Adapting the principle of neutral sulphite cooking for modification of textile quality of jute fibre

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Received 2 November 1999; revised received and accepted 30 June 2000

A study is reported on the modification of textile properties of jute fibre by treatment with neutral sodium sulphite liquor at varying temperature under pressure. The lignin of the fibre undergoes a sulphonation reaction and is partially dissolved out from the fibre along with some hemicelluloses depending on the degree of sulphonation. The residual lignin sulphonates probably form insoluble condensation products in the fibre. The treatment brings some changes in the physico-chemical properties of the fibre. The modified jute fibre may be utilized in fine yarn spinning for diversified textile uses.

Keywords: Jute fibre, Neutral sulphite cooking

1 Introduction

Jute is a hard and coarse fibre. It contains cellulose (58-63%) incrust with non-fibrous substances like lignin (12-14%), hemicelluloses (21-24%), pectin (0.2-0.5%) and waxy substances (0.4-0.8%). Partial removal of non-cellulosic components of jute fibre to improve its characteristics has recently been a subject of much interest. During retting, only waxy and pectic substances are mostly removed, resulting in the ordinary fibre filaments for commercial use. Lignin and phenolic components are progressively degraded and released from their incrustation when the fibre is bleached with chlorite/hypochlorite solution without appreciable improvement in its textile properties. The non-fibrous carbohydrate material is hydrolyzed by alkaline treatment, which impairs both the dry and wet strength of the fibre. To remove lignin and hemicelluloses partially or wholly from the fibre, one needs to have a two-stage treatment with chlorite and alkaline charges, which eventually accelerates the degradation of fibre structure and properties.

In pulping reaction with wood materials cooked at near 170°C with NaOH (soda)/Na2S plus NaOH/Na2CO3 (kraft), and Na2SO3 plus NaOH/Na2CO3 (sulphite process) in aqueous solution, both lignin and hemicelluloses come out from the different parts of the fibre cell at different extent, affecting mostly the middle lamella liberating the intrinsic fibre cells.

Of the different pulping processes, the chemical reaction involved in the sulphite cooking is interesting as regards its effect on lignin, hemicelluloses and residual composition of the fibre. Some workers have shown that the secondary walls of the fibre cells are more rapidly delignified than the middle lamella and the attachment between the intrinsic fibre cells are not weakened so much in contrast to that in other chemical pulping processes which destroy the interfibre strength considerably. Moreover, lignin and hemicelluloses are partially removed and the residual contents form condensation products, which are not washed out and remain incorporated within the fibre.

The chemical composition of jute fibre is very much akin to that of wood chips used for making pulp. Luee et al. have reported that jute pulp produced from neutral sulphite AQ cooking is comparatively better in strength and yield. This suggests that the jute fibre strength and the mass of the chemical components are well preserved during the sulphite cooking. It is, therefore, preferred to adopt the principle of neutral sulphite cooking to modify jute fibre properties, avoiding carefully the stage of defiberization. This paper describes the change in the chemical composition and the degree of sulphonation in jute fibre during neutral sodium sulphite cooking at optimum reaction conditions.
2 Materials and Methods

2.1 Materials

Sun-dried jute fibre from jute plant of variety D-154C (Corchorus capsularis), grown in an experimental plot of Bangladesh Jute Research Institute and retted under fresh water for 18 days, was used as the fibrous raw material. The extracted fibre reed was ten feet long. The not well-retted base, known as cuttings, was discarded and the rest of the fibre reed was cut into three parts (i) bottom part 10%, (ii) middle part 70% and (iii) top part 20%, which were used for the experiments.

2.2 Methods

2.2.1 Sulphonation

Jute fibre sample (15 g) was taken in a glass tube and sulphite liquor (75 ml) was poured into the tube in such a way that no air bubble remained stuck inside the fibre mass. The glass tube with the contents was sealed at the open end and was placed inside a high pressure autoclave, which was rotated twice in a minute. The temperature was raised to 100°C, 110°C, 130°C, 145°C and 165°C separately for each experimental sample and each temperature was kept constant for 0.5h, 1.5h, 2h, 2.5h and 3h individually for each experiment. The sulphite liquor was prepared by dissolving the required amount of sodium sulphite with/without sodium carbonate/ sodium hydroxide. All the chemicals were BDH reagents in distilled water. The composition of different sulphite liquors used for sulphonation reaction are given in Table 1.

