

THERMAL BEHAVIOR OF WATER RETARDANT TREATED JUTE FIBERS

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ABSTRACT

High water and moisture absorption of the cellulosic fibers causes swelling and plasticizing effect resulting in dimensional instability and poor mechanical properties. In order to reduce this effect, water retardant treatment has been conducted on the jute fiber. Following the trend, jute fiber was made water retardant by using a modified method with the help of poly vinyl chloride (PVC), parapret, acetic acid and magnesium chloride. The thermal (decomposition) behavior of water retardant treated jute fibers were investigated by means of Differential Scanning Calorimetry (DSC) and Thermo Gravimetric Analysis (TGA). After water retardant treatment, the jute fiber became more oxidation resistant compared to the raw jute fiber. This concludes that the rate of pyrolysis decreased after water retardant treatment. The crystallization properties of the water retardant treated fiber increased with the water retardant chemical concentration.

Keywords: Jute Fiber, Water Retardant, DSC, TGA, Crystallization.

1. INTRODUCTION

The idea of producing long lasting composite materials made of jute and other natural fibers has not been considered in the past because of their swelling properties. The scope of using jute fiber in place of the traditional glass fiber in different form is supported by the higher specific modulus and lower specific gravity of jute compared to those of glass. The major drawback of natural fiber reinforced composites is their affinity to moisture. Jute is the most abundant and cheapest among the natural fibers available in Bangladesh; as a result it has attracted much research interest. Attempts have been made with varied success to use jute fiber as reinforcement for thermoplastic polymers [1-3]. The low compatibility between the hydrophilic jute fiber and the hydrophobic polymer matrix is one of the major reasons for the limited use of jute fiber as reinforcement. To improve the interfacial bonding, various surface treatments have been attempted, like stretching, calendaring, thermo-treatment and chemical modification [4-6].

The performance and stability of fiber-reinforced composite materials depends on the development of coherent interfacial bonding between fiber and matrix. In natural fiber-reinforced composites, there is a lack of good interfacial adhesion between the hydrophilic cellulose fibers and the hydrophobic resins due to their inherent incompatibility. Short, cellulose-based fibers will also tend to agglomerate making their use in reinforced composites less attractive. The presence of waxy substances on fiber surface contributes immensely to make fiber to resin bonding ineffective and causes

poor surface wetting. Also the presence of free water and hydroxyl groups, especially in the amorphous regions, worsens the ability of plant fibers to develop adhesive characteristics with most binder materials. Plant fibers are also prone to microbiological attack leading to weak fibers and reduction in their life span [7].

Natural fibers are amenable to chemical modification due to the presence of hydroxyl groups. The interfacial properties can be improved by giving appropriate modifications to the components, which gives rise to changes in physical and chemical interactions at the interface. Most of the research done so far is concentrated on the fiber surface treatment. An enormous amount of work has been conducted in the field of fiber modification [8-11]. Thermal properties of fire retardant jute fiber [12] and other natural fiber [13] were evaluated by different researchers. To our knowledge, no work has been reported on water retardant treated jute fiber. With a view to investigate new water retardant treated jute fiber, present work deals water retardant treatment of jute fiber and thermal study of the treated jute fiber.

2. MATERIALS AND METHODS

The jute fibers were collected from the Bangladesh Jute Research Institute (BJRI), Faridpur Regional Station, Bangladesh. The supplied jute fiber was CVL-1 (*Corchorus capsularis* L.). The middle portions of the whole jute fiber were cut for water retardant treatment. Poly vinyl chloride (PVC), magnesium chloride ($MgCl_2$), acetic acid (CH_3COOH) and parapret were used for

water retardant (WR) treatment. The thermal (decomposition) behavior of 10%, 15% and 20% water retardant treated jute fibers were investigated by means of Differential Scanning Calorimetry (DSC) and Thermo Gravimetric Analysis (TGA). The DSC measurement involved DSC Q10 in nitrogen atmosphere. Control and treated jute fiber samples weighing between 5 and 10 mg were placed in an aluminum capsule sealed and punctured to allow gases to escape during heating. The heating scheme ranged between 30 to 500°C and heating rate was 10°C/min. The thermographs were analyzed for any changes in the thermal behavior of jute and water retardant (WR) treated fibers. The TGA measurements were done in TA Instrument SDT Q50 computer-controlled thermo-gravimetric analyzer. Fiber samples cut to 1 cm lengths weighing 50-70 mg were used for the analysis. The samples were heated from ambient to 500°C under nitrogen purging in all experiments. A heating rate of 10°C/ minute was maintained. Computer software was used to obtain data for derivative thermo gravimetric (DTGA) analysis from the TGA experiments.

