Studies on combined dyeing and resin finishing of jute fabrics using direct dye and DMDHEU

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Direct dyeing and anticrease finishing of jute fabrics were carried out in a single-step process under acidic conditions with a view to economize dyeing and finishing. The properties of the finished fabric, viz. colour strength, crease recovery and wash fastness, were comparable to those of the fabrics dyed and finished by the conventional double-step process. Work on optimizing the process parameters, viz. catalyst concentration and curing temperature, was also carried out. The duration of curing was kept constant in all the experiments. Incorporation of acrylamide in the padding bath of single-step process improved the colour yield.

Keywords: Colour strength, Crease recovery, Dimethyloldihydroxyethylene urea, Dyeing, Jute fabric, Resin finishing, Tensile strength

1 Introduction

For use in decorative and furnishing materials, jute fabrics need dyeing and easy care finishing. The usual procedure is to dye the jute first with direct dyes by the conventional batch method and then resin finish it. Attempts for carrying out the dyeing and finishing in a single-step process have been made for cotton textiles but no attempts seem to have been made for jute fabrics.

Jute differs from cotton in chemical composition. While the cotton is purely cellulosic, jute contains cellulose (62-64%), hemicellulose (21-23%) and lignin (12-14%) as major constituents.

The potentialities of crosslinking the jute fabrics have been reported by us earlier. This work was undertaken to study the feasibility of carrying out simultaneous dyeing and resin finishing of jute fabrics.

2 Materials and Methods

2.1 Materials

2.1.1 Fabric

A decorative, plain weave, bleached (2% H₂O₂ o.w.f.) jute fabric was used. The grey jute fabric had the following specifications: Warp—63 ends/dcm (count, 256 tex); weft—55 ends/dcm (count, 210 tex); and fabric mass (at 65% RH and 20°C)—275 g/m².

2.1.2 Chemicals

(i) Ahuramine YX based on dimethyloldihydroxyethylene urea with about 50% solid content was used as finishing agent.

(ii) NH₄Cl, NH₄NO₃ and (NH₄)₂S₂O₇ were used as catalysts. All these chemicals were of analytical grade.

(iii) Four dyes, viz. Chlorantine Fast Orange T4RLL, Chlorantine Fast Blue 3RLL, Chlorantine Fast Brown 4RLL and Chlorantine Fast Yellow Brown 2GLL (all of Hindustan Ciba-Geigy Ltd), were used without any further purification and the values are reported on that basis. The structures of the dyestuffs are given below.

![Chemical structures](image1)

Chlorantine Fast Orange T4RLL (C.I. Direct Orange 37)

Chlorantine Fast Blue 3RLL (C.I. Direct Blue 67)

Chlorantine Fast Brown 4RLL (C.I. Direct Brown 95)
2.2 Methods

2.2.1 Pad-dry-cure-wash

Bleached jute fabric was padded twice in a solution containing dye (0.5%), catalyst (0.5-1.5%), DMDHEU (10% solid add-on) and non-ionic wetting agent (0.1%). The wet pick-up was adjusted to 100%. The padded fabric was dried at 80°C for 5 min, cured at high temperatures (140-160°C) for 5 min, washed thoroughly and dried. The bleached fabric was dyed both by the conventional exhaust and pad dyeing method. The two-stage conventional process, i.e. dyeing followed by resin finishing, was also carried out.

2.2.2 Testing

The treated fabrics were evaluated for colour strength, expressed as $K/S$ (where $K$ is the adsorption coefficient; and $S$, the scattering coefficient). $K/S$ value was calculated from the reflectance measurement by photovolt reflection meter (model 670) and using the Kubelka-Munk equation.

Dry crease recovery angle was measured by the Monsanto crease recovery tester in accordance with ASTM D 1295-67. Tensile strength (warp) was measured by the ravelled strip (10 cm x 2.5 cm) method on an Instron machine (Model TTBM). Wash fastness was assessed by AATCC-61-1A-1965 method and the light fastness by AATCC-16A-1964 method.

Extraction with 50% dimethylformamide (DMF) solution was done for 30 min and dye fixation was measured as percentage colour strength ($K/S$) retention.

2.2.3 Dye Purity

Dye was first purified by sodium acetate method and then used as standard to determine the purity of commercial dye using spectrophotometry.

3 Results and Discussion

The selection of catalysts is an important factor since they often interfere with the dye in solution and cause precipitation, leading to poor and uneven dyeing. Hence, all acid liberating catalysts cannot be used in combined process due to their incompatibility with the dye solution though acid medium is necessary for cross-linking. The catalysts selected here for combined process were of latent acid type and all ammonium salts of strong acids, such as NH$_4$Cl, NH$_4$NO$_3$ and (NH$_4$)$_2$S$_2$O$_8$.

The effects of catalyst concentration and curing temperature on the colour strength, crease recovery, wash fastness and tensile strength loss (%) of combined dyed (Chlorantine Fast Orange T4RLL, 0.5%) and finished jute fabric are shown in Table 1. The table shows that the colour strength remains almost same with persulphate concentration.

