	39.8 ± 0.7	0.91 ± 0.05	12.9 ± 0.4
	30	41.3 ± 1.1	0.95 ± 0.04	13.6 ± 0.7
	40	43.3 ± 0.6	1.02 ± 0.03	14.4 ± 0.5
	50	42.2 ± 0.5	0.98 ± 0.05	13.8 ± 0.9
	60	41.7 ± 0.8	0.96 ± 0.04	13.2 ± 0.6
	70	39.6 ± 0.9	0.93 ± 0.06	12.7 ± 0.5

TS: Tensile strength, TM: tensile modulus, IS: impact strength



**Figure 2: Grafting (%) of HEMA onto AF against UV light with respect to monomer (HEMA) concentration**

The mechanical features of 10% HEMA treated irradiated AF/PP composites were evaluated and tabulated in Table 3. It can be seen that the mechanical features rise with growing UV light up to a definite value, and after reaching the all-out value it declines again with growing UV pass. The all-out tensile strength, tensile modulus and impact strength were found to be 48.1 MPa, 1.09 GPa and 15.7 kJ/m<sup>2</sup>, respectively, which improved by 25%, 22% and 30% compared to the untreated composite. It can be detected that the mechanical features rise up to a definite value and then decline due

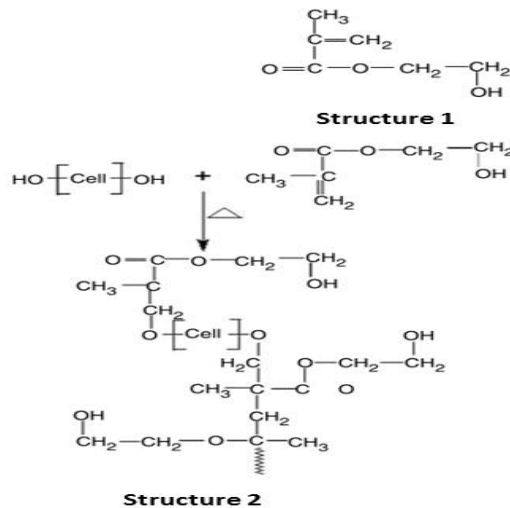
to two reverse phenomena such as photo-crosslinking and photo-degradation, which happen concurrently under UV light. At low UV passes, free radicals are stabilized by conjugation reactions, as an outcome, photo-crosslinking happens. The higher the number of active sites on the polymeric layer, the higher the grafting efficacy. Nevertheless, at higher UV passes, the key chain can break and cellulose degrades, ensuing in a decline in mechanical features as the UV pass rises. Irgacure-500 generates free radicals when exposed to UV light. These free radicals then initiate free

radical reactions between the HEMA and -OH groups of AF and thereby improve the interfacial interactions. The reaction of HEMA to AF contributes to the enhancement of mechanical features. The vinyl group of the acrylate moiety of HEMA reacts with the -OH

group of the cellulose backbone via graft-copolymerization (Scheme 2). This would reduce the hydrophilic nature of AF, which accounts for the superior mechanical features of the control sample.

**Table 3: Mechanical features of optimized HEMA treated AF/PP composites against dissimilar UV light.**

Ingredients	No. of UV pass	Features		
		TS (MPa)	TM (MPa)	IS (kJ/m <sup>2</sup> )
Optimized HEMA treated irradiated AF/PP composites	0	38.4 ± 0.9	0.89 ± 0.03	12.1 ± 0.6
	20	40.2 ± 0.5	0.93 ± 0.08	13.3 ± 0.5
	30	42.9 ± 0.7	0.97 ± 0.05	13.9 ± 0.8
	40	45.6 ± 0.8	1.00 ± 0.06	14.9 ± 0.7
	50	48.1 ± 0.7	1.09 ± 0.09	15.7 ± 0.8
	60	47.3 ± 0.6	1.01 ± 0.07	14.3 ± 0.7
	70	45.1 ± 0.8	0.98 ± 0.09	13.9 ± 0.6

