

Physicochemical Properties of Prepared Ion-Exchangers from Cellulose Incorporated with Different Functional Group

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ABSTRACT: Bagasse raw material and bleached bagasse pulp were used to prepare carbamoyl ethyl and cyanoethyl cellulose which were converted to ion exchangers. The effect of crosslinking on the properties of the carbamoyl ethyl and cyanoethyl cellulose was investigated. The molecular structure of the produced resin was also studied via infrared spectroscopy. New bands were seen at 2252 cm^{-1} and a shoulder at 3140 cm^{-1} , which are due to the cyano group (in cyanoethylated cellulose) and amino group (in the carbamoyl ethyl cellulose). Also, another band was appeared at 1715 cm^{-1} , which is due to the carbonyl group, formed due to hydrolysis of cyanoethyl or

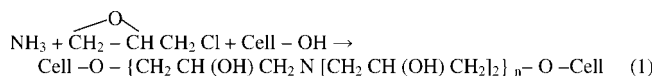
carbamoyl ethyl cellulose. Thermal gravimetric analysis (TGA) of the produced resin was studied. The existence of both cyano group and carbamoyl group increased the resistance of cellulose towards the thermal treatment. The efficiency of the produced resin towards metal ions uptake from solution mixture (Cu, Ni, and Cr) was also studied. © 2007 Wiley Periodicals, Inc. *J Appl Polym Sci* 105: 412–419, 2007

Key words: bagasse raw material; bleached bagasse pulp; cellulose derivatives; ion-exchanger; FTIR; thermo gravimetric analysis

INTRODUCTION

Plant residues, which are mainly lignocellulosic materials, can inherently adsorb waste chemicals such as dyes and cations in water, protein isolation, fractionation, and chromatography because of the electrostatic interaction between the two substrates and physical absorption. They are renewable agricultural wastes available abundantly at no or low cost. Agricultural residues are mixtures of complex polysaccharides and lignin. Some of the isolated components of these mixtures (i.e., cellulose, lignin, and hemicellulose) have increased its value when functionality is added. If these ionizable groups are acidic as carboxymethyl cellulose,¹ cellulose phosphate,^{2,3} cellulose phosphosulfonate,⁴ and cellulose sulfate,^{5,6} the resin is called cation exchangers. If these groups are basic e.g., primary, secondary, tertiary, or quaternary amine groups, the resin is called anion exchangers. By applying the same or similar methodology to the unprocessed residues, useful products could be produced. These products would be less costly because the isolation and purification steps would be eliminated. A potential waste disposal problem would be minimized because these

residues would now have some commercial utility. Crosslinking of cellulose prior to or followed by chemical modification may be used to control swelling and permit high degree of substitution.^{7,8} Epichlorohydrin (E) is commonly used as a crosslinking agent effectively stabilizes agricultural residues for the preparation of weakly acidic cation exchangers.² The reaction of E with ammonia in the presence of cellulose produces poly(hydroxyl propylamine)-modified cellulose, as suggested by the reaction scheme:



The resulting material may be more accessible to counter ions.⁹ Oxidized cellulose in which the resin contains carboxyl groups,^{10,11} amidoximated cellulose,^{12,13} and carbamoyl ethyl cellulose can be used as an ion exchange resin.^{14,15} The potential usefulness of these derivatives as a cation exchange agent was evaluated. The aim of this work to preparation of cyanoethyl and carbamoyl ethyl cellulose and their hydrolysis products from bagasse raw material and compare these products with their equivalent products obtained from bleached bagasse pulp and the ability of the prepared ion exchangers to remove heavy metal ions. Characterization of bagasse raw material and bleached bagasse pulp and its derivatives were investigated.

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EXPERIMENTAL

Materials

Sugarcane bagasse was provided by Sugar and Integrating Industries Company, Edfo, Egypt. Samples were ground to $\approx 400 \mu\text{m}$. Bleached bagasse pulp was prepared by three conventional bleaching methods¹⁶ [chlorination (C), extraction (E), and hypochlorite (H)].

Chlorination: 50% of the calculated required amount of chlorine according to the permanganate number (Tappi Standard Methods T 214 wd-76) was added as chlorine water to the pulp at a consistency of 3%, temperature of 20°C for 1 h. Then, the pulp was thoroughly washed with water.

Extraction: 2% NaOH (based on pulp) was added to the pulp at a consistency of 7%, temperature of 80°C for 1 h. Then, the pulp was washed with water till neutrality.

