

Studies on Cyanoethylation of Jute Fiber

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SYNOPSIS

Changes of reaction variables upon the reaction of jute fiber with acrylonitrile, like concentration of sodium hydroxide, reaction time, and reaction temperature, were studied in the present work. Benzene and dioxane were used as diluents for acrylonitrile and reactions were conducted in their presence in different amounts. Jute fibers were delignified progressively and their effect on the cyanoethylation reaction was studied. It was found that fiber swelled with ethylene diamine, prior to cyanoethylation, gave a higher yield of cyanoethylated jute. Some preliminary work was done to investigate the distribution of reacted chemicals among its major constituents. An FTIR study was performed to show the partial substitution of hydroxyl groups by the cyanoethyl group. The FTIR study also revealed that not only did hydroxyl groups of the cellulosic component of jute react with acrylonitrile but hydroxyl groups of lignin also took part in the reaction. © 1996 John Wiley & Sons, Inc.

INTRODUCTION

Cellulose reacts with various α,β -unsaturated compounds to form substituted ethyl ether. The most widely studied reaction of this type has been that of cellulose with acrylonitrile to form β -cyanoethyl-cellulose.

Partially cyanoethylated cotton cellulose was prepared by Daul and coworkers¹ using pure acrylonitrile in the presence of sodium hydroxide and they also described the effect of changes in time, temperature, and concentration of reagents. Several subsequent workers²⁻⁸ covered various aspects of cyanoethylated cotton. Now it is well known that partial cyanoethylation of cotton changes its various textile properties, e.g., fiber becomes permanently rot- and mildew-proof, more resistant to wet and dry heat degradation, more resistant to organic and mineral acids, and lower in moisture regain value.

Although cyanoethylation is one of the most important techniques to make chemically modified cellulosic fiber, very little work⁹ so far has been con-

ducted on the cyanoethylation of jute fiber. In the present article, we report the various aspects of the reaction of jute with acrylonitrile in the presence of sodium hydroxide as a catalyst.

Jute is a heterogeneous polymer. Apart from cellulose (58–63%), jute fiber contains 12–14% lignin and 21–24% hemicellulose as major constituents. It is, therefore, interesting to study the reaction of jute with acrylonitrile and also the distribution of the reacted chemical between its components, i.e., holocellulose (α -cellulose and hemicellulose) and lignin.

EXPERIMENTAL

Materials and Chemicals

The middle portion of corchorus olitorius jute of TD2 grade as per B.I.S. specification¹⁰ was used for all the experiments. The fiber was cut into 10 cm lengths and defatted with an alcohol–benzene (1 : 2 v/v) mixture before actual experiments.

Laboratory reagent-grade acrylonitrile of S. D. Fine Chemicals was used in this study without further purification. Analytical reagent quality sodium hydroxide, benzene, dioxane ethylene diamine, sodium chlorite, and acetic acid were obtained from E. Merck (I).

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Cyanoethylation of Jute Fiber

Cyanoethylation of jute fiber was carried out by following the same method used by Daul and co-workers¹ for preparation of cyanoethylated cotton. Dry defatted jute fibers, 2.5 g, were impregnated (for 2 min) with a sodium hydroxide solution at 27°C and the fibers were hydroextracted to about 90% wet pickup. The alkali-soaked fibers were then put in a 250 mL stoppered conical flask containing acrylonitrile. The fiber-to-acrylonitrile ratio of 1 : 20 was maintained. The reaction was conducted at the desired temperature by placing the conical flask containing alkali-stripped jute fiber and acrylonitrile in a thermostatically controlled water bath. After a stipulated time of reaction, the fibers were thoroughly washed with 5% acetic acid and finally with distilled water. The fibers were then dried at 105°C until constant weight was obtained.

Apparent Weight Gain

The apparent weight gain was determined by using the following formula:

Apparent weight gain %

$$= \frac{(\text{oven-dry weight of cyanoethylated jute fiber}) - (\text{oven-dry weight of jute fiber})}{\text{oven-dry weight of jute fiber}}$$

× 100

Theoretical Weight Gain

Theoretical weight gain was determined by using the following formula:

$$\text{Theoretical weight gain \%} = \frac{B - A}{C - B} \times 100$$

where *A* is the nitrogen content of fiber after auxiliary treatment; *B*, the nitrogen content of cyanoethylated fiber; and *C*, the nitrogen content of acrylonitrile.