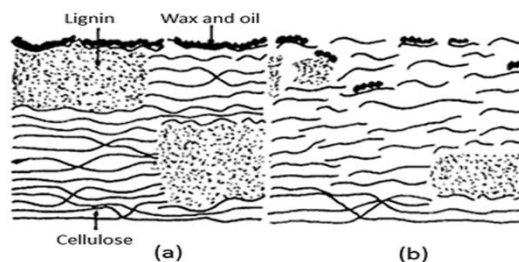


**Scheme 2: Reaction mechanism between cellulose and HEMA**

**Influence of Alkali (NaOH) Treatment on Mechanical Features**

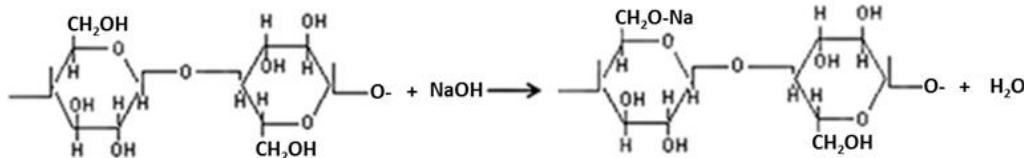
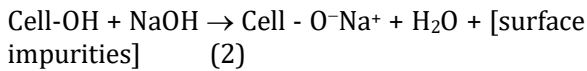
NaOH is the best frequently used chemical for bleaching and/or surface washing of NF. It modifications the sufficient structure of native cellulose I to cellulose II through a method known as alkalization [29]. Alkaline treatment

increases interfacial bonds by eliminating lignin, pectin, waxy ingredients and natural oils covering the outer surface of the fiber cell wall (Figure 3a). Besides, alkaline treatment decreases the fiber diameter and therefore rises the aspect ratio. This exposes the fibrils and provides the fiber an uneven surface topography (Figure 3b).



**Figure 3: Typical structure of (a) unmodified and (b) alkalized cellulosic fiber**

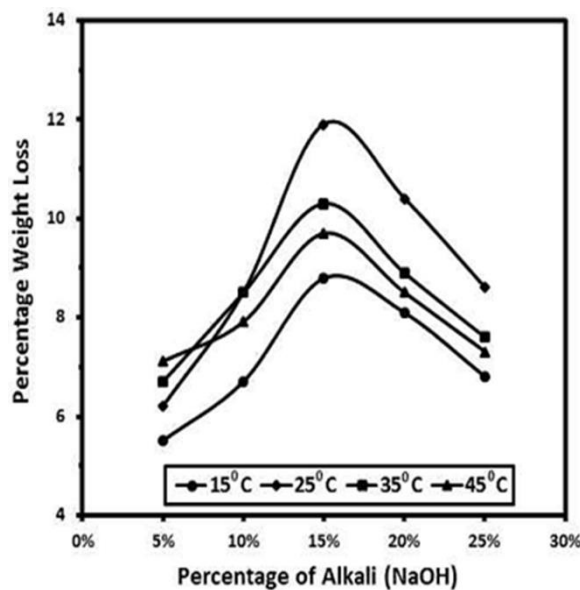
Alkaline treatment rises the surface roughness ensuing in well mechanical interlocking and exposes the cellulose content on the fiber surface. This rises the number of potential reaction sites and permits well fiber soaking. The reaction of NaOH with cellulose is presented in equation (2):



**Scheme 3: Proposed reaction of cellulose molecule with alkali with the production of water molecule**

Irradiated AFs were treated with dissimilar alkali concentrations at dissimilar temperature ranges from 15°C to 45°C. Weight loss was measured afore treatment with HEMA solution and presented graphically in Figure 4. It was observed that the weight loss due to alkaline treatment increased the temperature up to a definite value and reduced after getting the highest value. Maximum weight loss (11.9%) was found at 25°C and in 15% alkaline solution. Optimum alkaline solution and temperature were 15% and 25°C respectively. The optimized

alkaline AFs were then grafted with the optimized HEMA solution and photocured with the same UV light. Grafting values and mechanical features are presented in Table 4. The outcomes exhibited that grafting values and mechanical features were increased in the optimized alkali + optimized HEMA treated irradiated AF/PP specimen and the maximum grafting was about 9%, 15% of tensile strength, 20% of tensile modulus, and 38% of impact strength higher than the optimized HEMA treated irradiated AF/PP specimen.



**Figure 4: Effect of alkaline treatment on weight loss of AFs at dissimilar NaOH concentrations as a function of solution temperature**

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**Table 4: Polymer grafting (%) and mechanical features of optimized alkali + optimized HEMA treated AF/PP composites against dissimilar UV light**