Hypochlorite: The residual 50% of the required amount of chlorine according to permanganate number was at pH of (10–11), 3% consistency, at 40°C and for 2 h, then the pulp was washed with water till neutrality.

All the used chemicals and solvents are reagent grade and used without further treatment or purification.

Methods

Lignin and α -cellulose contents were determined according to Tappi standards T 22,205 - 54 and T 17m - 55, respectively, hemicellulose was determined according to Jayme and Sarten.¹⁷ The results are presented in Table I.

Preparation of cyanoethyl and carbamoyl ethyl cellulose

Cyanoethyl cellulose was prepared according to Mackawa.¹ 10 g of bagasse raw material or bleached bagasse pulp was steeped in 30% NaOH for 15 min. Then, filtered and pressed the cellulose soaked in alkaline solution till the weight of the produced alkaline cellulose reached 20 g. After that, 15 mL of acrylonitril was added with stirring to the alkaline cellulose under reflux and heating at 40°C for 40 min. After the reaction stopped, 50 mL of 10% glacial acetic acid were added and the mixture was left for 5 min. 250 mL of 50% methyl alcohol were added with stirring. The product was filtered and washed with distilled water till neutrality, and then air dried.

Carbamoyl ethyl cellulose was prepared as in the case of cyanoethyl cellulose. Whereas, 15 g of acrylamide was dissolved in 20 mL of 10% NaOH. The dissolved acrylamide was added to alkaline cellulose under reflux and heating at 50°C for 90 min. The

TABLE I
Analyses of Raw Materials

Material	α -Cellulose (%)	Hemicellulose (%)	Lignin (%)	Ash (%)
Bagasse raw material	41.50	27.20	20.40	1.80
Bleached bagasse pulp	78.40	24.20	0.30	1.00

resulting pulp was washed with 10% acidified water and methanol. The product was filtered and washed with distilled water till neutrality, and then air dried.

Nitrogen content was estimated for cyanoethyl cellulose and carbamoyl ethyl cellulose by Kjeldal method. The degree of substitution of cyanoethylation and carbamoylethylation were calculated from nitrogen content.¹⁸

Hydrolysis of cyanoethyl and carbamoyl ethyl cellulose

The raw materials were refluxed in presence of 5% NaOH for 180 min at 50°C. Then, the resulting pulp was washed with 10% acetic acid and the carboxylate precipitated material was washed with methanol. The product was filtrated and washed with water till neutrality, and then air dried.

Crosslinking of cyanoethyl and carbamoyl ethyl cellulose (bleached bagasse pulp) was carried out as the following: For every 0.5 g of the sample, the molar ratios of epichlorohydrine : cellulose is 42.66 : 1 and of ammonium hydroxide : cellulose is 85.66 : 1 respectively, the solutions were added for 60 min at room temperature. The reaction was terminated by dilution with ethanol, followed by isolation of the insoluble procedure by filtration. Filtrate was dried at 25°C.

Adsorption of different metal ions

To determine the affinity of the cyanoethyl or carbamoyl ethyl cellulose cation exchangers for the adsorption of metal ions, 0.2 g of the prepared materials was stirred with 25 mL of an aqueous solution of the metal chlorides containing 9.61, 7.87, and 8.52 μmol of Cr, Cu, and Ni respectively, for 30 min at room temperature.³ The suspension was then filtrated and the elements were determined in the filtrate using ICP-AES Jobin Yvon J4 Spectrometer.

Fourier transforms infrared analysis

Infrared spectra of bagasse raw material, bleached bagasse pulp, cyanoethyl cellulose, carbamoyl ethyl cellulose, and their hydrolysis products were obtained by using JASCO Fourier transforms infrared (FTIR) 800 E spectrometer. The samples were measured using KBr disc technique.

Thermogravimetric analysis

A Perkin-Elmer thermo gravimetric analyzer was used to study the thermal properties of the bagasse, bleached bagasse pulp, and their derivatives. The heating rate was set at 10°C/min over a temperature range of 50–500°C. Measurements were carried out in a nitrogen atmosphere, with a rate of flow of 50 cm³/min.

RESULTS AND DISCUSSION

Infrared spectroscopy of cyanoethyl and carbamoyl ethyl cellulose and their hydrolysis

Infrared spectroscopy is a very useful tool for obtaining information about the chemical changes taking place with the various treatments. Figure 1 shows the infrared spectra of bagasse raw material and bleached bagasse pulp. The relative absorbencies of the different bands were determined via the baseline correction method.¹⁹ Figure 2 shows the infrared spectra of cyanoethylated bleached bagasse pulp, cyanoethylated bagasse raw material, and their hydrolysis.