Weight Loss Due to Auxiliary Treatment

Dry defatted jute fibers were treated with a sodium hydroxide solution at 27°C for 2 min. The fibers were then centrifuged to 90% weight pickup and then fibers were thoroughly washed with 5% acetic acid and, finally, with distilled water. Fibers were

dried at 105°C for 4 h and then kept in a desiccator until constant weight was obtained:

Weight loss due to auxiliary treatment

$$= \frac{(\text{oven-dry weight of native jute fiber}) - (\text{oven-dry weight of alkali and acid treated jute fiber})}{(\text{oven-dry weight of native jute fiber})} \times 100$$

Nitrogen Content

Nitrogen content was determined by the Kjeldahl method.

Lignin Content

Lignin content was determined by the method suggested by Macmillan et al.¹¹

Infrared Spectra

Infrared spectra were obtained with a Nicolet FTIR (Model-Magna 750) by using the Kbr pellet technique.

RESULTS AND DISCUSSION

Effect of Variables Upon the Reaction

Effect of Concentration of Sodium Hydroxide

Experiments were conducted by impregnating the dry defatted jute fiber with varying concentrations of sodium hydroxide at 27°C. After centrifuging, the fibers were immersed in acrylonitrile at a temperature of 60°C and the reaction time was kept for 1 h. Table I depicts the extent of cyanoethylation of hydroxyl groups of jute with acrylonitrile. The weight gain and nitrogen content would measure the extent of the cyanoethylation reaction. It is observed that although the theoretical weight gain value is very near to the actual weight gain in every case there is a distinct lag between these two values.

It is evident that the extent of cyanoethylation increases with increase of the concentration of sodium hydroxide. But the hemicellulose portion of jute is soluble in strong alkali, so a higher concentration of alkali could not be used. It was found that fiber impregnated with 4% sodium hydroxide fairly retained its fiber form and strength. Therefore, sub-

Table I Effect of Change in the Concentration of Sodium Hydroxide on the Reaction of Jute Fiber with Acrolonitrile

Concn of Sodium Hydroxide (% w/w)	Wt Loss Due to Auxiliary Treatment (%)	Apparent Wt Gain (%)	Actual Wt Gain (Calculated) (%)	Nitrogen Content After Auxiliary Treatment (%)	Total Nitrogen Content of Cyanoethylated Jute (%)	Theoretical Wt Gain (%)
0.0	2.07	-2.07	0.00	0.30	0.30	0.00
0.5	3.10	-2.27	0.83	0.23	0.29	0.23
1.0	4.83	-3.89	0.94	0.20	0.74	2.10
1.5	4.89	5.72	10.61	0.20	2.84	11.20
2.0	4.95	14.89	19.84	0.20	4.88	21.73
4.0	5.19	25.00	30.19	0.15	6.51	31.95
6.0	6.90	58.58	65.48	0.10	11.07	71.49
8.0	7.35	56.58	63.93	0.10	11.09	71.71
10.0	7.89	80.26	88.15	0.04	12.69	92.17

sequent experiments were conducted with 4% sodium hydroxide.

Effect of Temperature

Several experiments were conducted by keeping the concentration of sodium hydroxide unchanged to 4% and the time of reaction for 1 h. The reaction temperature was varied from 27 to 70°C. The former is the room temperature and the latter is near to the boiling point of pure acrylonitrile, i.e., 77.3°C. The fiber-to-acrylonitrile ratio of 1 : 20 was maintained in all the experiments. The results of the effect of temperature on the cyanoethylation reaction on jute fiber are presented in Table II and also in Figure 1. Weight gain and nitrogen content data of Table II show that there is a steady increase of the reaction rate with increase of reaction temperature.

Effect of Reaction Time

A good number of experiments were conducted by varying the time of the reaction only from 10 to 180

min with alkali concentration at 4.0%, temperature at 60°C, and material-to-liquor ratio of 1 : 20. Table III shows the results. In addition, two more sets of experiments were conducted at temperatures of 50 and 40°C, which are represented in Figure 2.

It appears from the results of Table III and Figure 2, representing the variation of the total nitrogen content with time of treatment, that the rate of cyanoethylation is very rapid during the first 60 min of treatment and then slightly slows down with a prolonged period of reaction. The results of the above investigation demonstrate that the desired amount of cyanoethylation of jute fiber can be effected by controlling the time of treatment.

