Mechanical Properties Characterization of Jute Yarn Treated by Photo-curing with EG (Ethylene Glycol): Surface Treatment ($KMnO_4$)

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Abstract: Radiation-induced graft copolymerization is one of the most important methods to modify natural polymers. Jute (*Corchorus capsularis*) is an important natural fiber for its diversified application in eco-friendly environment. Jute is photografted with EG monomer to improve its characteristics. The different EG formulation was prepared in methanol along with 2% photoinitiator. The materials soaked in solution then radiation induced by UV processing. The highest mechanical properties of treated and untreated jute fibre like tensile strength (TS), elongation at break (Eb), and tensile modulus (Tm) were achieved with 5% EG concentration, 5 minutes soaking time and 4th pass of UV radiation intensities. The mechanical properties improvement of the jute yarns were increased at $P \geq 0.05\%$ on TS (2.4 MPa), Eb (1.8 MPa) and Tm (factor 2) and PL (17%) by the $KMnO_4$. The additives urea (1% w/v) showed the best results Pl (20%), Tf (2.6) and Ef (2). Water absorption capacity of treated samples was much lower (59%) up to 20 min then stable compared to the untreated samples (70%) where absorbed up to 110 min. Weathering effect on jute yarn exhibited less loss of weight compared to control fibers. The 1R analysis revealed that EG has been grafted onto jute cellulose at the sites of -OH groups of the jute cellulose backbone. Monomer concentration; soaking time and radiation intensity were optimized with respect to mechanical properties. The remarkable changes of physico-mechanical properties were achieved by the experiment.

Keywords: Modification, Jute, Cellulose, fibers, UV-radiation, monomer concentration.

INTRODUCTION

Polymer science and technology is one of the most active and promising fields in embracing a multitude of topics from natural polymers such as cellulose, wool, silk, jute etc. which are of utmost importance for living systems, to the synthetic high polymers. Jute (*Corchorus capsularis*) is a natural polymer composed mainly of cellulose, hemicellulose and lignin. The morphology of jute fiber describes the complex structural property of the fiber cells, which originate from proto-phloem tissues and developed into fiber bundle by the activity of the cambium [1]. Applications of natural polymers including jute materials faded away at the advent of synthetic polymers that are quite cheap and durable compared to natural polymer materials. Grafting promises to be a potentially effective means of altering the fiber properties through added polymer formed in situ without destroying the basic properties of the parent fiber. In recent years, grafting of vinyl monomer onto jute fibers and yarns has been receiving considerable attention by the scientist, particularly Indian and Bangladeshi scientists, because of the availability of raw jute production in this zone. Almost all of these works have been done by thermal method using different types of catalyst and radiation technique. Radiation is a very convenient method for graft initiation cause in allows considerable degree of control of structural factors of the polymer by careful selection of the dose and dose rate [2-6].

Improvement of jute yarn through in situ graft copolymerization using UV radiation was studied [7]. The experiment was conducted by radiation time varied from 15 to 180 min and concentration of MMA varied from 10 to 90%. The highest grafting of 11% is obtained with 50% MMA concentration at 60 minutes irradiation time; different types of minute amount additives (i.e. U, DP, MA EHA, NVP, TPGDA, TMPTA and $LiNO_3$) was incorporated into MMA+MeOH solution. Here the increase in grafting was observed by using additives TS & Eb increased 65 and 109% respectively. Modification of jute grafting for use in composites was performed [8]. Moisture absorption of jute fibers could be reduced significantly by treatment with graft copolymerization with MMA. The tensile strength and Elongation at break of jute fiber

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decreased on grafting whereas the initial modulus increased with increasing percentage of graft add on. Glass fiber grafted jute fiber unsaturated polystahybrid composites should give better tensile, flexural and laminar shear strength than composites fabricated using untreated jute fiber. Graft copolymerization of MMA onto jute fiber has been stated [9] by using eerie ion initiator. Effects of temperature, time of reaction, lignin content of jute, monomer concentration and initiator concentration have been studied. After studied the maximum percentages of grafting and grafting efficiency have been found to be 132 and 71% respectively. A kinetic study and activation energies have also been realized. Grafting of MMA onto jute fibers has been showed [10] using thiourea redox initiator system. The effects of monomer concentration, Si_20_2 and graft yield were studied-Beside this, the effect of temperature, time and amount of jute fibers and the effects of some inorganic salts and organic solvents and graft yields were also investigated. Graft polymerization of acrylonitrile onto jute fibers was studied using Ce (iv), lippuric acid redox initiator system [11]. The effect of time, temperature, monomer concentration, metal ion (Ce^{4+}) was observed. Lippuric acid, sulfuric acid and amount of jute fiber on graft yield were also studied. The effects of some organic solvents and inorganic salts on graft yield were also studied. IR spectra of chemically modified bleached jute and grafted jute were taken and their characteristic bonds were identified more than 90% graft was achieved. Graft copolymerization of MMA, acrylonitrile and acrylamide onto jute fiber using iron (II) hydroperoxide initiator were explained [12]. The effects of concentrations of ferrous ammonium sulfate, monomer and H_20_2 time and temperature on percentage of graft yield were studied. The grafted fibers were characterized by thermo gravimetric analysis, IR Spectroscopy and X-ray diffraction studies. Degradable property of UV-cured hessian clothe (jute) performed [13]. Enhancement of tensile strength and elongation was determined. Loss of these properties due to simulating weathering was also measured and degradable to be buried in water and mud for a long period and soil retained their tensile properties. Improvement of physico-mechanical properties of hessian cloth (jute) by graft copolymerization of urethane acrylate with UV-radiation studied [14].

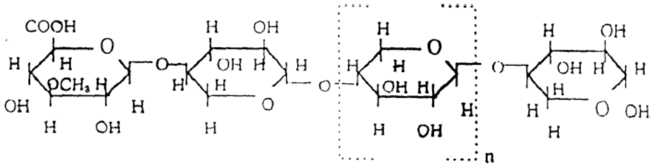
Natural fiber reinforced biodegradable matrix composite: effect of surface modifications of jute on the performance of jute-biopol composites has been revealed [15]. The effect of chemical modification (dewaxing, alkali treatment, and 10% acrylonitrile grafting) of jute on performance of biodegradable jute-biopol composites is reported.

In this work, at first, grafting of monomer EG onto jute yarn has been performed by UV radiation. After that effect of pretreatment on the surface of jute yarn using $KMnO_4$ and different radiation sources such as ultraviolet radiation and has been studied. Also different physico-mechanical properties have been observed and determined.

MATERIALS AND METHODS

Materials

The samples cellulosed based jute yarns were collected from the local market.



Cellulose structure

The chemicals; ethylene glycol (HO-CH_2-CH_2-OH), methanol (CH_3OH) extra pure (Merck, Germany); acetone (CH_3COCH_3), Urea, Potassium permanganate ($KMnO_4$) (BDH, UK) and the photoinitiator; benzyl dimethyl ketal (IRGACURE 651) was supplied by Ciba Geigy.

Methods

Photo-Curing Process

The ultra violet ray was applied for radiation processing. The radiation was applied the intensities of passes (2-20 times) for radiation dose. The ultraviolet radiation has been used to initiate grafting [16]. The UV manicure Machine (IST Technik, Germany) with intensity of the lamp 2 kW 9.5 A current and the wave length 254–313 nm a conveyer speed of 4m/min. For each pass the samples moved 0.50 m under the UV conveyer belt speed [17]. Processing and characterizing of jute fiber reinforced thermoplastic polymers was reported [2].

