Sequential bleaching of jute with eco-friendly peracetic acid and hydrogen peroxide

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An attempt has been made to investigate a two-stage eco-friendly bleaching of jute with peracetic acid-hydrogen peroxide as a substitute for the conventional sodium hypochlorite-hydrogen peroxide bleaching. A non-silicate organic stabilizer has been used in place of conventional sodium silicate in hydrogen peroxide bleaching. It is observed that peracetic acid-hydrogen peroxide bleaching gives higher whiteness, lower loss in strength and abrasion resistance, and improved softness compared to the conventional process. However, the problem of photoyellowing of the fabric on photoexposure for long duration still persists.

Keywords: Bleaching, Jute, Whiteness index, Yellowness index

1 Introduction
Quite a number of substances utilized in textile chemical processing are known to pose various environmental problems. Chlorine bleaching is recommended¹ to be avoided by the environmentalists as residual chlorine in waste water and chloro derivatives of organic impurities in cellulosic natural fibres lead to the problem of absorbable organic halogen (AOX). Keeping in mind the environmental awareness and hence the production of eco-friendly textiles, the natural fibres including jute are again gaining importance in textile manufacturing. The conventional bleaching process for jute is based on sodium hypochlorite followed by hydrogen peroxide bleaching. Satisfactory whiteness is obtained in this method. Hypochlorite bleaching offers some advantages like low cost, easy availability and saving in energy as it works at room temperature, but the problem with hypochlorite bleaching is its non-ecofriendliness. The formation of highly toxic chlorinated organic byproducts (AOX), during the bleaching process has limited its use over the last few years because these compounds have a potential hazard to the drinking water resources when discharged.

In the present study, therefore, an attempt has been made to substitute sodium hypochlorite (NaOCl) by peracetic acid (CH₃COO.OH) in the conventional sequential bleaching process (sodium hypochlorite followed by hydrogen peroxide) of jute. The effects of single and double bleaching of jute with sodium hypochlorite, peracetic acid and hydrogen peroxide on jute properties are also compared.

2 Materials and Methods
2.1 Materials
2.1.1 Fabric
Jute fabric having the following specifications was used: weave, plain; area density, 555 g/m²; warp count, 8 lb; weft count, 8 lb; ends/in., 17; and picks/in.,16.

2.1.2 Chemicals
Sodium silicate, sodium hydroxide, sodium sulphite, sodium hypochlorite, tetrasodium pyrophosphate, peracetic acid (10%), Stabilizer SIFA (a non-silicate organic stabilizer, Sandoz), Stabilizer AWNI (a silicate type stabiliser, Sandoz), all of commercial grade, were used.

2.2 Methods
2.2.1 Scouring
Scouring of fabric was carried out using 6 g/l soda ash at 95°C for 60 min at pH 8-9, keeping the material-to-liquor ratio at 1:30.
2.2.2 Bleaching

2.2.2.1 Single Bleaching

2.2.2.1.1 Bleaching with Sodium Hypochlorite

A portion of scoured fabric was bleached with 3 g/l (available chlorine) NaOCl at room temperature, maintaining the pH between 9.5 and 10.5 for 90 min. After bleaching, the fabric was antichlored with 5% (owf) sodium sulphite for 20 min at 70°C.

2.2.2.1.2 Bleaching with Peracetic Acid

A portion of scoured fabric was bleached with 10 ml/l peracetic acid (10%). The pH of the bath was maintained at 6.5 with tetrasodium pyrophosphate as buffer. The bleaching was carried out for 1 h at 70°C, keeping the material-to-liquor ratio at 1:30.

2.2.2.1.3 Bleaching with Hydrogen Peroxide

Another portion of scoured fabric was subjected to hydrogen peroxide bleaching with 3% (owf) H₂O₂ (50%) for 90 min at 85°C, maintaining the pH between 10 and 11 and material-to-liquor ratio at 1:30 and using 1 g/l sodium silicate as stabilizer.

2.2.2 Double Bleaching

A segment of the scoured fabric was subjected to two consecutive bleaching treatments with a particular bleaching agent under the same condition and concentration of bleaching agents as used in single bleaching.

2.2.2.3 Sequential Bleaching

2.2.2.3.1 Bleaching of NaOCl-bleached sample

A portion of single hypochlorite-bleached fabric was again bleached with 3% (owf) H₂O₂, keeping the material-to-liquor ratio at 1:30 and maintaining the pH of the bath at 10-11. Bleaching was carried out for 90 min at 85°C in the presence of 1 g/l sodium silicate as stabilizer.

2.2.2.3.2 Bleaching of CH₃COOOH-bleached Sample

A portion of single peracetic acid-bleached sample was further bleached with hydrogen peroxide in exactly the same manner as given in section 2.2.2.3.1 except that in this case, eco-friendly non-silicate type stabilizer SIF-A (1 g/l) was used.

After the completion of single, double and sequential bleaching, the fabric samples were thoroughly washed, neutralized, dried in air and conditioned at 65% RH and 27°C before testing.