Effect of Diluent

Cyanoethylation of jute fiber has also been studied in the presence of different diluents. Acrylonitrile is miscible with all common organic solvents. In this present study, we chose benzene and dioxane as diluents for a series of experiments in which the concentration of the acrylonitrile was varied from 25 to 100%. Alkali

Table II Effect of Temperature on the Reaction of Jute Fiber with Acrylonitrile

Reaction Temperature (°C)	Wt Loss Due to Auxiliary Treatment (%)	Apparent Wt Gain (%)	Actual Wt Gain (Calculated) (%)	Nitrogen Content After Auxiliary Treatment (%)	Total Nitrogen Content of Cyanoethylated Jute (%)	Theoretical Wt Gain (%)
27	5.19	9.29	14.48	0.15	3.50	14.60
40	5.19	16.43	21.62	0.15	4.90	22.08
50	5.19	18.94	24.13	0.15	5.70	26.79
60	5.19	25.00	30.19	0.15	6.51	31.95
70	5.19	28.34	33.53	0.15	7.30	37.40

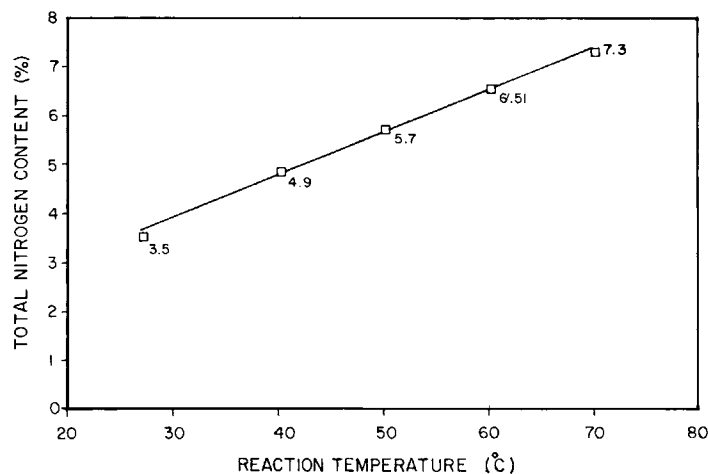


Figure 1 Effect of variation in reaction temperature on the reaction of jute fiber with acrylonitrile.

concentration, temperature of reaction, and material-to-liquor ratio were kept unchanged as in previous experiments, i.e., 4.0%, 60°C, and 1 : 20, respectively. Reaction times of 10, 30, and 60 min were considered. Results are shown in Table IV(A) and (B).

It is seen that the extent of cyanoethylation increases with increase of the concentration of the cyanoethylating agent, i.e., acrylonitrile. This could be interpreted in terms of the greater availability of the acrylonitrile molecule in the vicinity of the hydroxyl groups of jute fiber at a higher concentration of the acrylonitrile. It is understandable that the hydroxyl groups of jute fiber are immobile and reactivity relies on the availability of the cyanoethylating agent molecule in their vicinity. It is also observed that the reactions conducted in the benzene medium give a higher yield of cyanoethylated jute compared to the reaction conducted in the dioxane medium. This could be in-

terpreted by the general rules of F. G. Soper.¹² According to this rule, if the reaction is one in which the product has a higher polarity than that of the reactants, then it is accelerated by solvents of higher polarity; if the products are of lower polarity, however, the reaction will be retarded by the solvents. Since cyanoethylated jute has lower polarity than that of untreated jute fiber, the reaction conducted in the nonpolar benzene medium gives a higher yield.

Cyanoethylation in Presence of Water

Water is a universal solvent. Therefore, effort has been made to conduct the reaction in the presence of water. Moreover, from a commercial point of view, if the reaction could be performed in the presence of water, great economy could be attained. But acrylonitrile is not miscible with water in all proportions: Only about

Table III Effect of Change in Reaction Time on the Reaction of Jute Fiber with Acrylonitrile