3. RESULTS AND DISCUSSION

The jute fiber chars and burns without melting until heating up to high temperature. Even with the supply of sufficient heat energy, the long chain molecules bound by numerous hydrogen bonds cannot flow past one another to exhibit plasticity. With increasing heat the chain molecules vibrate more and ultimately disintegrate leading to violent chemical reactions observed as fiber combustion [14].

3.1 Thermo Gravimetric Analysis:

The TGA graphs of the control and water retardant treated jute fiber are shown in Fig 1. A comparison of thermographs for treated fiber with that of the control fiber shows differences in the characteristic peak patterns due to the chemical treatment. From thermo-gravimetric analysis (TGA) curves of control and water retardant jute fiber (Fig 1. (a)), it is seen that control fiber was stable up to 281°C, while water retardant treated jute fiber was stable up to 265°C. TGA was used to monitor the fiber decomposition as a function of temperature. DTGA thermographs (Fig 1.(b)), clearly show main decomposition peaks for each sample. Control fiber had high derivative loss compared to the water retardant fiber. After 350°C, mass loss followed the trend of 20% WR<15% WR<10% WR<Control. A small loss in mass occurred in the first stage when the fibers reached about 50-100°C. This is due to the loss of absorbed water. The TGA curve remained relatively flat until the main decomposition reaction occurred at about 225 to 275°C in nitrogen. The main pyrolytic transformation occurred over a narrow temperature range (275-350°C) involving a substantial break-down of the main polymer network structure by a random scission process [13]. 10% and 50% weight loss [15] data are presented in Table 1. The weight change due to temperature decreased compared to the control fiber after water retardant treatment. Again after water retardant treatment, the residue increased compared to control jute fiber due to volatile components

coated by non volatile material [16]. Reaction between hydroxyl groups (O-H) of the fiber with acetyl groups (CH₃CO) rendered the fiber surface more hydrophobic [17].