Sample Preparation

Locally collected jute yarns were cut into 25cm and washed with acetone to remove the foreign particles. Then dried in the oven at 105^0 C for about 24 hrs to remove moisture and stored in the desiccators. The weight of the individual fiber was taken by the electronic balance separately.

Preparation of Formulations

The sensitizer as sodium 2,7–anthraquinonedisulfonate and 2-methylanthraquinone have used to graft acrylamide, styrene and other monomers onto cellulose (cellophane) and cellulose acetate films. Approximately 0.5% of the sensitizer (based on monomer) was used [18]. For this experiment a series of formulation was prepared using different proportions of EG monomer in methanol along with 2% photoinitiator IRGACURE – 651. A number of 100 ml beakers were taken for different formulations. Bulk monomer EG of different proportions (3, 5, 10 and 20% v/v) were mixed with MeOH (95, 93, 88 and 78% v/v respectively). In each of the solutions 2% photoinitiator was added. The mixtures were stirred thoroughly by a glass rod until a clear transparent solution was obtained and the beakers were covered with foil paper to resist degradation of photoinitiator. The beakers were labeled as 3, 5, 10 and 20% v/v for the stock solution.

Determination of Polymer Loading

The mechanical properties of polymer characterization are an important for polymeric materials [19-20]. The previously weighted and dried samples were kept immerged in different formulations to determine the polymer loading. Ten individual weighted fibers were taken for each formulation. The fibers were marked according to their weights and dipped in each of the solutions and kept immerged for different period of time (soaking times). The soaking time varied from 3-20 minutes (3, 5, 10 and 20 min). After soaking in the formulations, they were passed under UV curing lamp for different radiation doses (2, 4, 6, 8, 10 passes). It was necessary to pass the treated substrates through the UV radiation several times to ensure curing. The irradiated fibers were then left in dark for 24 hrs to complete of the polymerization. After 24 hrs the fibers were washed with acetone for about 5 minutes to remove unreacted monomer and dried in the oven for 2 hrs at 105^0 C. The dried fibers were then cooled in the desiccators and were weighed for the second time in the electronic balance. The polymer loading of EG treated jute fibers were calculated by deducting the final weight from the initial weight. $\text{Polymer Loading}(\%) = \frac{W_t - W_0}{W_0} \times 100$ Where, W_t = weight of the treated dry sample, W_0 = weight of the dry sample before treatment. The polymer loading of individual fiber was added to calculate the polymer loading of each of the formulations for each of the soaking times.

Determination of Tensile Properties

The measurement of mechanical properties is very much important for polymeric materials. Scientist are followed the proper technique for characterizing the properties. Various tensile properties such as tensile strength and elongation at break of both treated (T_1, E_1 respectively) and untreated virgin yarns (T_2, E_2 respectively) were measured by a universal testing machine (INSTRON, model 1011, UK). The load capacity was 500 N, efficiency was within ± 1%. The cross-head speed was 2 mm/min and the gauze length was 20 mm. The increment in tensile properties after UV curing was expressed as tensile strength factor Tf ($Tf = T_1/T_2$) and elongation factor Ef ($Ef = E_1/E_2$).

Surface Treatment

Pretreatment with $KMnO_4$

Virgin jute yarns were subjected to pretreatment with $KMnO_4$. Firstly different solution containing 0.03, 0.05, 0.1% $KMnO_4$ (v/v) were prepared. The fibers were then dipped in the beakers containing solutions for 5 minutes. Then they were washed with running water until $KMnO_4$ was removed completely. After drying the fibers were treated with monomer. The polymer loading, tensile properties were determined.

Addition of Additive

An additive urea was added to impress better properties to the treated samples. For this purpose different small concentration of urea (0.5, 1 and 2% w/v) was incorporated with the optimized formulation during the treatment of the pretreated jute yarn.

Determination of Water Uptake Values

In order to measure the water uptake of both treated and virgin samples, the fibers were immerged in water in a static bath at 25^0C for 30 minutes. The fibers were taken out of the water container at constant time interval, were wiped carefully and then weighed. The weight gain of the samples was calculated.

Simulated Weathering Test

Both untreated and treated fibers (previously weighed) were subjected to simulated weathering test by using weather tester (Model: QUV, Q-Panel Company, U.S.A, Volts: 230, Hz: 50, Watts: 150) for 600 hours which was performed in alternating cycles of sunshine over 4 hrs (65 ± 2^0C) and dews and condensation 2 hrs (45 ± 2^0C). The samples were then dried in the oven for half an hour, were weighed and their mechanical properties were measured.

Pretreatment with $KMnO_4$ and Addition of Urea

In this method, at first jute yarns were treated by $KMnO_4$. Then urea was used in monomer solution and was subjected to grafting at optimized condition. Tensile properties of these treated samples were determined. Water uptake, weathering effect and soil degradation studies were also performed.

IR Sample Preparation

The acetone-extracted jute yarn were dried at 105^{0}C for 24 hrs and powdered in a mortar. Fourier transforms infrared spectroscopy (FTIR) spectra are characterized by the pure potassium bromide pellet technique on RX1 (Model IR-470, Shimadzu, Japan, region 4000-400 cm). The jute compounds for IR analysis were frequently obtained by mixing and grinding a small amount of the powdered jute materials (1 mg) with dry and pure KBr (200 mg). The thorough mixing and grinding were accomplished in a mortar by a pistler. The powdered mixture was then compressed in a metal holder under a pressure for 8-10 tonnes to produce a pellet. The pellet was then placed in the path of the infrared beam for measurements.

Statistical Analysis

For each measurement, 3 samples in each replicate were tested. Analysis of variance and Duncan's multiple-range tests were used to perform statistical analysis of all results, using PASW Statistics Base 18 software (SPSS Inc., Chicago, IL, USA). Differences between means were considered to be significant when $p \leq 0.05$.

RESULTS AND DISCUSSIONS

Optimization of Grafting Condition of Monomer EG (UV Curing Method)

Cellulose is usually grafted with vinyl monomers which are unsaturated compounds having the general formula $CH_2=CHX$, where X is a functional group of the type -OH, -Cl, -C≡N, $-C_6H_5$. Their reaction with cellulose involves either a free radical mechanism or an ionic mechanism, depending on the monomer one or the other type of initiation may be preferred. Techniques involving UV are particularly attractive since the UV sources relatively cheap, flexible and easy to install. Photo initiation is also unique in that it allows a precise control of the duration and the rate at which initiating species are produced. This explains photo induced polymerization has attracted so much interest during the last decade and has found a growing number of industrial applications. An advantage of using UV-radiation is the fact that rather inexpensive radiation sources such as mercury lamps or germicidal lamps can be used to initiate grafting. Owing to the low energy of this type of radiation the degradation of the cellulose substrate is almost negligible. On the other hand, this method is only applicable for surface grafting because of the low penetrating power of the UV-radiation. It is therefore most useful for modifying the surface properties of films and fibers. Intense irradiation with near-ultraviolet radiation results in a loss of tensile strength, a reduced degree of polymerization and an increase in number of carboxyl and carbonyl groups [21-23]. The results of mechanical properties of photocured jute fibers are presented in individual parameter with figure and their interpretation are described below,

Optimization of Monomer Concentration

Monomer concentration plays an important role because it affects the polymerization rate and the overall conversion as the properties of cross-linked polymerization [24]. Polymer loading values of the yarns were calculated as the weight gain (%) after they were cured under UV radiation. The PL values of the EG treated yarns at different radiation intensities as a function of monomer concentration are shown in the Figure **1**.