Reaction Time (min)	Wt Loss Due to Auxiliary Treatment (%)	Apparent Wt Gain (%)	Actual Wt Gain (Calculated) (%)	Nitrogen Content After Auxiliary Treatment (%)	Total Nitrogen Content of Cyanoethylated Jute (%)	Theoretical Wt Gain (%)
10	5.19	8.13	13.62	0.15	3.59	14.97
20	5.19	11.30	16.49	0.15	4.32	18.74
30	5.19	12.72	17.91	0.15	4.92	19.33
40	5.19	14.15	19.34	0.15	5.30	21.36
50	5.19	20.10	25.29	0.15	5.88	27.70
60	5.19	25.00	30.19	0.15	6.51	37.71
90	5.19	28.69	33.18	0.15	7.14	35.98
120	5.19	35.16	40.35	0.15	8.55	46.63
180	5.19	61.11	66.11	0.15	10.11	69.06

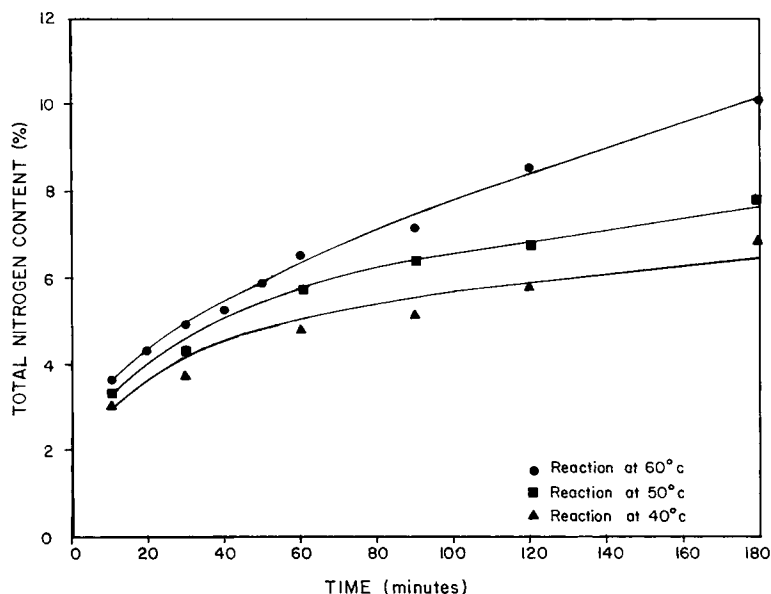


Figure 2 Effect of time on the reaction of jute fiber with acrylonitrile: (●) reaction at 60°C; (■) reaction at 50°C; (▲) reaction at 40°C.

9% is miscible at 60°C. So, to avoid this difficulty, sodium lauryl sulfate at the concentration of 1% of the total volume was used to obtain a uniform emulsion.

As the reaction has been conducted in the presence of water in alkaline pH, the possibility of the hydrolysis of some of the cyanide group to carboxylic acid could not be avoided. Therefore, the carboxylic acid content was reported in this experiment. In the first set of experiments, acrylonitrile containing 3% water was the general composition after it was recovered from a mixture of water and acrylonitrile by the dis-

tillation process. In each experiment, the reaction time was held for 2 h and the material-to-liquor ratio of 1 : 20 and a temperature of 60°C were maintained. Sodium lauryl sulfate to the extent of 1% on the total volume of liquor was used. The result of the experiment is shown in the Table V. It is observed from the nitrogen content and weight gain value that the rate of cyanoethylation is drastically reduced as the concentration of water is increased. From the result of the carboxylic acid content, it is clear that the hydrolysis of the cyanide group is negligible.

Table IV Effect of Dilution with Benzene and Dioxane

(A) Effect of Dilution with Benzene								
Reaction Time (min)	Apparent Wt Gain (%) with Acrylonitrile Percentages of				Nitrogen Content (%) of Cyanoethylated Jute Under Reaction Conducted with Acrylonitrile Percentages of			
	25	50	75	100	25	50	75	100
10	-3.72	3.02	8.12	8.13	0.68	2.43	3.50	3.59
30	-3.06	5.09	11.96	12.72	0.75	2.86	4.32	4.92
60	-2.89	8.76	20.53	25.00	0.81	3.86	5.86	6.51
(B) Effect of Dilution with Dioxane								
10	-4.20	2.87	8.10	8.13	0.50	2.12	3.37	3.59
30	-3.92	4.85	11.53	12.72	0.65	2.65	4.26	4.92
60	-3.85	8.22	15.70	25.00	0.69	3.47	4.91	6.51