The bands relative absorbances were calculated as the band intensity at the subsequent wave number to the band intensity of the wave number at ≈ 1315 cm⁻¹, which is due to the —CH₂ rocking of the ring.²⁰ Table II indicates the relative absorbance intensity, nitrogen content, yield (%), and degree of substitution of bagasse raw material, bleached bagasse pulp, and their derivatives. From Table II and Figure 2, it is clear that, as a result of cyanoethylation of bagasse and bleached bagasse pulp, a new band appeared at 2252 cm⁻¹, which is due to the nitrile group —CN. The band relative absorbance of the cyanoethylated bleached bagasse pulp is higher than that in case of cyanoethylated bagasse raw material; this can be attributed to the presence of lignin in bagasse raw material.

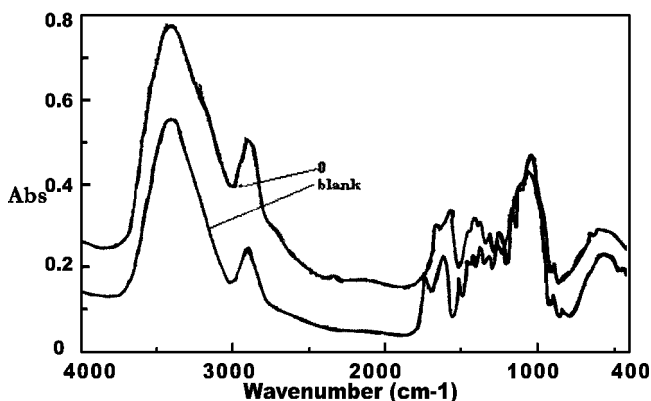


Figure 1 Infrared spectra of (0) bleached bagasse pulp, (blank) bagasse raw material.

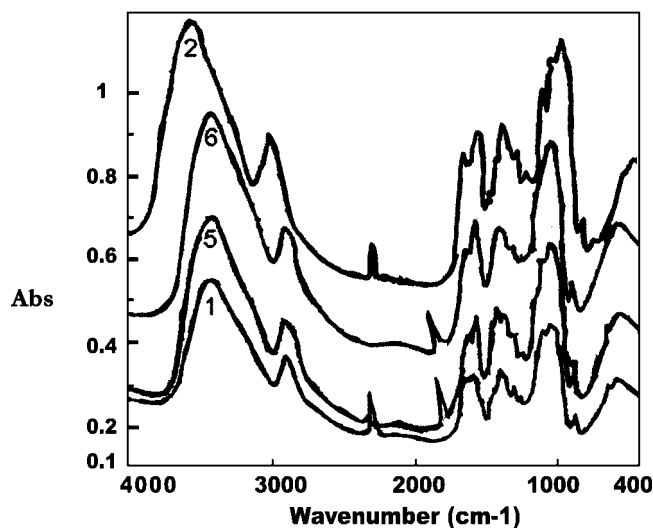


Figure 2 Infrared spectra of (1) cyanoethylated bleached bagasse pulp, (2) cyanoethylated bagasse raw material, (3) hydrolyzed cyanoethylated bleached bagasse pulp, and (4) hydrolyzed cyanoethylated bagasse raw material.

The crystallinity index was determined from the spectra via the O'Connor method¹⁹ (ratio of the band intensity at 1425 cm⁻¹/band intensity at 900 cm⁻¹). It was found that, the crystallinity index of bagasse raw material (1.4) is higher than that in case of bleached bagasse pulp (1.2)²¹ i.e., this decrease in crystallinity index means increase in the disordered regions, which enhanced the cyanoethylation process. Furthermore, the rate of flow of the cyanoethylated chemicals through the bagasse fiber is less than that in case of bleached bagasse pulp. This can be confirmed by the higher nitrogen content of cyanoethylated bleached bagasse pulp (7.5%) more than cyanoethylated bagasse raw material (5.6%) (Table II). From Table II, it is clear that, the absorbency ratio (—CH₂ at 2900 cm⁻¹ to —OH at 3450 cm⁻¹) of the cyanoethylated bagasse and cyanoethylated bleached bagasse pulp (0.62 and 0.67 respectively) are higher than the untreated bagasse raw material and bleached bagasse pulp (0.58 and 0.60 respectively). This is due to the cyanoethylation which resulted in introducing CH₂—CH₂ group to the cyanoethylated materials as seen in eq. (2).