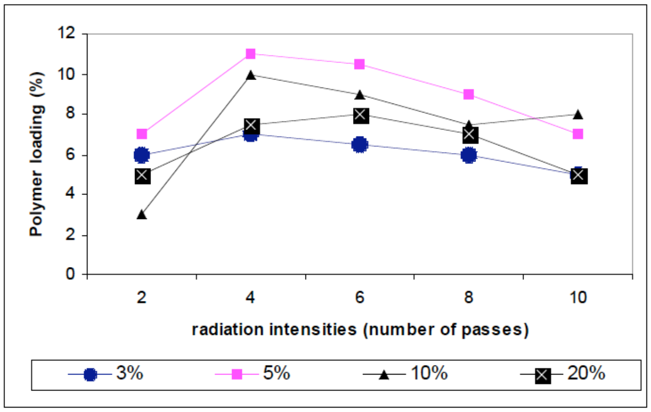


Figure 1: Polymer loading values of the treated jute yarn against radiation intensities as a function of monomer concentration; soaking time 5 minutes.

The values were low at low monomer concentration. It was increased with EG concentration and reached maximum with 5% EG (11%) at 4th pass of UV radiation. The PL values increases with initial radiation doses, attains the maxima and then decreases as the radiation dose (number of pass) increases. The decrease in PL values after the attainment of the maximum PL values could be caused by the radiation degradation at higher UV doses, which was established in previous work by different detection technique. However, the highest PL value is achieved at 5 minutes soaking time by the sample treated with 5% EG after which the PL maximum values decreases with increases with soaking time. Maximum PL values are obtained mostly with the 4th UV pass.

Tensile Properties

The tensile properties like tensile strength and elongation at break are expressed as tensile strength factor (T*f*) and elongation at break factor (E*f*). The tensile strength factor *Tf* is measured as T_1/T_2 where, T_1 is the tensile strength of the treated yarn and T_2 is that of the untreated yarn. The tensile strength values are plotted in the Figure **2** against radiation intensities as a function of monomer concentration. The figure indicates that the T*f* values increase with the increase of monomer concentration which is highest with 5% EG (1.8) and after that it decreases with the increase of monomer concentration. The increase of T*f* with the EG concentration is due to the increase of the rate of polymerization. And the decrease is because of the radical-radical recombination reaction among the growing EG molecules.

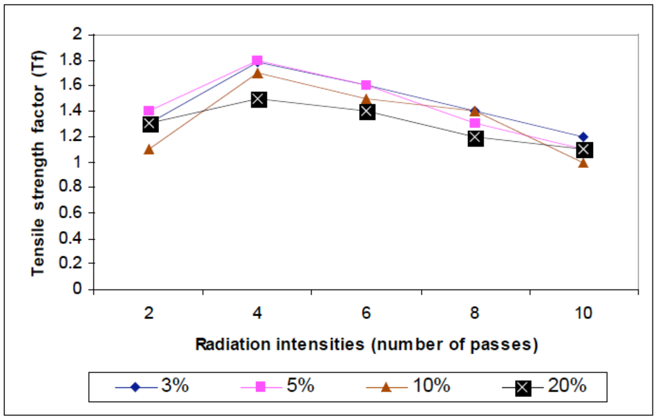


Figure 2: Tensile strength factor of the treated jute yarn against radiation intensities as a function of EG monomer concentration, soaking time 5 minutes.

The elongation up to the breaking point of treated and untreated jute yarns samples were expressed as elongation factor (E*f*) and E*f* = Eb_t/Eb_u, where Eb_u and Eb_t are the elongation at break of the untreated and treated yarns respectively. The enhancement of elongation is depicted in Figure **3** against UV doses as a function of monomer concentration.

Modulus Factor

The modulus factor or Mf is the ratio of the modulus of the treated jute samples (M_t) to that of the untreated or virgin sample (M_v), i.e., $M_f = \frac{M_t}{M_v}$; Where, M_t, M_v are the modulus of treated and untreated jute yarns. Modulus factor (Mf) of the treated jute yarns against radiation intensities as a function of monomer concentration is shown in Figure **4**.

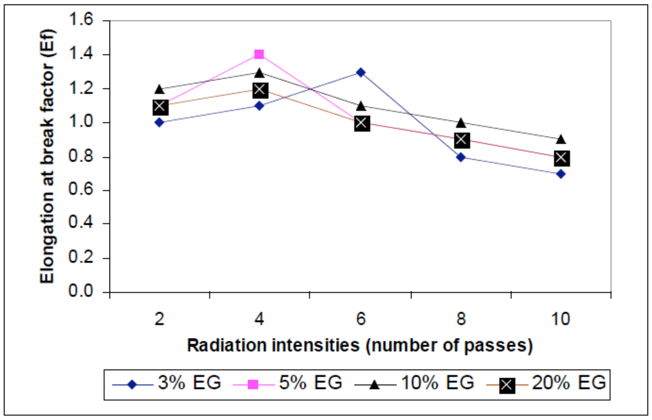


Figure 3: Elongation at break factor of the treated jute yarn against radiation as a function of monomer concentration, soaking time 5 minutes.

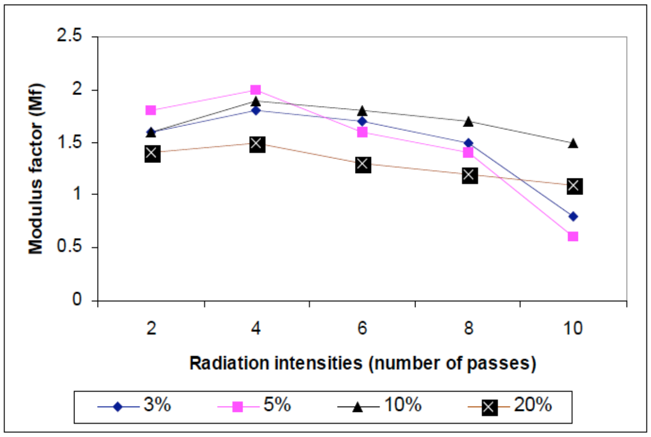


Figure 4: Modulus factor (Mf) of the treated jute yarns against radiation intensities as a function of monomer concentration, soaking time 5 minutes.

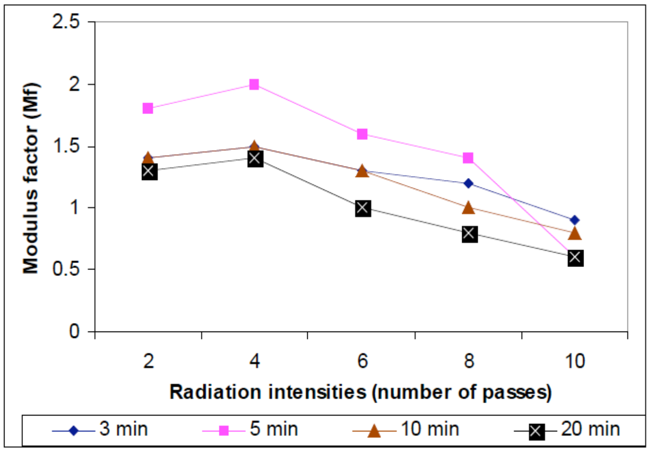


Figure 5: Modulus factor of the treated jute yarns against radiation intensities as a function of soaking time, monomer concentration 5%.