Table V Effect of Acrylonitrile Concentration on Cyanoethylation of Jute Fiber

Concentration of Acrylonitrile (%)	Apparent Wt Gain (%)	Nitrogen Content (%)	Milliequivalent COOH/100 g
97	30.11	7.16	11.98
50	9.23	3.74	11.65
40	7.36	3.31	11.54
30	6.05	3.01	11.87
20	3.26	2.49	11.67
10	0.01	1.59	11.86

Progressive Removal of Lignin from Jute Fiber and Its Effect on the Reaction of Jute with Acrylonitrile

Dry defatted jute fibers were treated with a sodium chlorite solution of varying concentration adjusted to pH 4.0 with acetic acid and sodium acetate buffer for 1 h at 95°C. The material was then washed and the removal of the last traces of sodium chlorite from the fibers was effected by stripping in a solution containing 5% sodium bisulfate for 30 min at room temperature. The partially delignified jute fibers were subsequently washed with distilled water and dried at 102°C. The delignified jute fibers were cyanoethylated using 4% sodium hydroxide, temperature at 60°C, time of 1 h, and material-to-liquor ratio maintained at 1 : 20. Results are shown in Table VI and Figure 3.

If we look at Table VI and Figure 3, it is observed that as the lignin is progressively removed from the fiber by the sodium chlorite treatment the weight loss percent, due to auxiliary treatment, is also gradually increased. This is due to the greater solubility of delignified jute in aqueous alkali. In native jute fiber, the primary bonding¹³ (ester and ether linkage) between lignin and hemicellulose or the physical

protection¹⁴ conferred by lignin upon the hemicellulose, or both, impart a resistance upon the hemicellulose to become soluble in aqueous alkali. The native jute fiber, on auxiliary treatment, loses weight to the extent of 5.19%. But as the lignin is progressively removed from the jute fiber, automatically, linkages between hemicellulose and lignin are also gradually ruptured or the physical protection conferred by lignin is reduced, resulting in a gradual increase of weight loss due to the auxiliary treatment.

The enhanced reactivity of delignified jute may be associated with the morphological changes due to partial removal of the lignin by sodium chlorite treatment. With jute being a multicellular¹⁵ fiber, the unit cells, which are composed mainly of α -cellulose, are cemented together by lignin and hemicellulose. The unit cells are gradually separated with the increased removal of lignin, and so the fibers become more accessible toward reacting chemicals and give a higher amount of cyanoethylated jute. Moreover, due to greater accessibility of delignified jute, better swelling occurs in the initial alkali impregnation stage and the result is the greater yield of cyanoethylated jute.

Effect of Swelling on the Reaction of Jute with Acrylonitrile

Accessibility of jute fiber was improved¹⁶ by treating the dry defatted jute fiber with ethylene diamine (EDA) at 27°C. Three experiments were carried out by changing the time of swelling with EDA and one experiment was carried out by impregnating the jute fibers with EDA at 27°C for 30 min and then the fibers were washed, dried, and then again treated with EDA for 30 min. In another experiment, the fibers were swelled with boiling water for 1 h.

After swelling, fibers were cyanoethylated using 4.0% sodium hydroxide and the reaction was car-

Table VI Effect of Removal of Lignin on the Reaction of Hydroxyl Groups of Jute with Acrylonitrile

Sodium Chlorite (% owf)	Removal of Lignin (%)	Wt Loss Due to Auxiliary Treatment (%)	Apparent Wt Gain (%)	Actual Wt Gain (Calculated)	Total Nitrogen Content
0	0.00	5.19	25.00	30.19	6.51
5	4.32	8.76	24.55	33.31	6.92
10	23.02	11.76	35.50	47.26	8.61
20	52.52	16.51	32.64	49.15	8.85
30	60.43	18.02	31.30	49.32	8.90
35	71.94	18.18	31.98	50.16	9.03