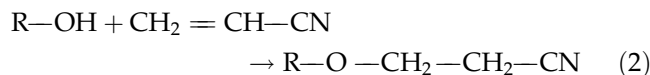


Figure 3 shows the infrared spectra of carbamoyl ethylated bleached bagasse pulp, carbamoyl ethylated bagasse raw material and their hydrolysis. From Table II and Figure 3 the carbamoyl ethylated cellulose shows the same behavior as in case of cyanoethylated cellulose. The absorbency ratios ($A_{\text{CH}_2}/A_{\text{OH}}$) of both carbamoyl ethylated bagasse

TABLE II
Relative Absorbance Intensity, Nitrogen Content (%), Yield (%), and Degree of Substitution of Bagasse Raw Material, Bleached Bagasse Pulp, and Their Derivation

Material	A_{CH}/A_{OH}	—CN band (cm^{-1})	—NH ₂ band (cm^{-1})	—CONH ₂ band (cm^{-1})	—COOH band (cm^{-1})	Nitrogen content (%)	Yield (%)	Degree of substitution
Bagasse raw material	0.58	—	—	—	—	—	—	—
Bleached bagasse pulp	0.60	—	—	—	—	—	—	—
Cyanoethylated bagasse raw material	0.62	0.60	—	—	—	5.60	30.02	0.82
Cyanoethylated bleached bagasse pulp	0.67	0.66	—	—	—	7.50	69.89	1.21
Carbamoyl ethylated bagasse raw material	0.62	—	0.35	0.42	—	4.80	24.99	0.74
Carbamoyl ethylated bleached bagasse pulp	0.65	—	0.42	0.54	—	5.20	65.12	0.82
Hydrolysed cyanoethylated bagasse raw material	—	—	—	0.22	0.50	0.41	19.89	0.05
Hydrolysed cyanoethylated bleached bagasse pulp	—	—	—	0.34	0.54	0.55	62.11	0.07
Hydrolysed carbamoyl ethylated bagasse raw material	—	—	—	—	0.38	0.06	18.23	0.007
Hydrolysed carbamoyl ethylated bleached bagasse pulp	—	—	—	—	0.43	0.10	51.99	0.012

and carbamoyl ethylated bleached bagasse pulp (0.62 and 0.65 respectively) are higher than in case of the untreated bagasse and bleached bagasse pulp (0.58 and 0.60 respectively). A new shoulder band was appeared at 3140 cm^{-1} , which is due to —NH₂ of stretching amino group in the carbamoyl ethyl cellulose and another new band at 1645 cm^{-1} which is due to —CONH₂ amide group as seen in Eq. (3).

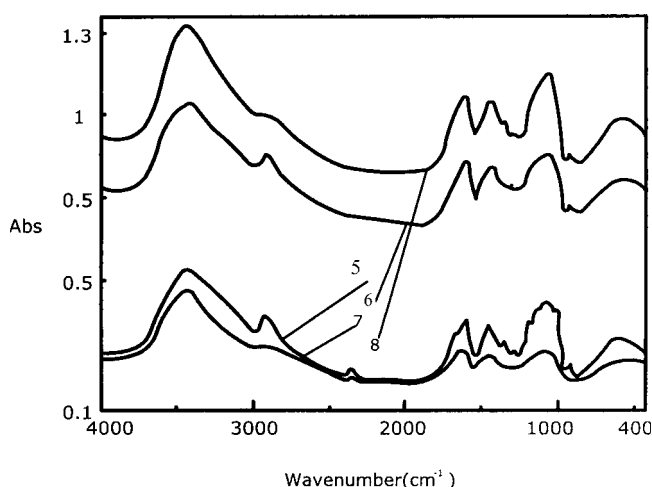
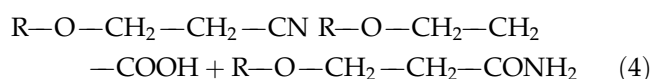


Figure 3 Infrared spectra of (5) carbamoyl ethylated bleached bagasse pulp, (7) hydrolyzed carbamoyl ethylated bleached bagasse pulp, (6) carbamoyl ethylated bagasse raw material, and (8) hydrolyzed carbamoyl ethylated bagasse raw material.