The highest modulus factor 2 is achieved by the sample treated with 5% monomer at 4 irradiation passes at 5 minutes soaking time. Also, Modulus factor of the treated jute yarns against radiation intensities as a function of soaking time is shown in Figure **5**.

Optimization of Soaking Time

Polymer Loading

The values of PL are presented in the Figure **6** as a function of soaking time. At low soaking time, PL value is low; it increases with the increase of time with the same monomer concentration (5% EG). The highest value is obtained with 5 minutes of soaking. After that, it decreases with time.

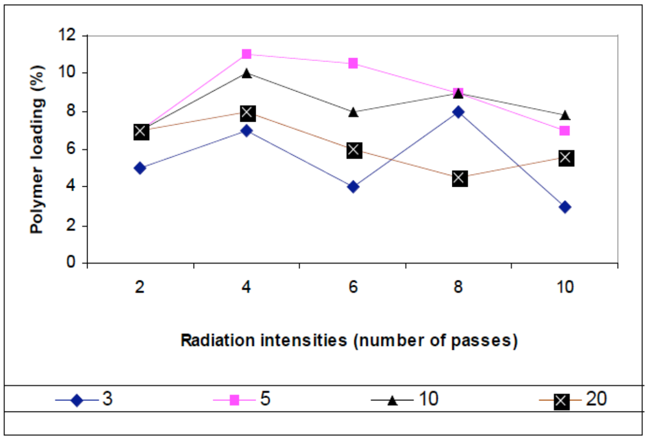


Figure 6: Polymer loading values of the treated jute yarn against radiation intensities as a function of soaking time (minutes), monomer concentration 5%.

Tensile Properties

The tensile strength factor *(Tf)* of the treated EG jute yarns as function of soaking times are presented in the Figure **7**. At low soaking times, the values are low, it increases with time and it was highest with 5 minutes of soaking (1.8). After attainment of the highest value, it decreases with time. The decrease of values with time may be due to the lower rate of polymerization at higher soaking times. The elongation at break factor (*Ef)* of the treated yarns with respect to soaking times is shown in the Figure **8**. The highest value is achieved with 5% EG at 5 minutes of soaking time (1.4) Modulus factor against radiation intensities as a function of soaking time are shown in Figure **8**. The highest value is 2% at 5 minutes soaking time.

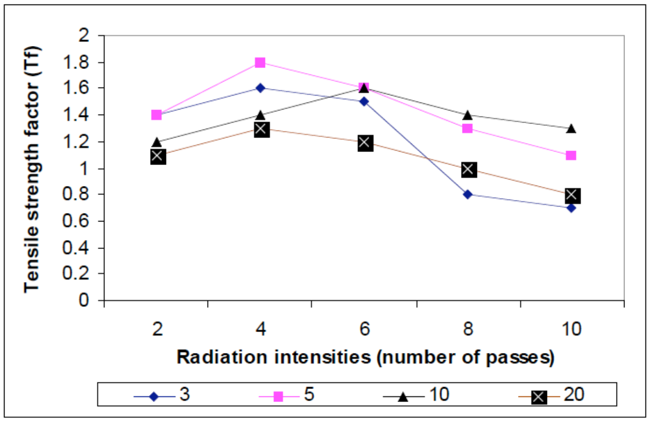


Figure 7: Tensile strength factor of the treatment jute yarn against radiation intensities as a function of soaking time, monomer concentration 5%.

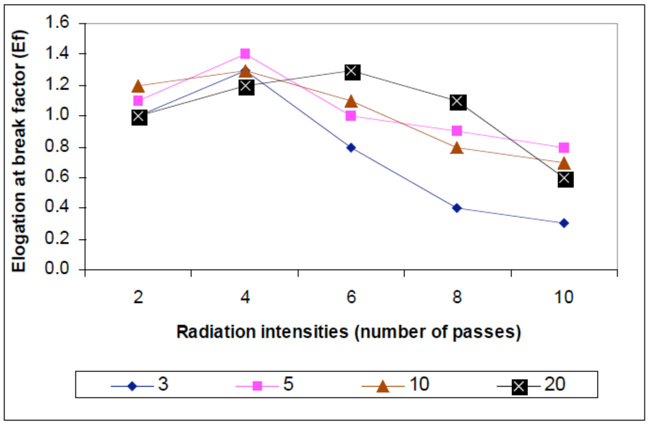
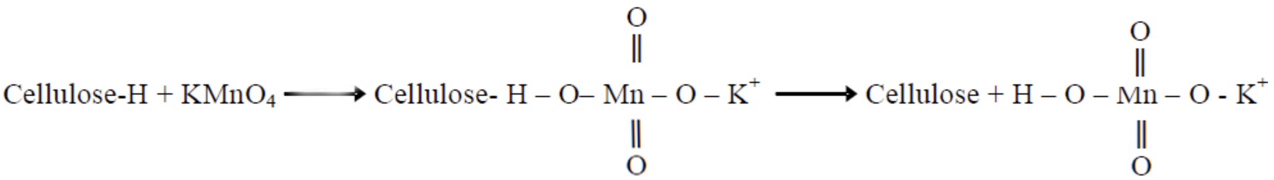


Figure 8: Elongation at break factor of the treated jute yarns against radiation intensities as a function of soaking time, monomer concentration 5%.

Effect of Surface Treatment with KMnO4

Polymer Loading

Jute yarns were subjected to surface treatment with $KMnO_4$. The yarns were soaked for different soaking times (1, 5 and 10 minutes) with $KMnO_4$ of varying concentrations (0.03, 0.05, 0.1% v/w respectively). Then they were treated with 5% EG. Among the different concentrations, 0.05% $KMnO_4$ at 5 minute of soaking time produced the best results (PL = 17% and *Tf* = 2.4). The results of PL with respect to KMnO4 concentration is shown in the Figure **9**. In presence of $KMnO_4$ the cellulose molecules of jute yarns undergo the following reactions (proposed):



$$\text{Cellulose-H} + KMnO_4 \longrightarrow \text{Cellulose- H} - O - \underset{\underset{O}{\|}}{\overset{\overset{O}{\|}}{Mn}} - O - K^+ \longrightarrow \text{Cellulose} + H - O - \underset{\underset{O}{\|}}{\overset{\overset{O}{\|}}{Mn}} - O - K^+$$

This cellulose free radical is quite stable which supports the higher rate of reaction with monomer molecules. Thus permanganates induce grafting of EG on to cellulose molecules of jute yarns.

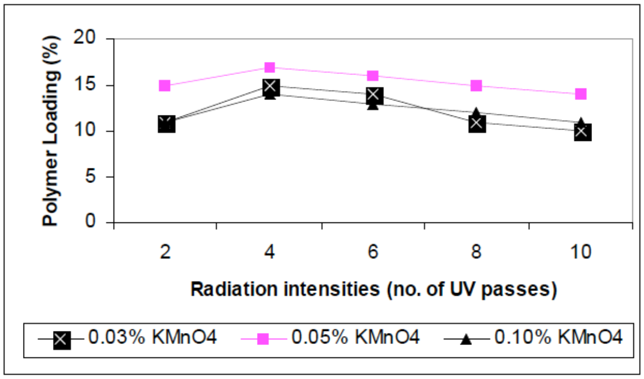


Figure 9: Effect of $KMnO_4$ (different concentration) on the polymer loading values of treated jute yarn, treating time 5 min (monomer concentration 5%).