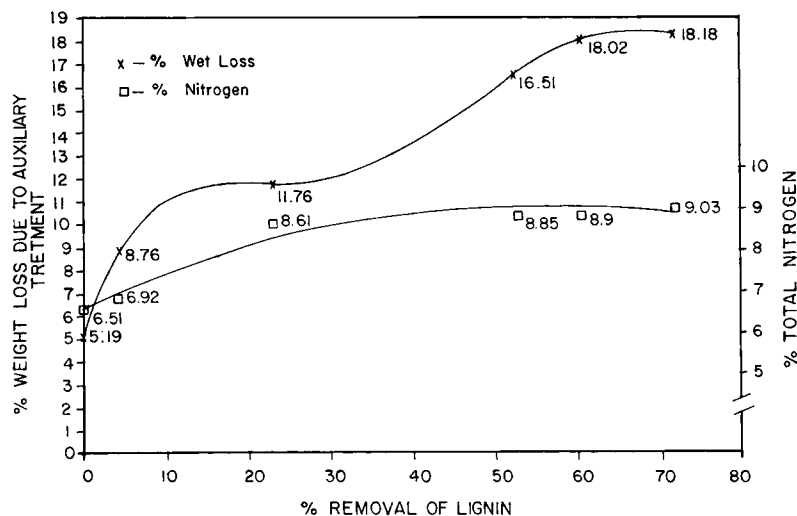


Figure 3 Effect of progressive removal of lignin on the weight loss percent due to auxiliary treatment and on the reaction of jute fiber with acrylonitrile: (X) weight loss %; (□) percent nitrogen.

ried out at 60°C; time of the reaction was kept for 60 min in all the experiments. Table VII shows the results. It appears from the nitrogen content data of Table VII that fibers, swelled with EDA before cyanoethylation, greatly enhance the rate of reaction. Under the conditions cited in the preceding paragraph, EDA swelling resulted in the reaction to about 10.6% nitrogen instead of 6.5% with the typical process. Table VII also reveals that there is a very little effect on the drastic application of EDA compared to experiments conducted at a comparatively milder condition, i.e., 30 min of swelling with EDA. This enhanced rate of reaction is probably due to the breakage of intermolecular hydrogen bonding of the hydroxyl group of cellulose by EDA, resulting in greater accessibility of the hydroxyl group toward the cyanoethylating agent.

Distribution of Bonded Chemicals in the Cell Wall Polymers of Jute Fiber

Three numbers of samples of cyanoethylated jute were prepared by using 2, 4, and 6% sodium hydroxide, respectively, to evaluate the distribution of bonded cyanoethyl groups among the holocellulose and lignin parts. The nitrogen content of these samples as well as the lignin samples isolated from these three cyanoethylated jutes were estimated. The results are depicted in Table VIII. From this table, it is observed that in every case the nitrogen content of lignin is less than the corresponding cyanoethylated jute, but the differences of nitrogen content values of the corresponding cyanoethylated jute and lignin have been gradually reduced with the increase of cyanoethylation. These lower values of nitrogen content of the lignin compared to cyanoethylated

Table VII Effect of Swelling with Ethylene Diamine on the Reaction of Jute Fiber with Acrylonitrile

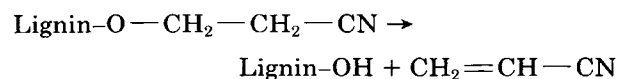
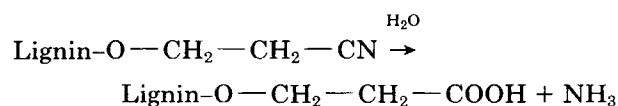
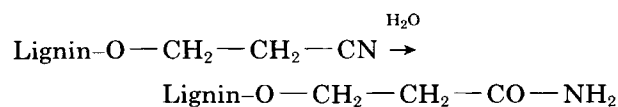
Swelling Agent	Duration of Swelling (min)	Apparent Wt Gain (%)	Total Nitrogen Content of Cyanoethylated Jute (%)
Nil	—	25.00	6.51
98% EDA	30	57.33	10.42
98% EDA	60	57.31	10.46
98% EDA	120	57.30	10.52
Repeated treatment with EDA	—	53.62	10.58
Boiling water	60	24.92	6.53

Table VIII Nitrogen Content of Cyanoethylated Jute and Lignin Isolated from the Same Cyanoethylated Jute Sample

Concentration of Sodium Hydroxide (%)	Nitrogen Content of Cyanoethylated Jute (%)	Nitrogen Content of Lignin (%)	Nitrogen Content of Holocellulose (%) (Calculated ^a)
2	5.02	3.97	5.19
4	6.83	5.77	7.00
6	6.97	6.39	7.06