<table>
<thead>
<tr>
<th>Catalyst conc.</th>
<th>Colour strength $(K/S)$</th>
<th>Dry crease recovery angle (W + F), deg</th>
<th>Wash fastness (Grade)</th>
<th>Tensile strength loss, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>140 150 160</td>
<td>140 150 160</td>
<td>140 150 160</td>
<td>140 150 160</td>
</tr>
<tr>
<td>$(\text{NH}_4)_2\text{S}_2\text{O}_8$</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>0.5</td>
<td>3.61 3.73 3.61</td>
<td>230 235 238</td>
<td>2-3 3 3-4</td>
<td>9.6 13.23 15.40</td>
</tr>
<tr>
<td>0.75</td>
<td>3.61 3.61 3.61</td>
<td>235 240 242</td>
<td>2-3 3 3-4</td>
<td>13.02 19.10 22.05</td>
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<tr>
<td>1.0</td>
<td>3.61 3.71 3.61</td>
<td>236 240 244</td>
<td>2-3 3 3-4</td>
<td>16.6 23.5 47.0</td>
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<tr>
<td>$(\text{NH}_4)\text{Cl}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>3.42 3.46 3.46</td>
<td>232 238 240</td>
<td>3 3-4 4</td>
<td>10.4 15.75 26.46</td>
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<tr>
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<td>258 266 276</td>
<td>4 4 4</td>
<td>28.56 30.24 37.17</td>
</tr>
<tr>
<td>1.5</td>
<td>3.61 3.73 3.71</td>
<td>262 266 276</td>
<td>3-4 4 4</td>
<td>35.15 35.70 50.8</td>
</tr>
<tr>
<td>$(\text{NH}_4)\text{NO}_3$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>3.16 3.16 3.33</td>
<td>230 238 242</td>
<td>3 3-4 3-4</td>
<td>16.12 18.1 17.25</td>
</tr>
<tr>
<td>1.0</td>
<td>3.08 3.20 3.16</td>
<td>256 264 272</td>
<td>3 3-4 4</td>
<td>14.70 27.36 39.05</td>
</tr>
<tr>
<td>1.5</td>
<td>3.08 3.16 3.16</td>
<td>260 268 270</td>
<td>3-4 4 4</td>
<td>30.7 37.14 39.42</td>
</tr>
<tr>
<td>Bleached fabric pad dyed</td>
<td>2.76</td>
<td>159</td>
<td>1-2</td>
<td>6.38</td>
</tr>
<tr>
<td>with 0.5% Chlorantine Fast Orange T4RLL at room temperature without resin and catalyst</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Dry crease recovery angle (W + F) of bleached jute fabric (control), 160°

* Tensile strength of bleached jute fabric (control), 47 kg
(0.5-1.0%) whereas the crease recovery and wash fastness improve slightly at higher curing temperature and the loss in tensile strength (%) increases with higher concentrations as well as curing temperature.

In the case of NH₄Cl, as the catalyst concentration is increased from 0.5 to 1.5% the colour strength, crease recovery, wash fastness and loss in tensile strength (%) also increase. The colour strength, however, attains optimum value at 150°C for all the concentrations used.

In the case of NH₄NO₃, the colour strength shows higher values at 0.5% catalyst concentration at all the curing temperatures. Other properties increase with rise in concentration and curing temperature.

From Table 1 and Figs 1 & 2 it is observed that the colour strength obtained with 3 catalysts at 0.5% concentration follows the following order: (NH₄)₂S₂O₈ > NH₄Cl > NH₄NO₃. This may be attributed to the difference in the acid catalyzing power of the three salts.

Crease recovery values indicate that the effectiveness of catalysts NH₄Cl and NH₄NO₃ is better than that of (NH₄)₂S₂O₈ at all the curing temperatures and catalyst concentrations (Table 1).

The bleached fabric was also dyed to 0.5% shade with Chlorantine Orange T4RLL by padding in dye solution without resin and catalyst and the values of colour strength, wash fastness, dry crease recovery angle and loss in tensile strength (%) are reported in Table 1.

### 3.1 Combined Process vs. Double-step Process

Table 2 shows the data on colour strength, dye fixation after extraction with DMF (50%) solution, dry crease recovery angle, wash fastness, light fastness and loss in tensile strength for jute fabrics subjected to: (a) control exhaust dyeing, (b) exhaust dyeing followed by resin finishing, (c) pad dyeing followed by resin finishing, and (d) combined dyeing and resin finishing, using four dyestuffs at 0.5% conc, 0.5% (NH₄)₂S₂O₈ as catalyst and 150°C curing temperature.

The results show that wash fastness, light fastness and crease recovery are nearly same for both combined and double-step processes.

The colour strength for Chlorantine Orange and Yellow is better in combined process than in the two-step process.

The dye fixation shows improvement in both combined and double-step processes with respect to only dyed fabric. The fixation is somewhat better in exhaust dyeing followed by resin finishing process due to better diffusion of dye molecules inside the fibres (Fig.3).

### 3.2 Nature of Dye

The colour strength, dye fixation and wash fastness in the combined process depend on the nature of the dye, i.e. its molecular size, configuration, substituents or reactive groups and solubility. The direct dyes are linked to cellulosic fibre via physical bonds, e.g. by van der Waals' forces, hydrogen bonding, etc., and hence affinity for cellulosics.