Tensile Properties

The tensile properties *(Tf* and *Ef)* of the treated yarns with respect to $KMnO_4$ concentration and reaction time are shown in the Figure **10** (for T*f*) and Figure **11** (for *Ef)* respectively. The highest *Tf* (2.4), *Ef* (1.8) are achieved with 0.05% concentration at 4 pass. Both PL and mechanical properties increase with $KMnO_4$ concentration and is highest with 0.05% $KMnO_4$. On increasing the concentration the properties decrease very much due to the degradation of fiber of yarn.

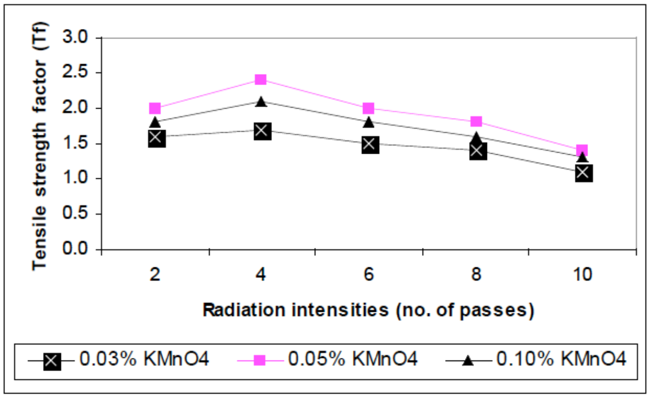


Figure 10: Effect of $KMnO_4$ (different concentration) on the tensile strength factor (Tf) of the treated jute yarn, treating time 5 min.

Effect of Additive on the Monomer Treated Jute Yarns

For the improvement of the properties an additive Urea of different concentrations (0.5 - 2%) was added to the optimized solution to monitor its effect on the properties. Enhanced properties (PL=20%, *Tf* = 2) were achieved with 1 % Urea. The results of PL, Tf and *Ef* are presented in the Figures **12**, **13**, **14** respectively. Urea possesses >C=O group adjacent to a nitrogen atom having a lone pair of electrons which are activated to form a bridge between the monomer and the cellulose through the additive. Oxygen has more affinity towards electrons; thus, the electron clouds are densely populated around the oxygen atom of >C=O groups, thereby pulling more electrons towards the oxygen from the area of the nitrogen atom or its vicinity, creating some favorable conditions for the augmentation of the monomer and the additive units with the cellulose backbone polymer of the substrate [25]. Urea is an inclusion compound whose properties would assist partitioning by complexing with monomer. This can lead to an increase in monomer concentration at a grafting site and thus enhance reactivity at that site [26].

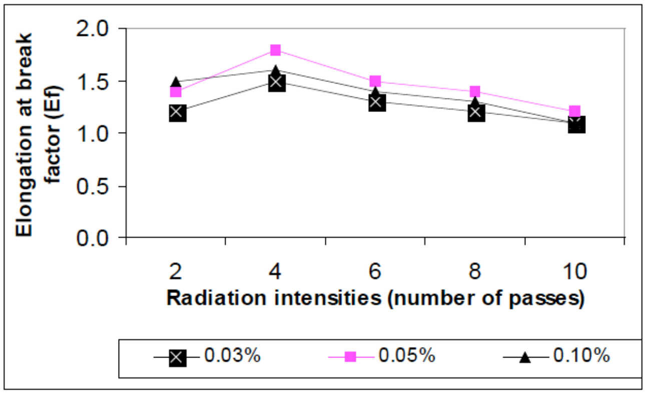


Figure 11: Effect of $KMnO_4$ (different concentration) on the elongation at break factor (Ef) of treated jute yarn, treating time 5 min.

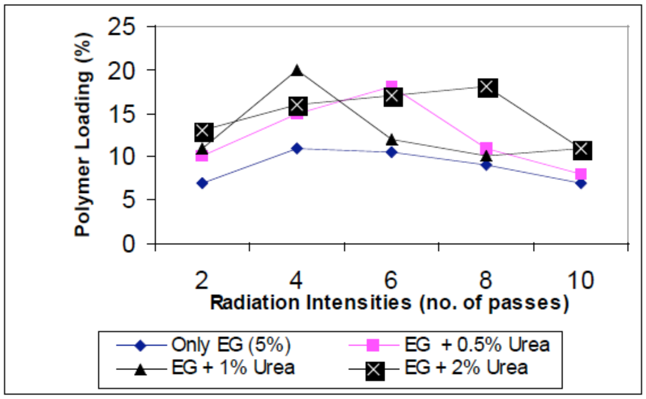


Figure 12: Effect of urea on the polymer loading values of the treated jute yarn as a function of urea concentration soaking time 5 minutes.

Effect of Pretreatment with $KMnO_4$ and Addition of Urea

Again urea was also incorporated with 5% EG solution when the permanganate treated yarns were

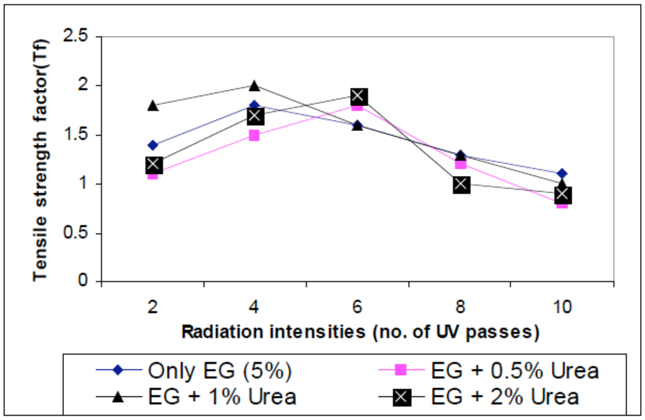


Figure 13: Effect of Urea on the tensile strength factor of the treated jute yarn as a function of urea concentration, soaking time 5 minutes.

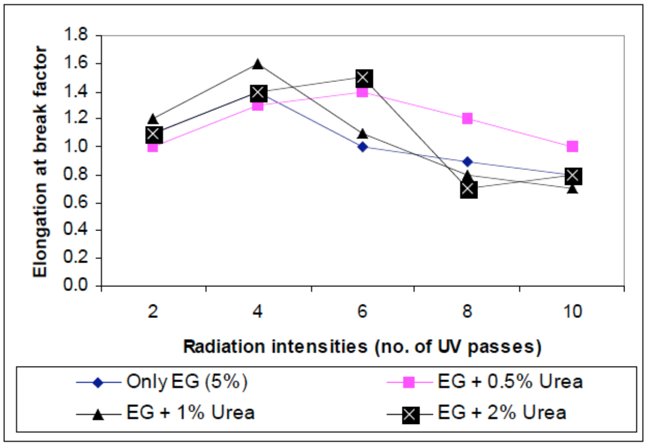


Figure 14: Effect of urea on the elongation at break factor of the treated jute yarns as a function of urea concentration.

treated with the optimized formulation. Then more enhancements of properties were observed with 0.05% KMnO4 and 1% Urea at 5 minute of soaking. The PL value reached to 20% and the Tf was 2.6 (Figures **15-17**) There was a minor change in the Ef was 2.0.