^a Considering jute fiber is composed of 86% holocellulose and 14% lignin.

jute may be due to the higher reactivity or accessibility of holocellulose compared to lignin. As jute fiber contains a higher amount of hemicellulose (21–24%) compared to lignin (12–14%) and it is believed that both these constituents present in an amorphous region of jute, greater reactivity of hemicellulose with acrylonitrile is expected. The diminishing tendency of differences of nitrogen content values between cyanoethylated jute and lignin samples isolated from the same cyanoethylated jute might be due to generation of a new hydroxyl group of lignin by the hydrolysis of ester linkages between polyuronide hemicellulose and hydroxyl groups of lignin. Possibly, hydrolysis of these ester linkages takes place with greater ease at a higher concentration of caustic alkali and so a greater number of new hydroxyl groups are generated when cyanoethylated jute is being prepared with a comparatively higher concentration of alkali and the subsequent result is the higher nitrogen content of lignin isolated from cyanoethylated jute when prepared with a higher concentration of sodium hydroxide as compared to when the same is prepared with a lower concentration of caustic alkali. At the same time, the possibility of hydrolysis of the cyanide group of cyanoethylated lignin during isolation by the sulfuric acid method¹¹ to the corresponding amide or carboxylic acid and the cleavage of some of the cyanoethyl groups may not be ignored to account for the lower nitrogen content of lignin:



Spectral Analysis

Evidence that a chemical reaction has taken place between the jute cell wall hydroxyl groups and the acrylonitrile is seen in the infrared spectra^{17,18} of chemically modified jute fiber (Fig. 4). Spectrum (a) of the unmodified jute in the region of 2240–2260 cm^{-1} shows no pick. After jute is modified to a 5.72%

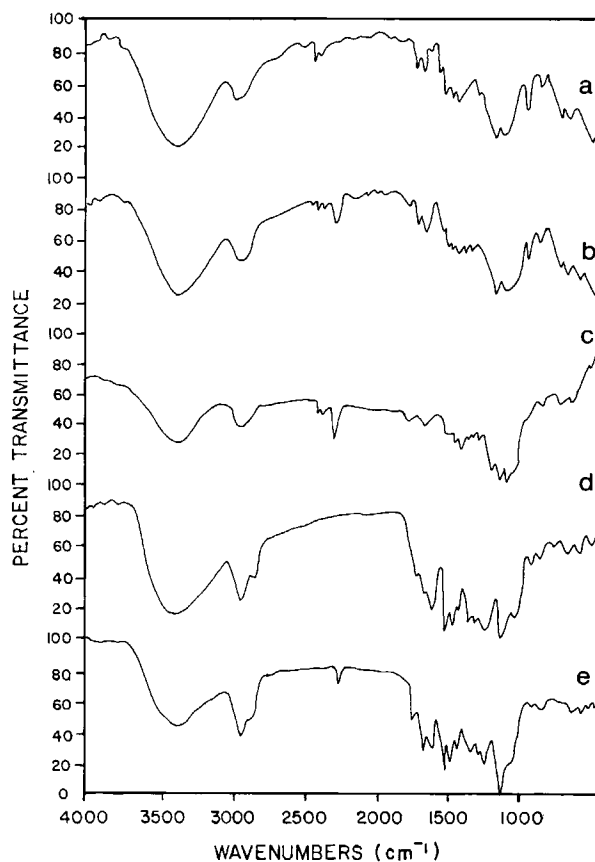
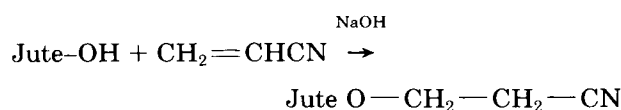


Figure 4 FTIR spectrophotographs of (a) untreated jute, (b) cyanoethylated jute to 5.72% weight gain, (c) cyanoethylated jute to 7.62% weight gain, (d) lignin isolated from unmodified jute, and (e) lignin isolated from cyanoethylated jute to 5.72% weight gain.