From Table II, the relative absorbance of —NH₂ band in carbamoyl ethylated bleached bagasse pulp is higher than in case of carbamoyl ethylated bagasse raw material. This result is in agreement with the high nitrogen content and degree of substitution in carbamoyl ethylated bleached bagasse pulp.

Hydrolysis of cyanoethylated and carbamoyl ethylated cellulose

Table II and Figure 2 indicate that, by hydrolysis the nitrile group (—CN) band is disappeared and a new shoulder band is formed at 1715 cm^{-1} which characterized of carboxyl group —COOH. In addition, a new band is formed at 1645 cm^{-1} which characterized to —CONH₂ amide group as the following equation.



From Table II, the relative absorbencies of the carboxyl and amide groups are higher in case of hydrolyzed cyanoethylated bleached bagasse pulp more than that in case of bagasse raw material. These results are in agreement with the nitrogen content values which were decreased due to hydrolysis.

Table II and Figure 3 show that, by hydrolysis of carbamoyl ethyl cellulose, the band at 3140 cm^{-1} , which is due to —NH₂ amino group is disappeared and a new shoulder band at 1715 cm^{-1} , which represents a carboxyl group was formed. As shown in the previous results, the relative absorbance intensity of the band at 1715 cm^{-1} of hydrolyzed carbamoyl

TABLE III
Metal Ion Uptake Efficiency of Bagasse Raw Material Bleached Bagasse Pulp and Their Duration

Material	Metal ion uptake ($\mu\text{mol/g}$)		
	Cu	Cr	Ni
Bagasse raw material	0.05	0.03	0.00
Bleached bagasse pulp	0.1	0.07	0.01
Cyanoethylated bagasse raw material	0.40	0.20	0.10
Cyanoethylated bleached bagasse pulp	0.50	0.40	0.10
Hydrolyzed cyanoethylated bagasse raw material	55.30	70.30	62.10
Hydrolyzed cyanoethylated bleached bagasse pulp	20.50	17.70	17.50
Cross linked hydrolyzed cyanoethylated bleached bagasse pulp	60.30	77.50	81.50
Carbamoyl ethylated bagasse raw material	51.90	76.50	85.00
Carbamoyl ethylated bleached bagasse pulp	28.70	65.00	76.60
Cross linked carbamoyl ethylated bleached bagasse pulp	44.00	68.30	80.90
Hydrolyzed carbamoyl ethylated bleached bagasse pulp	23.70	65.00	58.10
Crosslinked hydrolyzed carbamoyl ethylated bleached bagasse pulp	61.60	81.30	86.40

ethylated bleached bagasse pulp (0.43) is higher than that in case of bagasse raw material (0.38).

Ion exchange properties of cyanoethylated cellulose

The adsorptions of the selected heavy metals ions (Cr, Ni, and Cu) by the prepared cyanoethylated bagasse raw material, cyanoethylated bleached bagasse pulp, and their hydrolysis products were studied. Table III gives the quantity of metal ions that were picked up by the different derivatives of bagasse raw material and bleached bagasse pulp. The ion exchange affinity is related to the charge and the hydrated radius of the metal ion. Also, adsorption of the metal ions onto the ion exchanger can be attributed to two terms; coulombic interaction and intrinsic adsorption. Coulombic interaction results from the electrostatic energy of the interactions between the adsorbents and adsorbates. The charges on substrates as well as softness or hardness of the charge on both sides are mostly responsible for the amount of adsorption. The intrinsic adsorption is determined by their surface areas, which can be observed by the effect of different sizes of adsorbents on the adsorption.²² As shown from Table III, cyanoethylated bagasse raw material and cyanoethylated bleached bagasse pulp have a small affinity for Cu, Cr, and Ni adsorption when compared to their hydrolyzed materials.

Also, the hydrolyzed cyanoethylated bagasse raw material has a higher affinity towards metal ions uptake more than the hydrolyzed cyanoethylated bleached bagasse pulp, i.e., hydrolyzed cyanoethylated bleached bagasse pulp is structurally unstable under mildly acidic conditions $\text{pH} \approx 2$ in presence of metal ion solution. This instability may be due to the relatively high presence of the carboxylic group

in the cyanoethylated bleached bagasse pulp (where the carboxylic relative absorbance for both hydrolyzed cyanoethylated bleached bagasse pulp and hydrolyzed cyanoethylated bagasse raw material are 0.54 and 0.50 respectively), which in turn cause swelling and dissolving of a part of the pulp in the solution.