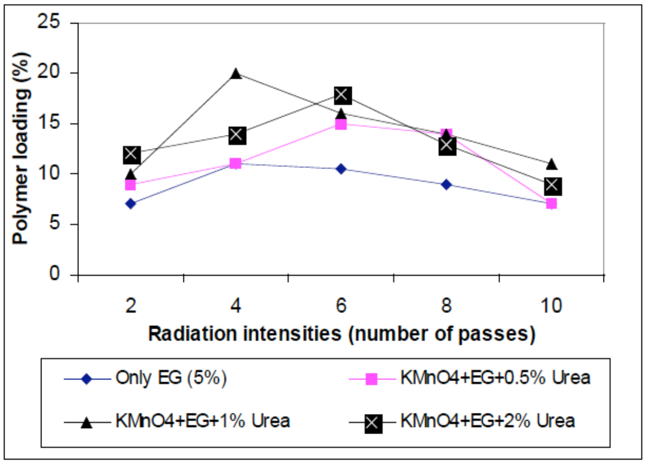


Figure 15: Effect of $KMnO_4$ + Urea on the polymer loading values of treated jute yarn, soaking time 5 minutes.

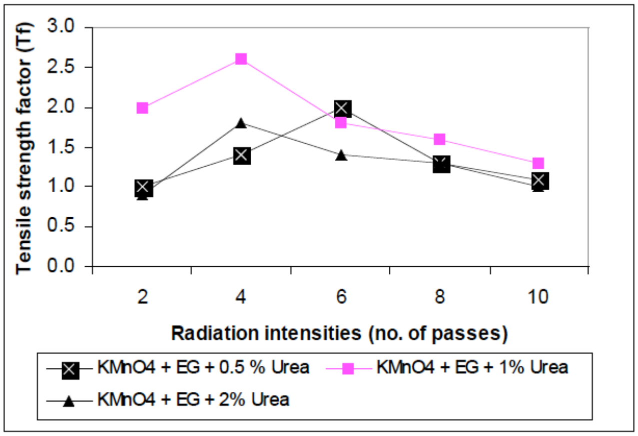


Figure 16: Effect of $KMnO_4$ + Urea on the tensile strength factor (Tf) of the treated jute yarn, soaking time 5 minutes.

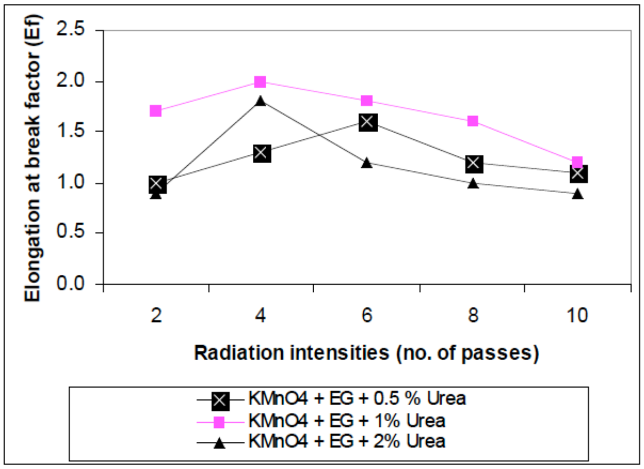


Figure 17: Effect of $KMnO_4$ + Urea on elongation at break factor of the treated jute yarn, soaking time 5 minutes.

Water Uptake

Water uptake values of the virgin and treated yarns were calculated by immerging the fibers in water contained in a static bath at the room temperature .The yarns were taken out of water after constant time interval and their weight gain were calculated. The results of water uptake values of the treated and untreated yarns are shown in the Figure **18**. All the 5% EG treated yarns took up water within the first 20 minutes of soaking, the values were constant. But the untreated fibers continued to take up water throughout the period of monitoring. The hydroxyl groups of the cellulose molecules were filled up by the monomer molecules. So the water uptake value of that system was lowest. This achievement is similar to the findings for the improvement of jute fiber through UV cured film urethane acrylate [27]. Physical and mechanical properties of the LJV cured film, role of plasticizers and water uptake were investigated. Water and moisture

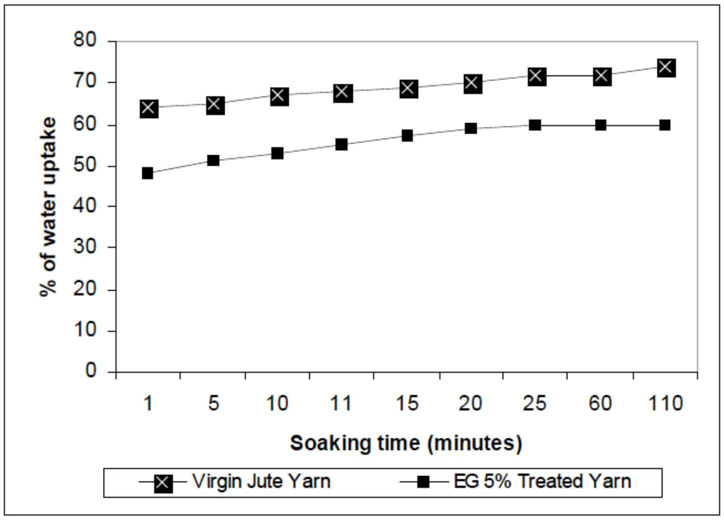


Figure 18: Water Uptake values of the treated jute Yarn.

take up at different relative humidity conditions decrease significantly.

IR Spectra of Jute

The characteristic features of the infrared (IR) spectra of jute fibers are due to its lignin and hemicellulose constituents. The IR spectra of jute yarn were taken with good resolution and are shown in the Figure **19**; peak assignments are given in Table **1**. The H-bonded O-H stretching causes the board band between 3600 and 3200 cm^{-1}. The O-H is present in the cellulose and hemicellulose of the jute fiber. The usual glucose linkage in the cellulose is characterized through the C-H stretching around the 2940-2890 cm^{-1} band and 1377 cm^{-1}. The linkage vibration is also observed at 895 cm^{-1}. The acetylated xylam bands are noticed at 1728 and 1246 cm^{-1}. The band at 1740 cm^{-1} is due to the hemicellulose constituent (carboxylic and acetyl functionalities and ester linkages). It is necessary to mention that the C=O stretching of the uronic acid of the hemicellulose, and the unconjugated keto groups of the lignin can be observed around 1700 cm^{-1}, but the conjugated aryl carbonyl stretching can be noticed at 1644 cm^{-1}. The asymmetric C-H deformation present in methyl and methylene groups is observed by the 1454 cm^{-1} band. The aromatic skeleton of lignin is observed at 1418 cm^{-1} and 1497 cm^{-1}. The peak at 1318 cm^{-1} is attributed to the aromatic ring breathing with C-O stretching in syringyl units of lignin; but the peak at 1111 cm^{-1} is due to the aromatic C-H in plane deformation of guaiacyl and syringyl units. The