2.3 Testing and Evaluation of Fabric

2.3.1 Whiteness Index

The whiteness index of the fabric after each bleaching treatment was measured in the Hunter lab scale employing Macbeth spectrophotometer interphased with computer colour matching system.

2.3.2 Tensile Strength

The tensile strength of the samples was measured as per the IS: 1969-1968 method using 1445 CRT Zwick universal tensile testing equipment. Test samples of 50 mm x 20 mm were used and the traverse speed and pretension level were 100 mm/min and 0.2N respectively. An average of 10 observations was taken for each sample.

2.3.3 Bending Length

The bending length of the samples was measured in both warp and weft directions as per the IS: 6490-1971 (Cantilever test 90) method using Sasmira stiffness tester with a specimen size of 200 mm x 25 mm. The average of five tests was taken for each sample.

2.3.4 Abrasion Resistance

Flex abrasion test was carried out using C.S.I. abrasion tester. Specimens (6 in. x 1 in.) from both warp and weft directions were clamped, one at a time, at the edges over the flex plates and a load of 4 lb was placed to the spigot and 2 lb weight to the bell crank lever; a 2:1 velocity ratio created a tension of 4 lb in the specimen. When the machine was switched on, the fabric was repeatedly pulled back and forth due to the movement of the carriage and eventually ruptured. The number of cycles to cause rupture of the specimen was noted down by the counter. An average of ten observations was taken for each sample.

2.3.5 Surface Morphology

Surface morphology of scoured and bleached jute fabrics was examined using a scanning electron microscope (model—Stereoscan 360, Cambridge Instrument Limited, UK). The photographs were taken at a magnification of ×2000.

2.3.6 Lignin Content

About 2 g of the sample was treated with 100 cc H₂SO₄ (72%) at about 20°C for 2 h to dissolve the carbohydrate fraction of jute. The acid was then diluted to 3% with distilled water and the liquor was boiled for some time and cooled. The residual matter (lignin) was allowed to settle. The liquor was filtered through sintered glass crucible, washed with distilled water, dried and weighed. Lignin content was calculated and expressed in percentage on the basis of the oven-dry-weight of jute.
3.3.7 Photostability
The samples were photoexposed in a Fadometer (SDL 237) for different durations (2, 8, 14, 26, 32 and 40 h) and yellowness index (ASTM E-313) of these photoexposed samples was measured using reflectance spectrophotometer interfaced with computer colour matching system.

3 Results and Discussion
3.1 Effect of Single Bleaching on Fabric Properties
Table 1 shows that NaOCl bleaching gives the minimum whiteness index and the maximum loss in strength and abrasion resistance. The lignin content in this case is lowest. On the other hand, H₂O₂ bleaching gives the maximum improvement in whiteness. The loss in strength and abrasion resistance in H₂O₂ bleaching is lower than that in NaOCl bleaching but greater than that in CH₃COO.OH bleaching. In case of CH₃COO.OH bleaching, the whiteness index lies in between the values for NaOCl and H₂O₂ bleaching. The loss in strength, abrasion resistance and lignin content is minimum. The minimum bending length of CH₃COO.OH-bleached sample shows that this treatment has a softening effect also. The highest loss in strength and abrasion resistance of NaOCl-bleached sample shows that this treatment has an appropriate from the point of view of adverse effect

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Whiteness index</th>
<th>Strength loss %</th>
<th>Weight loss %</th>
<th>Abrasion resistance (No. of cycles)</th>
<th>Lignin content %</th>
<th>Bending length, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Warp</td>
<td>Weft</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>38.1</td>
<td>—</td>
<td>—</td>
<td>486</td>
<td>462</td>
<td>12.48</td>
</tr>
<tr>
<td>(scoured)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>NaOCl</td>
<td>52.6</td>
<td>14.6</td>
<td>3.67</td>
<td>231</td>
<td>221</td>
<td>7.16</td>
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<tr>
<td>H₂O₂</td>
<td>58.8</td>
<td>8.6</td>
<td>2.88</td>
<td>341</td>
<td>330</td>
<td>12.22</td>
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<tr>
<td>CH₃COO.OH</td>
<td>54.2</td>
<td>4.4</td>
<td>1.58</td>
<td>402</td>
<td>395</td>
<td>12.33</td>
</tr>
</tbody>
</table>

3.2 Effect of Double Bleaching on Fabric Properties
In commercial practice, normally two bleaching treatments are given to jute fabric to get the acceptable whiteness. The effect of double bleaching with various bleaching agents on jute fabric properties is shown in Table 2. It is observed that the double bleaching improves the whiteness over that by the single bleaching. However, the improvement in whiteness with CH₃COO.OH is marginal. Here again, the maximum improvement in whiteness is found with H₂O₂ bleaching. NaOCl bleaching, as expected, results in the maximum loss in strength and abrasion resistance due to heavy loss of lignin content. The loss in strength and abrasion resistance of CH₃COO.OH-bleached sample is lowest because of the high lignin content, whereas in case of H₂O₂-bleached sample, the loss is within the acceptable limits. Here again, CH₃COO.OH-bleached sample is quite softer.