Epichlorohydrin (E) is commonly used as a cross-linking agent, effectively stabilizes agricultural residues for the preparation of weak acidic cation exchangers.² Hydrolyzed cyanoethylated bleached bagasse pulp needs to be crosslinked to prevent or retard dissolution and to improve certain physical properties. From Table III the use of crosslinker increases the efficiency of the resin toward metal ions uptake, also, the quantity of the metal ions uptake by the crosslinker hydrolyzed cyanoethylated bleached bagasse pulp is increased more than that in case of hydrolyzed cyanoethylated bagasse raw material.

From the previous results, one can obtain, since the metal ions uptake for both hydrolyzed cyanoethylated bagasse raw material and crosslinked hydrolyzed cyanoethylated bleached bagasse pulp are approximately the same, so, it is suggested to prefer hydrolyzed cyanoethylated bagasse raw material. The proposed process do not need bleaching step, so it is economical and environment friendly. Furthermore, it may not need crosslinking before use, which is another advantage of the proposed process.

Ion exchange properties of carbamoyl ethylated cellulose

From the results obtained in this study, it was found that carbamoyl ethylated bagasse raw material has a higher efficiency for metal ions uptake than

carbamoyl ethylated bleached bagasse pulp. The obtained results are given in Table III. This is due to carbamoyl ethylated bleached bagasse pulp swell and part of it is dissolved in the solution. On the other hand, the carbamoyl ethylated bleached bagasse pulp has a higher adsorption affinity for Ni and Cu metals than hydrolyzed carbamoyl ethylated bleached bagasse pulp, which can probably attributed to both steric and electronic effects. The ion-exchange affinity is also related to the charge and the hydrate radius of the metal ion.²³ In addition, the binding ability of the different metal ions to the exchanger is affected by the semi hard acid.²⁴ As shown from the same table, hydrolyzes of the produced carbamoyl ethylated bleached bagasse pulp lower its affinity towards metal ions adsorption. This is due to the swelling process of the hydrolyzed bleached bagasse pulp. Crosslinking of the carbamoyl ethylated and hydrolyzed carbamoyl ethylated bleached bagasse pulp increases their adsorption of metal ions when compared to carbamoyl ethylated bleached bagasse pulp. On the other hand, crosslinking the hydrolyzed carbamoyl ethylated bleached bagasse pulp has higher affinity toward metal ion uptake more than the crosslinked carbamoyl ethylated bleached bagasse pulp.

Table III shows the metal ion uptake by the hydrolyzed cyanoethylated, hydrolyzed carbamoyl ethylated bleached bagasse pulp and their crosslinking. From this table, it is clear that the hydrolyzed cyanoethylated bleached bagasse pulp has lower adsorption of metal ion than the hydrolyzed carbamoyl ethylated bleached bagasse pulp. This can be due to more carboxylic group in the hydrolyzed cyanoethylated than hydrolyzed carbamoyl ethylated bleached bagasse pulp. This can be confirmed by the higher relative absorbance of $-\text{COOH}$ of hydrolyzed cyanoethylated than the hydrolyzed carbamoyl ethylated bleached bagasse pulp Table II. Also, the crosslinked of hydrolyzed carbamoyl ethylated bleached bagasse pulp adsorb metal ion more than crosslinked hydrolyzed cyanoethylated bleached bagasse pulp.

Thermal analyses

Thermal decomposition of bagasse raw material, bleached bagasse pulp and their derivatives were investigated. Figure 4(A,B) shows TG curves of bleached bagasse pulp (A) and bagasse raw material (B). About 8–9% weight loss at 90–110°C was observed. This is due to the moisture evaporation. After the initial loss of moisture, a loss of weight of bagasse and its derivatives occurred. This weight loss was attributed to the actual pyrolysis by the minor decomposition stage reaction at about 250 and 300°C for bleached bagasse pulp and bagasse raw material, whereas, the weight loss were 10 and 11%

respectively. The major decomposition temperature is preceded at 325 and 365°C for bleached bagasse pulp and bagasse raw material, respectively. The weight loss at the major decomposition temperature was 60 and 78% for bleached bagasse pulp and bagasse raw material respectively. As shown from Figure 4(A,B) the bleached bagasse pulp has a minor and major decomposition temperature less than that in case of bagasse raw material. This can be attributed to the lower crystallinity index of bleached bagasse pulp and the presence of lignin in the bagasse raw material. Whereas, lignin increases the adhesive forces between cellulose, hemicellulose and lignin, results in more resistance for the thermal decomposition and an increase in thermal stability.