<table>
<thead>
<tr>
<th>Reaction process</th>
<th>Treatment No.</th>
<th>Liquor consistency, % (Oven dry jute fibre)</th>
<th>pH of liquor</th>
<th>pH of waste liquor</th>
<th>Alkali Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Na2SO3</td>
<td>Na2CO3</td>
<td>NaOH</td>
<td>AQ/EDTA</td>
</tr>
<tr>
<td>Neutral sulphite</td>
<td>1</td>
<td>20</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>cooking</td>
<td>2</td>
<td>15</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>10</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NS-AQ</td>
<td>1</td>
<td>10</td>
<td>4</td>
<td>0</td>
<td>0.15</td>
</tr>
<tr>
<td>NS-EDTA</td>
<td>1</td>
<td>10</td>
<td>4</td>
<td>0</td>
<td>0.15</td>
</tr>
<tr>
<td>Alkaline sulphite cookings</td>
<td>1</td>
<td>20</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>sulphite cooking</td>
<td>2</td>
<td>15</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Acid sulphite</td>
<td>1</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>15</td>
<td>0</td>
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<tr>
<td></td>
<td>3</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

NS — Neutral sulphite; AQ — Anthraquinone; and EDTA — Ethylenediamine tetraacetic acid
and water was added to it to make up the volume to 600 ml. 75 ml of KMnO₄ (0.1N) and 75 ml of H₂SO₄ (4N) were then simultaneously added to it. The reaction was proceeded at 25°C for exactly 10 min. The quantity of permanganate consumed was obtained by titrating the solution with sodium thiosulphate for KMnO₄ not consumed by the ground sample of the fibre.

2.2.5 Determination of Carbohydrate Contents

The amounts of hemicelluloses, xylan and pectic substances in the sulphonated jute fibre were determined following the procedures of Sarker et al.²⁰, Doree et al.²¹, and Kartesz²² respectively. The percentage of hexosans was calculated by subtracting xylan content from hemicelluloses and that of cellulose content by subtracting the weights of other constituents (hemicelluloses, lignin, pectic substances and waxy materials) from the weight of fibre mass.

3 Results and Discussion

3.1 Fibre Mass and Composition

Jute fibre samples were treated with different sulphite pulping liquors avoiding carefully defiberisation to modify fibre properties for better textile quality. Treated fibres were carded. Table 2 shows that jute fibres become comparatively more soft, flexible, smooth, bright and well textured on being treated in the neutral sulphite liquor. Fibres are more degraded in alkaline sulphite liquor and more harsh and coarse in acid sulphite liquor than the control fibre sample. Addition of antraquinone (AQ) or ethylenediamine tetaacetic acid (EDTA) to the neutral sulphite liquor improves the colour and lustre of the fibres. Improvement in the properties due to the neutral sulphite liquor seems to increase from the bottom part to the upper part of the fibre reed. Bundle strength data for all the treated samples are given in Table 3. Apparent strength was evaluated through usual mill practice by the Shorters for grading of jute, which is accepted internationally for jute market. Linear densities for all the treated samples are also given in Table 3.

The loss of the fibre mass due to the neutral sulphite treatment is 4 - 23% of the weight of fibre depending on the chemical charge and reaction condition (Fig. 1). The fibre mass loss is maximum at temperature nearing 170°C and varies for different parts of the fibre, indicating that the result of reaction is also dependent on the distribution of the fibre characteristics or composition along the length of the fibre reed. From an analysis of the sulphonated fibre, it is found that the cellulosic components remain unaffected, but the lignin and hemicelluloses are partially removed in all reactions at temperature ranging from 95°C to 165°C and time ranging from