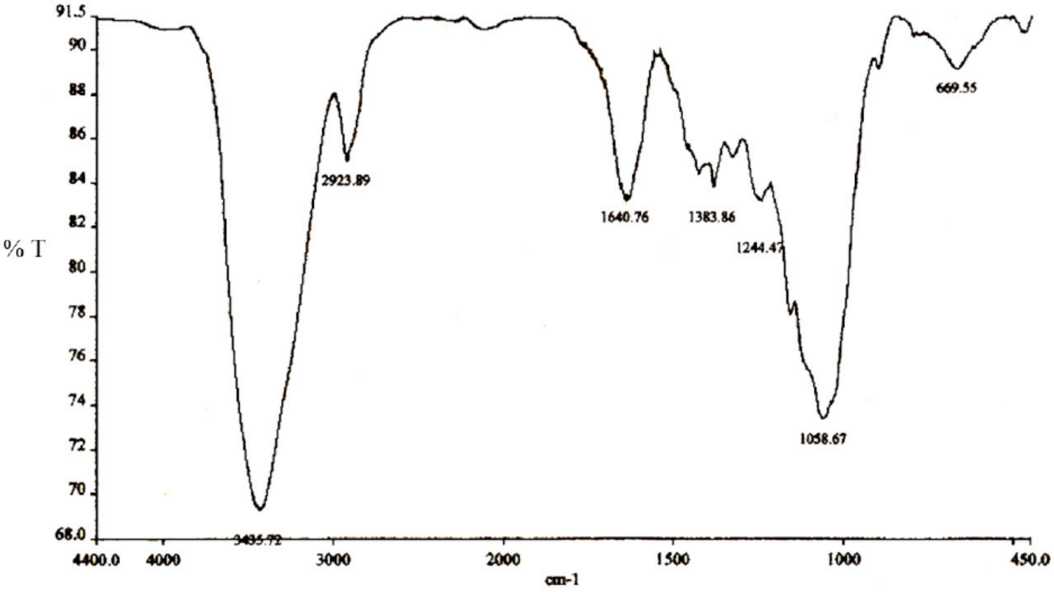


Figure 19: IR spectrum of Virgin Jute (VJ).

Table 1: Characteristics IR Peaks of Jute

Frequency (cm^{-1})	Vibration
3600 – 3200	H-bonded OH stretching
2940 – 2890	C-H stretching
1728	C=O stretching of acetyl group in jute xylans
1644	Conjugated arylcarbonyl stretching
1497	Aromatic skeletal vibration
1454	Asymmetric C-H deformation in methyl and methylene group
1418	Aromatic skeletal vibrations coupled with C-H in plane deformation
1377	C-H bending
1318	Aromatic ring breathing with C-O stretching in syringyl unit
1246	C-O stretching of acetyl group
1156	Antisymmetric bridge oxygen stretching of guaiacyl
1111	Aromatic C-H in plane deformation of guaiacyl and syringyl units
895	Linkage variation

antisymmectric bridge oxygen stretching is observed at the 1156 cm^{-1} peak.

IR Analysis of $KMnO_4$ and EG Treated Jute

The IR analysis of jute + EG is shown in Figure **20**. There is a clear stretch at 1427cm^{-1} in IR spectrum of $KMnO_4$ and EG treated jute compared to virgin jute in Figure **19**. This is due to asymmetric C-H deformation in methylene group.

The findings are related to the reported radiation induced jute plastic composite; preparation and IR studies [28]. Jute plastic composite has been prepared with tossa jute yams and MMA mixed with methanol at different properties using Co-60 gamma sources irradiation. Incorporation of a minute amount of (1%) additive like N-Vinyl pyridine, Tripropyleneglycol diacrylate and trimethylol propane triacrylate, or urea substantially increased the grafting of MMA onto jute yarn. The TS, water absorption and moisture absorption at different relative humidity has been detected. Both TS, EB, decreased with increased grafting. The IR study reviled that MMA has been grafted onto jute cellulose at the sites of OH groups of the jute cellulose backbone.

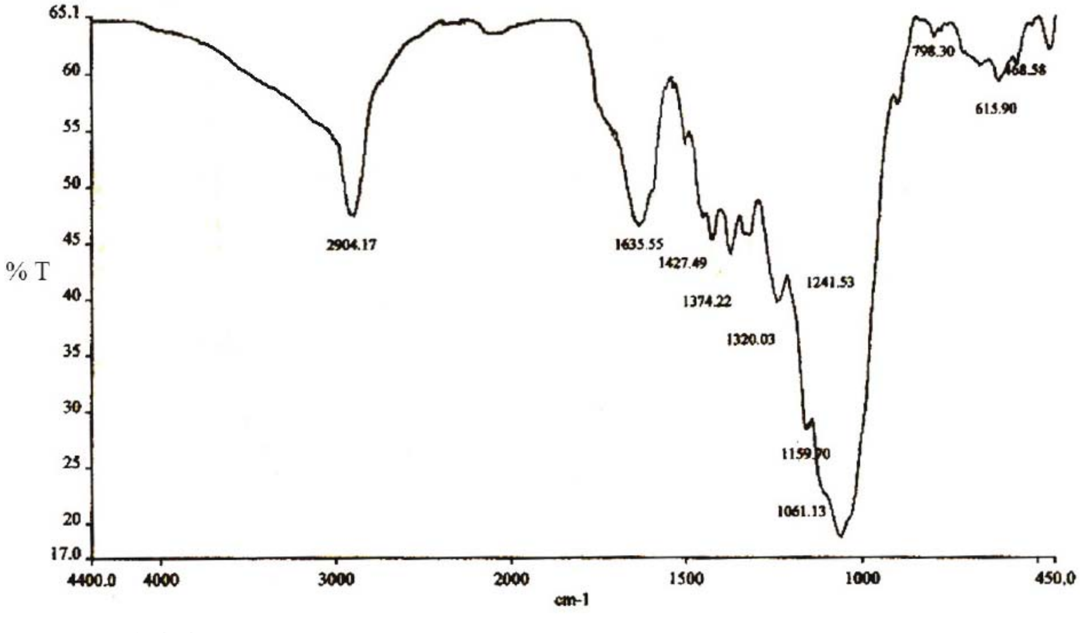


Figure 20: IR spectrum of Virgin Jute + EG + $KMnO_4$.

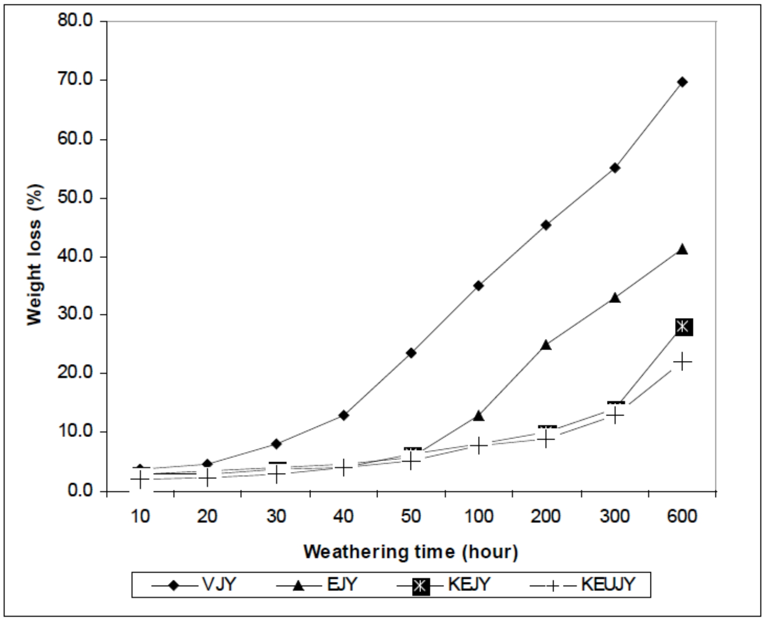


Figure 21: Weigth loss (%) study of Virgin Jute (VJY), Ethylene glycol + Jute Yarn (EJY), $KMnO_4$ +EGJY and $KMnO_4$ + EG +Urea+JY.