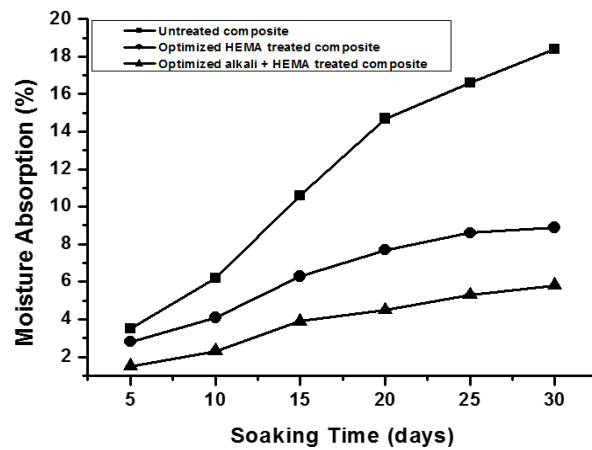
Ingredients	No. of UV pass	Features			
		Grafting (%)	TS (MPa)	TM (MPa)	IS (kJ/m <sup>2</sup> )
Optimized alkali + optimized HEMA treated AF/PP composites	0	—	38.4 ± 0.9	0.89 ± 0.03	12.1 ± 0.6
	20	4.3	43.5 ± 0.7	0.95 ± 0.06	14.6 ± 0.7
	30	4.9	46.4 ± 0.6	0.99 ± 0.07	16.8 ± 0.6
	40	5.7	50.3 ± 0.9	1.13 ± 0.06	18.7 ± 0.8
	50	7.3	55.3 ± 0.9	1.31 ± 0.07	21.6 ± 0.6
	60	6.8	53.2 ± 0.7	1.25 ± 0.08	19.5 ± 0.6
	70	6.2	50.6 ± 0.5	1.21 ± 0.09	17.3 ± 0.8

TS: Tensile strength, TM: tensile modulus, IS: impact strength

**Moisture Absorption Features**

The moisture absorption values of unmodified, optimized HEMA and optimized alkali + optimized HEMA treated irradiated AF/PP composite specimens (30 × 15 × 2.5 mm<sup>3</sup>) were calculated by immersing the specimens in deionized water contained in a static glass beaker at the room temperature and the outcomes are presented in Figure 5. After constant time intervals the specimens were taken out of water and their weight gain was measured. The modified specimens (optimized HEMA and optimized alkali + optimized HEMA treated irradiated AF/PP composite) absorbed moisture within 30 days of soaking and then the

values remained almost constant. However, the unmodified specimen continued to take up moisture throughout the observation period. The lowest amount of moisture was taken up by the optimized alkali + optimized HEMA treated irradiated AF/PP specimen (6.4%) and the highest by the unmodified AF/PP specimen (16.8%). The moisture absorption of the modified specimens decreases because HEMA reacts with the -OH group of AF and hence reduces the hydrophilic nature of AF. It can be observed that the optimized HEMA treated irradiated AF/PP specimen also exhibits better resistance to water. It is also compatible with mechanical and grafting standards.



**Figure 5: Moisture absorption values of untreated and treated AF/PP composites against the soaking time**

**Weather Test**

Unmodified and modified composite specimens were exposed to severe weathering tests for 600 hours of simulated sunshine and condensation in periodic cycles. Weathering testers use a high-intensity mercury or xenon arc, water spray and humidity control. Tensile features such as tensile strength and tensile modulus of the specimens were measured

gradually. The loss of tensile strength and tensile modulus of the specimens due to weathering is illustrated in Figures 6 and 7, respectively. Tensile strength loss of the unmodified specimen over the maximum period of observation was about 33%, while that of the optimized HEMA and optimized alkali + optimized HEMA treated irradiated AF/PP specimens was about 18% and 14%, respectively. Correspondingly, the tensile

modulus loss was about 28.5% of the unmodified specimens, while the optimized HEMA and optimized alkali + optimized HEMA treated irradiated AF/PP specimens were about 15.4% and 10.7%, respectively. Weathering tests showed that unmodified specimens lost tensile features (tensile strength and tensile

modulus), but modified specimens retained tensile features for 600 hours despite exposure to severe weathering. The optimized alkali + optimized HEMA treated irradiated AF/PP specimen exhibits higher weatherability and is more durable than the other specimens.

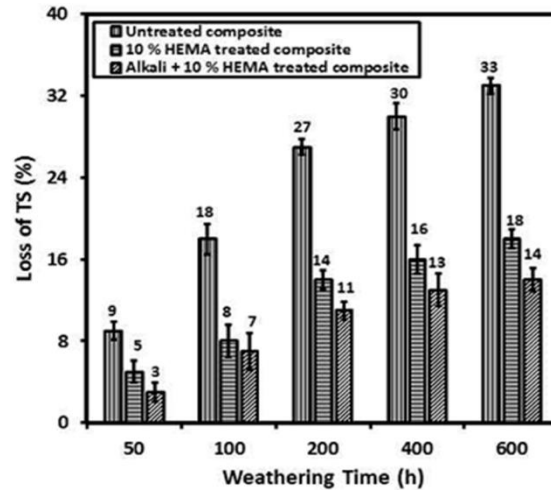


Figure 6: Loss of tensile strength of untreated and treated AF/PP composites due to weathering