After extraction with DMF solution, considerable loss occurs in dye fixation without finishing agent, whereas dye fixation improves considerably after the addition of resin.

It was assumed that some dye fixation takes place by the covalent bonds between the nucleophilic
Table 2: Effect of dyeing and resin finishing on properties of jute fabric

[Catalyst used — (NH₄)₂S₂O₈; Curing period, 5 min; Curing temp., 150°C]

<table>
<thead>
<tr>
<th>Dye</th>
<th>Dye conc.</th>
<th>Colour strength</th>
<th>Dye fixation after extraction with DMF (50%) solution</th>
<th>Dry crease recovery angle (W+F), deg</th>
<th>Wash fastness (Grade)</th>
<th>Light fastness (Grade)</th>
<th>Loss in tensile strength, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorantine Fast Orange T4RLL</td>
<td>0.5</td>
<td>2.93 2.25 2.47 3.73</td>
<td>38.12 87.59 61.64 72.69</td>
<td>160 234 234 236</td>
<td>3 3 5 5</td>
<td>5 5 5 5</td>
<td>18.10 13.23 16.20</td>
</tr>
<tr>
<td>Chloramine Fast Blue 3RLL</td>
<td>0.5</td>
<td>2.58 2.25 1.69 1.62</td>
<td>20.90 56.20 37.30 28.21</td>
<td>236 230 228</td>
<td>2 2 2 2</td>
<td>2-3 2 2 2</td>
<td></td>
</tr>
<tr>
<td>Chloramine Fast Yellow Brown 2GLLL</td>
<td>0.5</td>
<td>1.69 1.69 1.73 1.93</td>
<td>60.00 99.60 92.90 88.21</td>
<td>236 236 238</td>
<td>3-4 4 4 4</td>
<td>3 3 3 3</td>
<td></td>
</tr>
<tr>
<td>Chloramine Fast Brown BRLL</td>
<td>0.5</td>
<td>3.05 2.35 2.87 2.81</td>
<td>65.79 75.68 76.65 76.02</td>
<td>238 240 240</td>
<td>2-3 3 2-3 2-3</td>
<td>4 4 4 4</td>
<td></td>
</tr>
</tbody>
</table>

(a) Control exhaust dyeing; (b) Conventional exhaust dyeing and resin finishing; (c) Pad dyeing and resin finishing; and (d) Combined dyeing and resin finishing.

Table 3: Effect of addition of acrylamide on colour strength

<table>
<thead>
<tr>
<th>Dye</th>
<th>Dye conc.</th>
<th>Colour strength (K/S)</th>
<th>Dye fixation after extraction with DMF (50%) solution</th>
<th>Dry crease recovery angle (W+F), deg</th>
<th>Wash fastness (Grade)</th>
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<th>Loss in tensile strength, %</th>
</tr>
</thead>
<tbody>
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<td>0.5</td>
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<td>3 3 5 5</td>
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<td>18.10 13.23 16.20</td>
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<td>Chloramine Fast Yellow 2GLLL</td>
<td>0.5</td>
<td>2.38 1.97 4.26 3.73</td>
<td>60.00 99.60 92.90 88.21</td>
<td>236 236 238</td>
<td>3-4 4 4 4</td>
<td>3 3 3 3</td>
<td></td>
</tr>
<tr>
<td>Chloramine Fast Brown BRLL</td>
<td>0.5</td>
<td>3.05 2.35 2.87 2.81</td>
<td>65.79 75.68 76.65 76.02</td>
<td>238 240 240</td>
<td>2-3 3 2-3 2-3</td>
<td>4 4 4 4</td>
<td></td>
</tr>
</tbody>
</table>

The blue dye gives poor colour strength due to its big molecular size and more electronegative charges on the dye molecules. It has poor migration and diffusion to the fibre and remains aggregated in the padding bath. The brown dye gives somewhat lower colour strength value in the combined process due to less dispersion and penetration of dye molecules.
3.3 Role of Acrylamide

Table 3 and Fig.4 show that incorporation of acrylamide (3.0%) in the padding bath of combined process enhances colour strength significantly. This enhancement could be associated with the favourable effect of acrylamide on: (a) swellability and accessibility of jute fibres, and (b) reducing the aggregation and increasing the suitability of dye\(^3\).

With orange dye, acrylamide shows little effect on colour yield as the dye possesses small size and hence good accessibility to the fibre.

In the case of blue and brown dyes having some degree of aggregation in the padding bath, acrylamide increases the dispersion of dye molecules and swelling of fibres and thus helps the dye to penetrate inside the fibre.

4 Conclusion

Dyeing and resin finishing of jute fabrics can be carried out in one-step process with certain limitations. Combined process results in saving energy, time and manpower. The colour strength and crease recovery of fabrics dyed and finished in one-step process are as good as or even better in some cases than those of the fabrics dyed and finished in two-step process. Acid sensitive dyes, however, may be avoided for obtaining better results.

Acknowledgement

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References