Figure 4(A,C,D) shows the TG curves of bleached bagasse pulp (A), cyanoethylated bleached bagasse pulp (C), and hydrolyzed cyanoethylated bleached bagasse pulp (D). From the Figure, it is seen that, 9% weight loss begins at 80–110°C due to the moisture evaporation from the pulp. In addition, the cyanoethylated bleached bagasse pulp has a higher minor and major decomposition temperature at 280 and 360°C respectively, more than bleached and hydrolyzed cyanoethylated bleached bagasse pulp. This is related to the presence of cyano group in the pulp which increases its thermal stability. So, the weight loss is 6 and 78% at minor and major decomposition temperature respectively, in case of cyanoethylated bleached bagasse pulp Table IV. From Table IV, it is clear that, the weight loss in the hydrolyzed cyanoethylated bleached bagasse pulp at minor decomposition temperature is higher than that in case of bleached bagasse pulp. This is due to the cellulose degradation during hydrolyzes of cyanoethylated bleached bagasse pulp.

Figure 4(C,E,F) shows TG curves of cyanoethylated bleached bagasse pulp (C), carbamoyl ethylated bleached bagasse pulp (E), and hydrolyzed carbamoyl ethylated bleached bagasse pulp (F). The minor and major decomposition temperatures of cyanoethylated, carbamoyl ethylated and hydrolyzed carbamoyl ethylated bleached bagasse pulp are given in Table IV. It is seen that, the minor and major decomposition temperatures of cyanoethylated bleached bagasse pulp are higher than that in case of carbamoyl ethylated and hydrolyzed carbamoyl ethylated bleached bagasse pulp. These results can be attributed to the fact that, in case of cyanoethylated bleached bagasse pulp, the polyacrylonitrile chains ($-\text{CH}_2-\text{CH}_2-\text{CN}$) are attached to the cellulose, probably forms a ring structure during pyrolysis. This ring structure of acrylonitrile has a higher minor and major decomposition temperature than the linear polymer.²⁵ Also, from this table hydrolyzed carbamoyl ethylated bleached bagasse pulp and carbamoyl ethylated bleached bagasse pulp