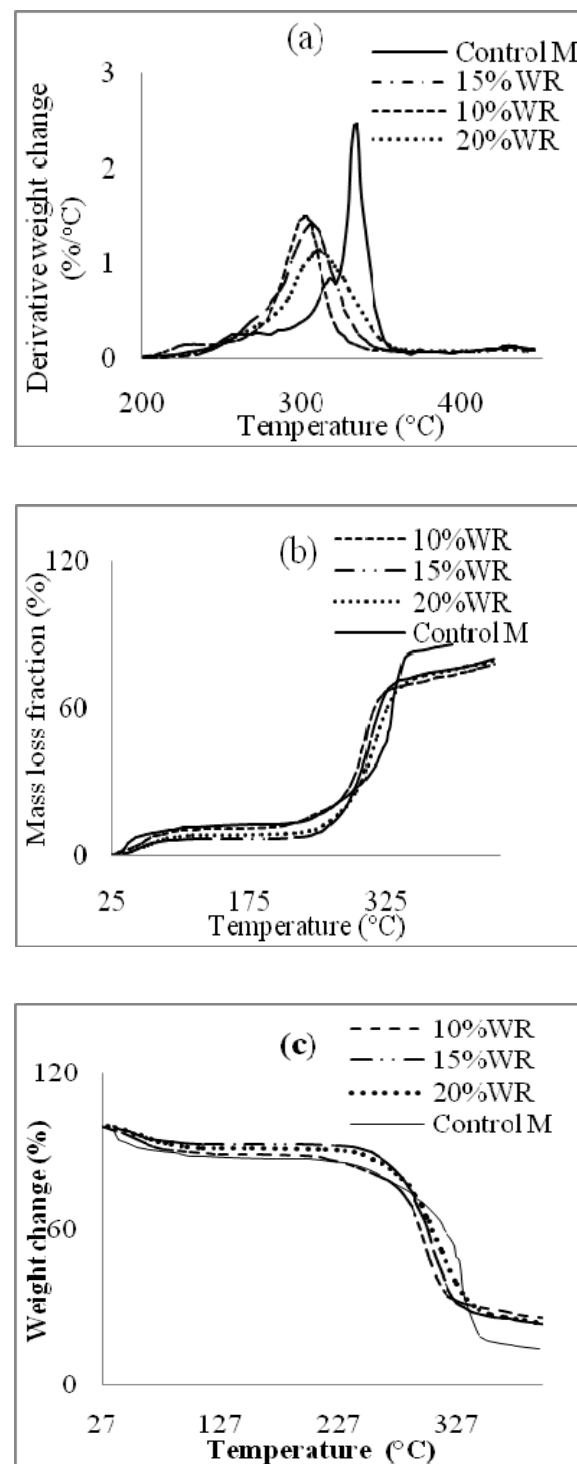


Fig 1. (a) Differential thermo-gravimetric analysis data, (b) mass loss and (c) TGA thermograph of water retardant jute fibers.

Table 1. Weight loss at different temperature and residue at final temperature.

Sample name	Weight change between 50-200°C (%)	Weight change between 200-350°C (%)	Weight change between 350-450°C (%)	Derivative weight change in temp (°C)	10% weight loss temp (°C)	50% weight loss temp (°C)	Residual weight (%)
10%WRM	4.944	33.34	33.95	305.62	97.22	303.46	21.53
15%WRM	7.365	33.34	33.95	301.80	237	308.88	21.26
20%WRM	6.37	23.99	46.95	310.07	254	315.69	20.42
Control M	5.471	17.83	55.82	332.85	76.31	327.10	13.96

3.2 Digital Scanning Calorimetric Analysis:

Fig 2 represented the DSC curves of the control and water retardant treated jute fiber. Differential Scanning Calorimetric (DSC) thermographs obtained from the control and water retardant jute fibers exhibit both endothermic and exothermic transitions (Fig 2. (a)). The peak-temperatures appeared differently with respect to the sample condition. The rate of the heat flow decreased with the chemical concentration compared to the control as shown in Fig 2 (b) and (c). The slope of the treated jute fiber also increased with the chemical concentrations. Thus it can be concluded that after WR treatment, the sample became less flammable as well as more water retardant.

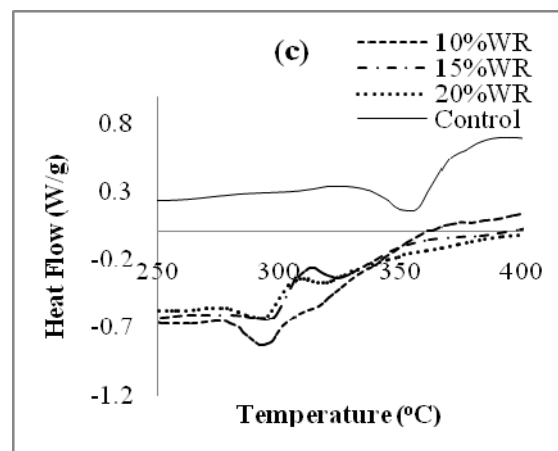
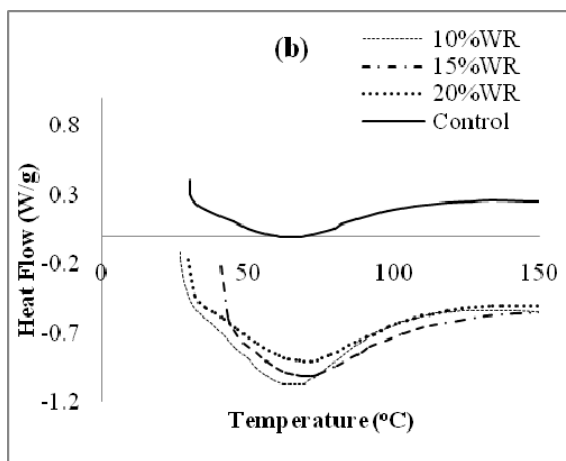
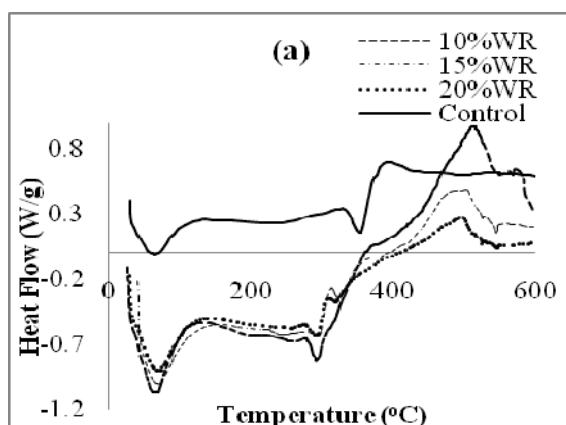