<table>
<thead>
<tr>
<th>Process</th>
<th>Feeling by hand</th>
<th>Appearance</th>
<th>Apparent strength</th>
<th>Filament texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral sulphite</td>
<td>Smooth and light</td>
<td>Brightly whitish gray</td>
<td>Good</td>
<td>Flexible, thin and well separated</td>
</tr>
<tr>
<td>Na₂SO₃ + Na₂CO₃</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkaline sulphite</td>
<td>Smooth and light</td>
<td>Light gray</td>
<td>Degraded</td>
<td>Flexible, thin and well separated</td>
</tr>
<tr>
<td>Na₂SO₃ + NaOH</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid sulphite</td>
<td>Moderately smooth</td>
<td>Brightly brownish gray</td>
<td>Good</td>
<td>Hard, thin and not well separated</td>
</tr>
<tr>
<td>NaHSO₃</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutral sulphite</td>
<td>Smooth</td>
<td>More bright, lustrous and whitish</td>
<td>Good</td>
<td>Flexible, thin and well separated</td>
</tr>
<tr>
<td>EDTA /AQ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Untreated</td>
<td>Rough and coarse</td>
<td>Dull brownish gray</td>
<td>Good</td>
<td>Hard, thick and not well separated</td>
</tr>
</tbody>
</table>

*Apparent strength was evaluated through usual mill practice by the Shorters (for grading of jute fibres).
1 h to 3 h. From Fig. 2, it seems that the limiting loss of lignin (about 35%) and hemicelluloses (about 65%) is mainly due to the loss of 40% xylan and 75% hexosan. Pectic substances are, however, removed very rapidly at early stage of reaction (Fig. 2).

3.2 Delignification

Jute lignin was sulphonated and became soluble due to the hydrolysis of ligno-sulphonic acid in water. From Fig. 3, it is seen that the rate of delignification increases on increasing time and temperature, which appears to be levelled to 35% at temperature nearing 170°C. Pentosans were slowly dissolved at approximately the same rate as that of hydrolysis and dissolution of lignosulphonate from jute sample. This suggests that the dissolution of lignin as sulphonate breaks down the xylan-lignin linkage, initiating simultaneously the depolymerization of hemicelluloses.

3.3 Residual Lignin and Sulphonation

Lignin sulphonates formed during neutral sulphite treatment are not all dissolved out. A major part of residual lignin in the fibre is sulphonated, but remains insoluble, probably due to the formation of condensation products. From Figs 4 and 5, it may be observed that jute fibres are sulphonated very rapidly at the initial stage of reaction, but delignification proceeds very slowly (Fig. 3), up to maximum 35% of the lignin content, and then substitution of sulphonic groups in the fibre seems to maintain the equilibrium of delignification. Fig. 5 shows that the degree of sulphonation increases with the increasing concentration of sodium sulphite, being maximum (about 75% of the residual lignin content) at 0.08M concentration.
sodium sulphite per 100 g of fibre at 145°C. Degree of sulphonation also increases with the increase in temperature (Fig. 4), but at temperature above 145°C the content of sulphonic groups, initially fixed in the fibre, decreases very slowly as the treatment is prolonged. It seems that at this stage of high temperature, the rate of hydrolysis of ligno-sulphonates is enhanced and delignification increases more than the degree of sulphonation.

It is found that the sulphur content of the untreated raw jute fibre is about 0.7%. At the initial stage of treatment, it decreases to 0.2 m.mole/g of lignin and then increases to about 1.0 m.mole/g of lignin with the extent of sulphonation, which simultaneously decreases the residual lignin content. The total sulphur content exceeds the amount equivalent to the total sulphonic acid groups of the fibre by about 20% which likely forms non-acidic lignin-sulphur compound in the sulphonated fibre.

4 Conclusion

The physical properties of jute fibres are improved by the sulphonation treatment with neutral sodium sulphite cooking liquor and the treated fibres may be utilized in fine spinning for diverse textile uses.

Acknowledgement

This work is partially supported by the Ministry of Agriculture, Bangladesh, and the Bangladesh Jute Research Institute, Dhaka, Bangladesh.

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