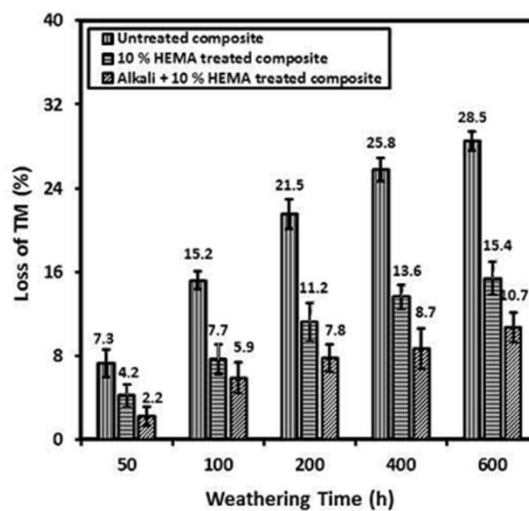


Figure 7 Loss of tensile modulus of untreated and treated AF/PP composites due to weathering

**CONCLUSIONS**

From the overhead, we can reach the resulting conclusions:

- In the present article, AF/PP composites were arranged by compression molding. Tensile strength, tensile modulus and impact strength of irradiated AF/PP composites exhibited superior outcomes than untreated ones.
- Irradiated AFs were treated with HEMA solutions and photocured under UV light at

dissimilar intensities. A momentous enhancement in tensile features was detected after HEMA treatment.

- Alkali treated AFs were grafted with optimized HEMA solution and photocured under UV light. The grafting of optimized alkali treated + optimized HEMA treated AF/PP composites exhibited the best mechanical features than optimized HEMA treated AF/PP composite.
- The moisture absorption behavior of the treated specimens exhibited a considerably inferior trend than that of the untreated

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specimens. We find in the weathering study that the tensile strength and tensile modulus of the treated specimens are inferior to those of the untreated specimens over the degradation period.

## REFERENCES

- [1] Amran, M., Izamshah, R., Hadzley, M., Shahir, M., Amri, M., Sanusi, M., Hilmi, H., 2015. The effect of binder on mechanical properties of kenaf fibre/polypropylene composites using full factorial method, *Applied Mechanics and Materials*. 695, 709-712.
- [2] Zaman, H.U., Khan, M.A., Khan, R.A., Arifur Rahman, M., Das, L.R., Al-Mamun, M., 2010. Role of potassium permanganate and urea on the improvement of the mechanical properties of jute polypropylene composites, *Fibers and Polymers*. 11, 455-463.
- [3] Zaman, H.U., Khan, M.A., Akter, N., Ghoshal, S., Khan, R.A., 2011. Role of gamma radiation and EGDMA on the physico-mechanical properties of jute fabrics/polypropylene composites, *Polymer Composites*. 32, 1888-1894.
- [4] Davindrabrabu, M., Januar, P.S., Dandi, B., Mohd Ruzaimi, M.R., Cionita, T., 2015. Effect of fibre loading on the flexural properties of natural fibre reinforced polymer composites, *Applied Mechanics and Materials*. 695, 85-88.
- [5] Komorek, A., Przybyłek, P., Brzozowski, D., 2015. The influence of UV radiation upon the properties of fibre reinforced polymers, *Solid State Phenomena*: 223, 27-34.
- [6] Khan, R.A., Zaman, H.U., Khan, M.A., Nigar, F., Islam, T., Islam, R., Saha, S., Rahman, M.M., Mustafa, A., Gafur, M., 2010. Effect of the incorporation of PVC on the mechanical properties of the jute-reinforced LLDPE composite, *Polymer-Plastics Technology and Engineering*. 49, 707-712.
- [7] Bodig J, Jayne BA. Von Nostrand Reinhold Company, New York, 1982, Chap. 10.
- [8] Ricciari, J., Vázquez, A., De Carvalho, L.H., 1999. Interfacial properties and initial step of the water sorption in unidirectional unsaturated polyester/vegetable fiber composites, *Polymer Composites*. 20, 29-37.
- [9] Gowda, T.M., Naidu, A., Chhaya, R., 1999. Some mechanical properties of untreated jute fabric-reinforced polyester composites, *Composites Part A: Applied Science and Manufacturing*. 30, 277-284.
- [10] Khan, M.A., Hossain, M., Hossain, M., Ali, K.I., 1997. Improvement of jute yarn through in situ copolymerization by UV radiation, *Polymer-Plastics Technology and Engineering*. 36, 285-296.
- [11] Ali, M.A., Khan, M.A., Ali, K.I., Hinrichsen, G., 1998. Mechanical studies of methyl methacrylate treated jute and flax fibers under UV radiation, *Journal of Applied Polymer Science*. 70, 843-848.
- [12] Mohanty, A., Khan, M.A., Hinrichsen, G., 2000. Surface modification of jute and its influence on performance of biodegradable jute-fabric/Biopol composites, *Composites Science and Technology*. 60, 1115-1124.
- [13] Khan, M.A., Haque, N., Al-Kafi, A., Alam, M., Abedin, M., 2006. Jute reinforced polymer composite by gamma radiation: effect of surface treatment with UV radiation, *Polymer-Plastics Technology and Engineering*. 45, 607-613.
- [14] Zaman, H.U., Khan, M.A., Khan, R.A., 2011. Surface modification of jute fabrics using acrylic monomers: Effect of additives, *International Journal of Polymeric Materials*. 60, 754-765.
- [15] Valadez-Gonzalez, A., Cervantes-Uc, J., Olayo, R., Herrera-Franco, P., 1999. Effect of fiber surface treatment on the fiber-matrix bond strength of natural fiber reinforced composites, *Composites Part B: Engineering*. 30, 309-320.
- [16] Zaman, H.U., Khan, M.A., Khan, R.A., 2011. Effect of ultraviolet radiation and potassium permanganate on the physico-mechanical properties of jute polymer composites, *Polymer-Plastics Technology and Engineering*. 50, 651-659.
- [17] Zaman, H.U., Khan, M.A., Khan, R.A., Mollah, M., Pervin, S., Al-Mamun, M., 2010. A comparative study between gamma and UV radiation of jute fabrics/polypropylene composites: effect of starch, *Journal of Reinforced Plastics and Composites*. 29, 1930-1939.
- [18] Joseph, S., Sreekala, M., Oommen, Z., Koshy, P., Thomas, S., 2002. A comparison of the mechanical properties of phenol formaldehyde composites reinforced with