3.3 Effect of Sequential Bleaching on Fabric Properties
In commercial practice, normally the jute fabric is sequentially bleached with NaOCl followed by H₂O₂. It is thought that this treatment may not be appropriate from the point of view of adverse effect

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Whiteness index</th>
<th>Strength loss %</th>
<th>Weight loss %</th>
<th>Abrasion resistance (No. of cycles)</th>
<th>Lignin content %</th>
<th>Bending length, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Warp</td>
<td>Weft</td>
<td></td>
</tr>
<tr>
<td>NaOCl</td>
<td>62.5</td>
<td>30.2</td>
<td>7.77</td>
<td>198</td>
<td>188</td>
<td>5.1</td>
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<tr>
<td>H₂O₂</td>
<td>68.8</td>
<td>14.5</td>
<td>4.6</td>
<td>111</td>
<td>107</td>
<td>12.1</td>
</tr>
<tr>
<td>CH₃COO.OH</td>
<td>56.3</td>
<td>5.8</td>
<td>3.0</td>
<td>378</td>
<td>373</td>
<td>12.0</td>
</tr>
</tbody>
</table>
on strength and abrasion resistance because any treatment with chlorine containing bleaching agent (e.g. NaOCl) is likely to produce loss of lignin, resulting in heavy loss in strength and abrasion resistance. Moreover, the process is not eco-friendly. Therefore, in the present work, jute fabric was sequentially bleached with CH₃COO.OH followed by H₂O₂ since both of them are non-chlorine compounds and peracetic acid particularly has only marginal effect on lignin. Table 3 shows that this treatment produced the jute fabric with high lignin content and relatively high strength and abrasion resistance. Whiteness and softness (in terms of bending length) are also better in this case compared to that in sequential NaOCl-H₂O₂ bleaching.

The SEM photomicrographs (Fig. 1) show that there is fibre surface disruption due to the removal of lignin in the case of sequential NaOCl-H₂O₂ bleaching which is not evident in CH₃COO.OH-H₂O₂ bleaching. This suggests that sequential bleaching with CH₃COO.OH-H₂O₂ is much milder in action on jute compared to NaOCl-H₂O₂ bleaching.

One of the major drawbacks of bleached jute fabric is the loss of whiteness or development of yellowness on photoexposure which is due to the absorption of UV component of light by the lignin present in the bleached jute fabric.

It is assumed that sequential CH₃COO.OH-H₂O₂ treatment retains a substantial quantity of lignin which might lead to severe photo-yellowing on prolong photoexposure. To confirm the above hypothesis, jute fabrics sequentially bleached with NaOCl-H₂O₂ and CH₃COO.OH-H₂O₂ were exposed continuously to artificial daylight for different durations (up to 40h). The yellowness indices of these two samples were measured at different time intervals and the results are shown in Table 4. It is observed that in both the treatments, yellowness index increases up to first 20 h exposure after which there appears to be a stabilisation effect. The lower values of yellowness index at all the time intervals in case of CH₃COO.OH-H₂O₂ bleached sample is due to its initial higher whiteness index.

To eliminate the effect of initial difference in whiteness, the increase in yellowness index at each time interval was determined by subtracting the yellowness index value of unexposed sample from the yellowness index value at any particular time of exposure. The results (Table 5) show that the yellowness index values determined in this way are higher for CH₃COO.OH-H₂O₂ bleached sample as compared to that for NaOCl-H₂O₂ bleached sample. This may be attributed to the higher lignin content of CH₃COO.OH-H₂O₂ bleached sample.

Thus, the suggested sequential bleaching treatment of jute fabric with CH₃COO.OH-H₂O₂ has the
Fig. 1—Scanning electron photomicrographs of jute fibres (a) control, (b) bleached with NaOCl, (c) bleached with CH$_3$COO.OH, (d) bleached with NaOCl-H$_2$O$_2$ and (e) bleached with CH$_3$COO.OH-H$_2$O$_2$
advantage of highest degree of whiteness with maximum retention of strength and abrasion resistance. The fabric bleached through this sequence is surprisingly softer, though the harshness of jute is known to be because of its high lignin content and the same remained almost unaffected due to peracetic acid or hydrogen peroxide treatment.

4 Conclusions

4.1 Single bleaching of jute with NaOCl/H$_2$O$_2$/CH$_3$COO.OH does not produce adequate whiteness. Bleaching with NaOCl results in higher strength and weight loss whereas that with CH$_3$COO.OH gives better feel and higher abrasion resistance.

4.2 Double bleaching with H$_2$O$_2$ gives better whiteness, whereas double bleaching with NaOCl causes severe damage to the fibre and that with CH$_3$COO.OH does not give adequate whiteness.

4.3 Conventional NaOCl-H$_2$O$_2$ sequential bleaching gives acceptable whiteness but other properties are adversely affected.

4.4 Sequential bleaching with CH$_3$COO.OH and H$_2$O$_2$ gives higher whiteness, lower loss in strength and abrasion resistance, and an improved softness.

4.5 Both conventional and suggested bleaching sequences have a major drawback of photo-yellowing of bleached samples on photoexposure.

Acknowledgement

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