Fig 2. DSC curves of the control and water retardant jute fibers at (a) 0-600°C (b) 0-150°C and (c) 250-400°C temperature.

From the DSC data, the crystallinity can be calculated using enthalpy of fusion of 100% crystalline material. But this value is not known. The assumption of the crystallinity can be found from the enthalpy value given in Table 2.

Table 2. Melting onset, melting peak, Enthalpy and crystallinity from DSC curve of control and water retardant treated jute fiber.

Sample name	Melt onset temp. (°C)	Melt peak temp. (°C)	Enthalpy (J/g)	Crystallinity (%)
10%WRM	282.21	296.67	296.67	Very high
15%WRM	276.59	294.43	294.32	High
20%WRM	276.49	293.21	293.32	Low
Control M	190.24	202.59	271.0	Very low

At temperature range of 60°C to 100°C, the control and water retardant treated jute fiber had endothermic peak due to water or moisture release [15]. Around 300°C, sufficient energy was available for a rapid

cleavage of the glycosidic bond that resulted in products evaporation, levoglucosan and formation of other tarry products [13]. Hemicelluloses, on the other hand, showed an exothermic peak between 250-350°C [13]. The peak at 297°C corresponds to pyrolysis of hemicelluloses; the peak at 360°C was due to depolymerization of cellulose and the peak around 432°C resulted from decomposition of lignin [13]. One important observation was that the heat flow gradually decreased after water retardant treatment. On application of heat, treated jute fiber is seen to be more thermally stable compared to the raw jute fibers and this phenomena is more apparent at elevated temperatures.

The rate of heat flow decreased and slope increased after water retardant treatment with chemical concentration compared to the control jute fiber. This concludes that the rate of pyrolysis decreased after water retardant treatment. The crystallization behavior of the water retardant treated fiber increased with the water retardant chemical concentration.

The DSC technique is reported [18] to be a very useful tool to determine the drop in crystallinity and decomposition of plant fiber cellulose. The results obtained in this work using the first exothermic DSC peak (removal of moisture) corresponds well with the results obtained using the second and stronger endothermic peak (reduction in the crystallinity) to assess the thermal degradation of crystallites in plant fibers. Shenouda [20] and Nguyen et al. [19] have found the similar observations with respect to the second peak [13].

4. CONCLUSION

Water retardant treatment of jute fibers effectively changes the surface topography of the fibers and their crystallographic structure. However care must be taken in selecting the concentration of PVC, MgCl₂ and perapret for water retardant as results show that some fibers at certain PVC enhanced thermal resistance as elucidated by the DSC method. The coating impurities on plant fibers may be an advantage for fiber to matrix adhesion as it may facilitate both mechanical interlocking and the bonding reaction due to the exposure of the hydroxyl groups to chemicals such as resins and dyes. TGA (both non-oxidative or oxidative), on the basis of the presented results, can serve as a standard procedure for determining the influence of PVC, CH₃COOH on thermal stability. The results indicate that water retardant chemicals have a negligible influence on the thermal stability of the WR treated jute fiber. After water retardant treatment, the jute fiber became more oxidation resistant compared to the raw jute fiber. Thermal stability and residue of water retardant treated fiber increased above temperature of 325°C compared to the control jute fiber. The barrier mechanism is the most widely proposed mechanism by which composite formation imparts water retardancy to polymers.

5. REFERENCES

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6. NOMENCLATURE

WR	Water Retardant
%	Percentage
°C	Degree Celsius
J/g	Joule per gram
M	Middle Portion
DSC	Digital scanning calorimetric
TGA	Thermo Gravimetric Analysis
temp	Temperature