Simulating Weathering Effect

Virgin jute yarn, jute yarns treated with 5% EG, 0.05% $KMnO_4$ + EG, $KMnO_4$ + EG + Urea (1%) were exposed to accelerating weather tester over a period of about 600 hrs to study the degradation properties. The weight loss were periodically determined which are shown in Figure **21**.

CONCLUSION

For the improvement of physico-mechanical properties jute yarns were treated with methanolic solution of EG in along with photoinitiator IRGACURE 651 (2%) and cured under UV radiation. Concentration of monomer; soaking time and radiation intensity were optimized with respect to mechanical properties and found prominent increases.

In the case of EG (Photocuring method); enhanced tensile strength (tensile strength factor, Tf= 1.8, elongation at break factor 1.4) and polymer loading (11%) were achieved with 5% EG (at 5 min of soaking time). And modulus factor 2 is achieved by the sample treated with 5% monomer. Urea (0.5% - 2%) was added to the optimized solution (5% EG) to improve the properties and 1% Urea showed the best results (PL = 20%, Tf = 2, Ef =1.6). For further upgrading the properties the yarns were subjected to surface treatment with $KMnO_4$. All these yarns were treated with monomer along with and without urea. Among these $KMnO_4$ treated yarns produced the best results (PL = 20%, Tf = 2.6, Ef = 2) along with 1% Urea.

This is a unique achievement in the sense that the mechanical properties of the jute yarns can be improved by curing of $KMnO_4$ treated yarns followed by addition of additive (urea) rather than curing of jute yarns without pretreatment or any additive. Both $KMnO_4$ and Urea are very cheap. This method of modification of the jute yarn appears to be economical.

REFERENCES

[1] Ghosh SS, Rao KR, Patel JS. The anatomy of retted jute. Agric. Res. Memoir No.1, Indian Jute Committee 1944.

[2] Karmaker AC, Hinrichsen G. Processing and characterization of jute fiber reinforced thermoplastic polymers. Polym Tech Eng 1991; 30(5-6): 609. http://dx.doi.org/10.1080/03602559108019223

[3] khan MA, Hassan H. Polymer surface modification: Relevence to Adhesion 2044; 3: 263-283.

[4] Khan MA, Hossain MM, Hossain MA, Idriss-Ali KM. Polymer surface modification: Relevence to adhesion. Polym Tech Eng 1997; 36(2): 285. http://dx.doi.org/10.1080/03602559708000620

[5] Khan MA, Islam MN, Idriss-Ali KM. Graft copolymerization of urethane acrylate on Hessian cloth (jute) by UV radiation. Polym Tech Eng 1996; 35(2): 299. http://dx.doi.org/10.1080/03602559608000585

[6] Uddin MK, Khan MA, Idriss-Ali KM. Degradable jute plastic composites. Polym Degrad Stab 1997; 55(1): 1-7. http://dx.doi.org/10.1016/S0141-3910(96)00157-7

[7] Ali KMI, Khan MA, Akhunzada KS. *In situ* jute yarn composite with HEMA via UV radiation. J Appl Polym Sci 1999; 71(5): 841-846. http://dx.doi.org/10.1002/(SICI)1097-4628(19990131)71:53.0.CO;2-6

[8] Varma DS. Maralis, Modification of jute by grafting for use in composite, Indian. J Text Res 1989; 14(1): 9-13.

[9] Haque MM, Habibuddoula M, Mahammod AJ, Mian AJ. Graft copolymerization onto jute fiber-Ceric ion-initiated graft-

copolymerization of methyl-methacrylate. J Polym Sci Polym Chem Ed. 1980; 18: 1447-1458.

[10] Misra M, Mohanty AK, Sing BE. A study on grafting of methyl methacrylate. J Appl Polym Sci 1987; 33(8): 2809-19. http://dx.doi.org/10.1002/app.1987.070330815

[11] Sarangis PS, Mohanty AK, Singh BE. Graft copolymerization of acrylonitrile onto jute fiber. J Appl Polym Sci 1987; 37(8): 2099-2107. http://dx.doi.org/10.1002/app.1989.070370802

[12] Moharana S, Tnpathy SS. Chemical modification of jute fibers, 1. Permanganate-initiated graft copolymerization methyl methacrylate onto jute fibers. J Appl Polym Sci 1990; 40(3-4): 345-357. http://dx.doi.org/10.1002/app.1990.070400304

[13] Khan MA, Khabir Uddin MA, Nurul Islam M, Idriss Ali KM. Degradable property of UV-cured Hessian cloth (jute). J Appl Polym Sci 1995; 51(8): 31-39.

[14] Khan MA, Nurul Islam M, Idriss Ali KM. Improvement of physicochemical properties of Hessian cloth (jute) by graft copolymerization of urethane acrylate with ultraviolet radiation. Polym-plastic Technology and Eng 1996; 35(1): 53-65. http://dx.doi.org/10.1080/03602559608000081

[15] Mohanty AK, Khan MA, Misra M, Hinrichsen G. Surface modification of jute and its influence on performance of biodegradable jute fabric/ biopol composites. Composit Sci Technol 2000; 60(7): 1115-1124. http://dx.doi.org/10.1016/S0266-3538(00)00012-9

[16] Oster G, Shibata O. Graft copolymer of polyacrylamide and natural rubber product by means of ultraviolet light. J Polymer Sci 1957; 26(113): 233-234. http://dx.doi.org/10.1002/pol.1957.1202611311

[17] Mollah MZI, Khan MA, Hoque MA, Aziz A. Studies of physico-mechanical properties of photo-cured sodium alginate with silane monomer. Carbohydrate Polymers 2008; 72(2): 349-355. http://dx.doi.org/10.1016/j.carbpol.2007.09.001

[18] Norman AG. Biochemistry of Cellulose, the Polyuronides Lignin etd. Oxford University Press 1937; p. 38.

[19] George O. Principles of Polymerization, 3rd ed., J. Wiley, New York 1991.

[20] Jang BZ. Advanced Polymer Composites: Principles and Applications, ASM International, Materials Park, OH 1994.

[21] Encyclopedia of Poly Sci 3: 243.

[22] Berejka AJ. Research associate, Exxon Chemical Company.

[23] Reine J, Arthur JC Jr. Properties of graft and block copolymers of fibrous cellulose. Indian J Textile Res 1970; 40: 90.

[24] Rahman MM, Khan MA, Uddin MK, Ali KMI, Mustafa AI. Effect of $CaCO_3$ on the performance of partex, surface modification by Ultra Violet curing method. J Appl Polym Sci 2001; 81(8): 1858-1867. http://dx.doi.org/10.1002/app.1619

[25] Haworth WH, Hirst EL. Studies of dynamic isomerism. J Chem Soci 1927; 1733-1739.

[26] Zaman HU, Khan MA, Khan RA, Rahman MA, Das LR, Al-Mamun M. Role of Potassium Permanganate and Urea on the Improvement of the Mechanical Properties of Jute Polypropylene Composites 2010; 11(3): 455-463.

[27] Ali KMI, Uddin MK, Bhuiyan MIU, Khan MA. Improvement of jute fibre through ultraviolet-cured films of urethane acrylate. J Appl Polym Sci 1994; 53(3): 303-308. http://dx.doi.org/10.1002/app.1994.070540304

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