- banana fibres and glass fibres, *Composites Science and Technology*. 62, 1857-1868.
- [19] El-Meligy, M.G., El-Zawawy, W.K., Ibrahim, M.M., 2004. Lignocellulosic composite, *Polymers for Advanced Technologies*. 15, 738-745.
- [20] Bledzki, A., Mamun, A., Faruk, O., 2007. Abaca fibre reinforced PP composites and comparison with jute and flax fibre PP composites, *eXPRESS Polymer Letters*. 1, 755-762.
- [21] Kumar, S., Misra, R., 2007. Analysis of Banana Fibers Reinforced Low-density Polyethylene/Poly ( $\epsilon$ -caprolactone) Composites, *Soft Materials*. 4, 1-13.
- [22] Venkateshwaran, N., Elayaperumal, A., 2010. Banana fiber reinforced polymer composites-a review, *Journal of Reinforced Plastics and Composites*. 29, 2387-2396.
- [23] The Society of Fiber Science and Technology (1991). *Water Sorption of Fibers from Tropical Plants*, 47, 434438.
- [24] ASTM-D 638-03, Standard test method for tensile properties of plastics. ASTM Standard. New York, NY: American Society for Testing Materials, 1997.
- [25] Marcovich NF, Ostrovsky AN, Aranguren MI, Reboredo MM. Proceedings from the 3rd International symposium on Natural Polymers and Composites-IS NaPOL/2000, Sao Pedro, SP, Brazil, May 14-17.
- [26] Datta, S.K., Chaki, T., Tikku, V., Pradhan, N., Bhowmick, A., 1997. Heat shrinkage of electron beam modified EVA, *Radiation Physics and Chemistry*. 50, 399-405.
- [27] Khan, M., Islam, M., Idriss Ali, K., 1996. Graft copolymerization of urethane acrylate on hessian cloth (jute) by UV radiation, *Separation Science and Technology*. 35, 299-315.
- [28] Atkins, E. In *Applied Fibre Science*; Happey, F., Ed.; Academic Press: London, 1979, vol. 3, Chap. 8.
- [29] Bledzki, A., Gassan, J., 1999. Composites reinforced with cellulose based fibres, *Progress in Polymer Science*. 24, 221-274.
- [30] Bledzki, A., Gassan, J., 1999. Composites reinforced with cellulose based fibres, *Progress in polymer science*. 24, 221-274.