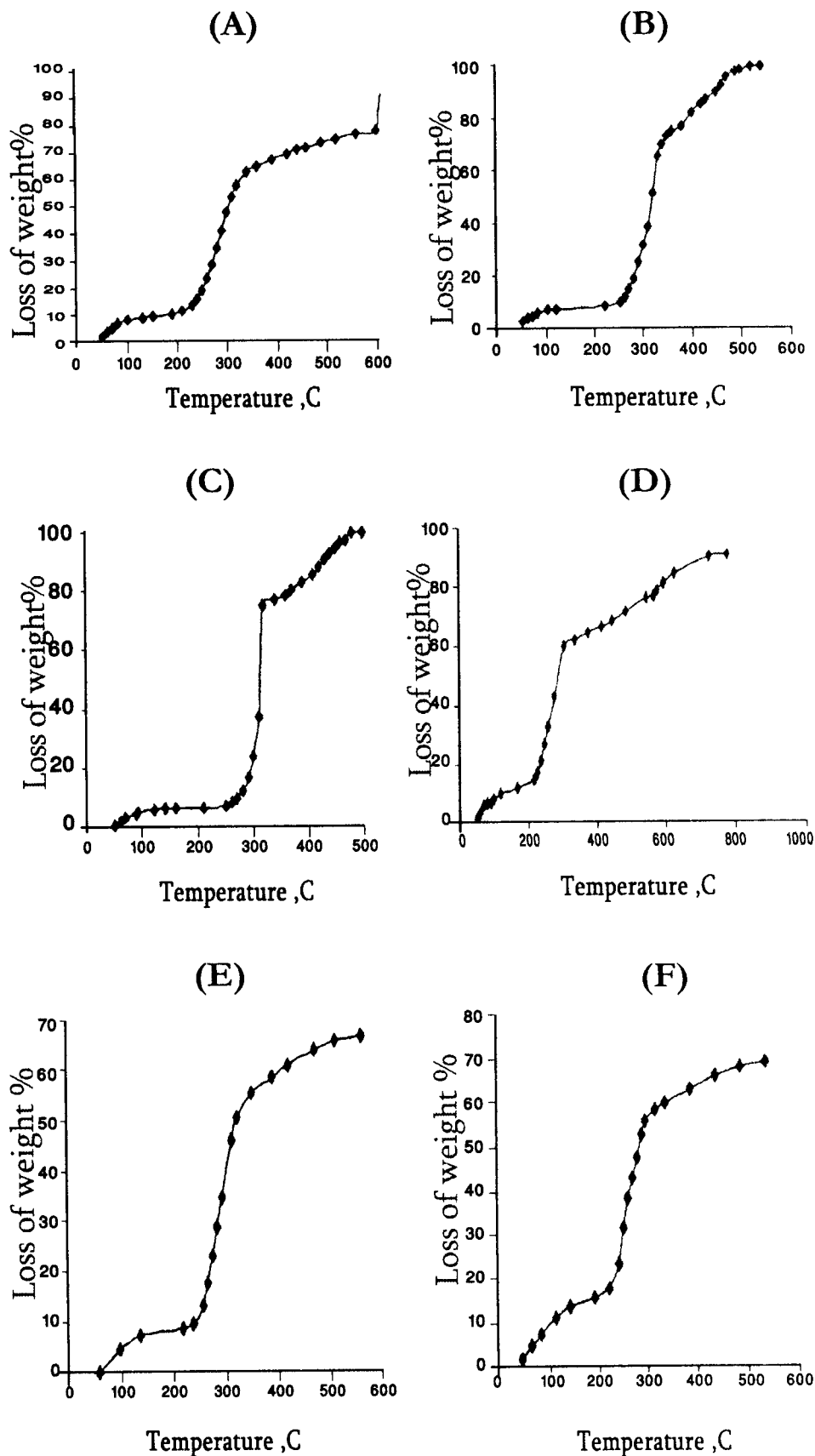


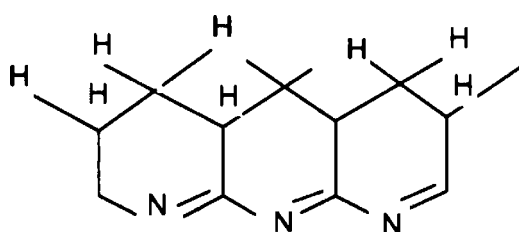
Figure 4 TG curves of (A) bleached bagasse pulp, (B) bagasse raw material, (C) cyanoethylated bleached bagasse pulp, (D) hydrolyzed cyanoethylated bleached bagasse pulp, (E) carbamoyl ethylated bleached bagasse pulp, and (F) hydrolyzed carbamoyl ethylated bleached bagasse pulp.

TABLE IV
Minor and Major Decomposition Temperature of Bleached Bagasse Pulp, Cyanoethylated, Carbamoyl Ethylated Bleached Bagasse Pulp and Their Hydrolysis

Material	Minor decomposition temperature (°C)	Weight loss (%)	Major decomposition temperature (°C)	Weight loss (%)
Cyanoethylated bleached bagasse pulp	280	16	360	78
Hydrolyzed cyanoethylated bleached bagasse pulp	255	15	300	62
Bleached bagasse pulp	250	10	325	60
Carbamoyl ethylated bleached bagasse pulp	260	12	350	60
Hydrolyzed carbamoyl ethylated bleached bagasse pulp	240	11	300	59

have weight loss at minor and major decomposition temperature less than cyanoethylated bleached bagasse pulp.

ethylated group decreases the resistance of the pulp towards thermal degradation.



Ring Structure

CONCLUSIONS

Bagasse raw material was bleached using the three stage conventional method to remove lignin from the pulp. The conversion of bagasse raw material compared to converting bleaching bagasse pulp into cation exchangers is economical and environment friendly. Metal ion uptake affinity by hydrolyzed cyanoethylated bleached bagasse pulp is lower than hydrolyzed cyanoethylated bagasse raw material. So, some of the products derived from bagasse raw material may not need crosslinking before use which is another advantage of the proposed process. Crosslinking of the cellulose derivatives increases its stability and increases the functional group affinity towards metal ions uptake. Infrared spectra show two new bands at 2252 and 3140 cm^{-1} which are due to $-\text{CN}$ and $-\text{NH}_2$ groups in cyanoethylated and carbamoyl ethylated bleached bagasse pulp respectively. Band intensity ratio of CH_2/OH for cyanoethylated and carbamoyl ethylated bleached bagasse pulp is higher than that of bagasse raw material and bleached bagasse pulp. Incorporation of cyanoethyl or carbamoyl ethyl group in the pulp increases its resistance towards thermal degradation. Hydrolyzes of cyanoethylated or carbamoyl

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