weight gain by reaction with acrylonitrile, some $C\equiv N$ stretching vibration (b) in the region of 2252 cm^{-1} is shown. After jute fiber is modified to a 7.62% weight gain, the $C\equiv N$ stretching band (c) becomes more prominent. The strong absorption at 3400 and 2903 cm^{-1} in all the three infrared spectra (a, b, and c) is caused by $O-H$ stretching and $C-H$ stretching of the methylene group, respectively. In the case of cyanoethylated jute, both spectra (b and c) show a reduced intensity of the $O-H$ stretching band and increased intensity of the $C-H$ band compared to the unmodified sample. This reduction of the $O-H$ stretching band and improvement of the intensity of the $C-H$ band of chemically modified jute may be attributed to the reduction of hydroxyl groups and increase of methylene groups by the following reaction:



The infrared spectrum of lignin (spectrum e, Fig. 4) isolated from the same cyanoethylated sample (5.72% weight gain) by the sulfuric acid method¹¹ also shows the $C\equiv N$ band. But lignin isolated from unmodified jute shows no pick (d) in this region. The lignin spectra show the characteristic aromatic skeletal vibrations at 1600 and at 1515 cm^{-1} (doublets).

The holocellulose, from a jute sample, modified by acrylonitrile to a weight gain of 5.72%, is isolated by the sodium chlorite procedure.¹⁹ Infrared spectra of holocellulose (spectrum b, Fig. 5) also shows the $C\equiv N$ band at 2252 cm^{-1} . But the holocellulose isolated from unmodified jute shows no pick (spectrum a, Fig. 5) in this region. From this spectral study, it is confirmed that both the cellulose hydroxyl and lignin hydroxyl take part in the chemical reaction with acrylonitrile.

CONCLUSIONS

The following concluding remarks can be drawn on the basis of results obtained in the present study:

- A desirable amount of cyanoethylation of jute fiber can be attained by controlling either the time or temperature of the reaction.
- Swelling of fiber before cyanoethylation greatly enhances the rate of reaction.
- Within the experimental range of the concentration of sodium hydroxide (0.5–10%), the

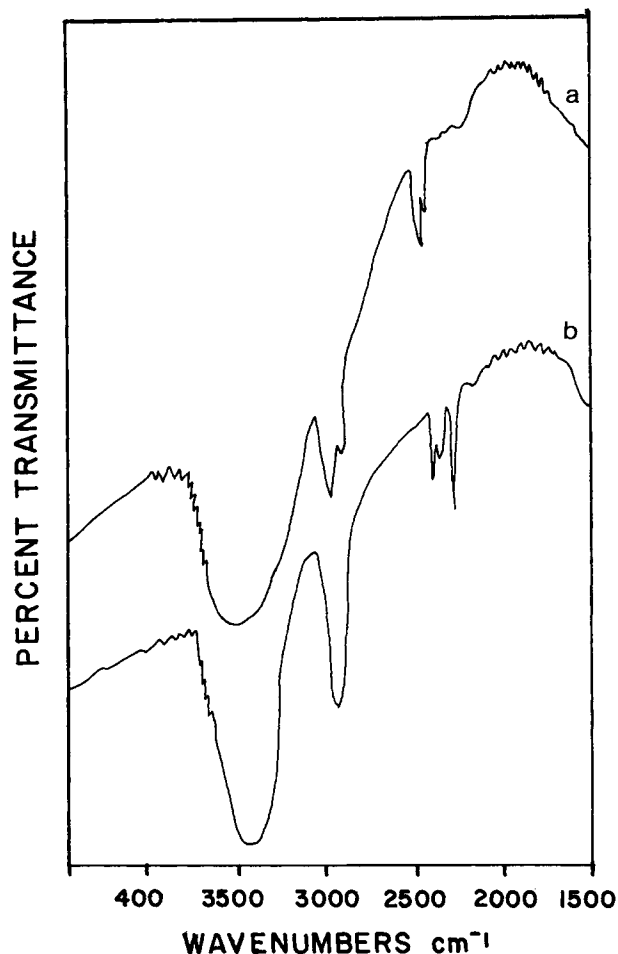


Figure 5 FTIR spectrophotographs of (a) holocellulose isolated from unmodified jute and (b) holocellulose isolated from a cyanoethylated sample to 5.72% weight gain.

extent of cyanoethylation increases with increase of the concentration of sodium hydroxide.

- Cyanoethylation in the presence of water abruptly reduces the rate of reaction.
- Hydroxyl groups of both holocellulose and lignin are simultaneously substituted by the cyanoethyl group. But the reactivity of holocellulose toward cyanoethylation is higher compared to lignin.

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