Dyeing of red sandalwood on wool and nylon

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The use of red sandalwood (*Pterocarpus santalinus*) extract as a dye for wool and nylon has been explored. The colouring components were extracted with organic as well as aqueous alkaline solution from the sandalwood and the physico-chemical properties of the dried extracts evaluated. The extracted dye was applied on wool and nylon with and without mordants and the fastness of the dyed samples to light and washing studied. The light fastness of the dyed wool samples improved substantially on mordanting with copper sulphate and ferrous sulphate. The wool and nylon samples dyed and treated with mordants, except copper sulphate, showed good wash fastness.

Keywords: Nylon, *Pterocarpus santalinus*, Red sandalwood, Wool

1 Introduction

The natural dyes, especially vegetable colourants, have aroused considerable interest in dyeing of textile due to their perceived ecofriendly nature. During last two decades, natural dyes have witnessed a process of revival

The present study has been concentrated on the extraction of the colouring components from the red sandalwood, which has been used in various fields besides colouration of textiles, foodstuffs and paper pulp.

Red sandalwood comprises complex colouring compounds (Fig. 1). Perkin and Everest* isolated the colouring matter and suggested that there are at least two colouring components in the red sandalwood, viz. Santalin and Deoxysantalin, of which Santalin is the main colouring component. Ravindranath and Seshadri* and Arnone et al. confirmed the presence of three colouring components in Santalin (A, B and C).

2 Materials and Methods

2.1 Extraction of Colouring Matter

The crushed red sandalwood for experiment was obtained from Alps Industries Ltd, Ghaziabad, India. The colouring matter was extracted from crushed wood by three different methods: (i) Extract-1: extraction with ethanol (yield 20.6%); (ii) Extract-2: first extracted with carbon tetrachloride to remove low polar substance and then with ethanol (yield 23.5%); and (iii) Extract-3: aqueous extraction obtained by treating wood chips with 20% (w/w) sodium hydroxide and precipitating the colouring component with 30% hydrochloric acid (yield 20%). All extracts were dried at 50°C under vacuum.

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2.2 Evaluation of Physico-chemical Properties
The physico-chemical properties like moisture content, pH of 1% dispersion in water and solubility of these extracts were evaluated following the standard methods.

2.3 Spectral Analysis
The UV/VIS spectra of extracted dye samples at different pH (0.01% solution in methanol) were recorded on Perkin-Elmer Lambda 2 spectrophotometer.

2.4 Dyeing
Wool and nylon fabrics were scoured with 1 g/L non-ionic detergent (Lissapol-D) at 90°C for 60 min, washed with hot and cold water and dried before dyeing. Dyeing was carried out at pH 4 for 60 min in water - methanol mixture (95:5, v/v) of dye extracts, keeping the material-to-liquor ratio at 1:50 in a laboratory shaker. The dyeing was started at 40°C and the temperature was raised to 90°C at a heating rate of 2-2.5°C/min. The dyeing was continued at 90°C for another 60 min. In all cases, 5% shade was dyed. Pre- and post-mordanting was carried out for 60 min at 90°C with following mordants plus other chemical auxiliaries by a two-bath, two-stage dyeing process:

- Alum, 20 % owf (pH 4)
- Alum, 20% owf + tartaric acid, 5% owf (pH 1)
- Potassium dichromate, 3%owf (pH 7)
- Ferrous sulphate, 3% owf (pH 7)
- Ferrous sulphate, 3% owf + tartaric acid, 6% owf (pH 6)
- Stannous chloride, 3%owf (pH 6)
- Stannous chloride, 3% owf + tartaric acid, 3% owf + oxalic acid, 3% owf (pH 1)
- Copper sulphate, 6%owf (pH 5)

2.5 Evaluation of Fastness Properties
The light fastness of the dyed samples was tested according to IS: 2454 -1984 and the wash fastness according to DIN-20105-CO2.

3 Results and Discussion

3.1 Physico-chemical Properties
The physico-chemical properties of the dye extracts are given in the Table 1. The pH of 1% aqueous dispersion shows its acidic character. Extract-3 is more acidic than others. This is because of the residual acid added during precipitation and formation of more phenolic hydroxyl groups due to the break down of the molecules. Red sandalwood is sparingly soluble in hot water. The extracts 1 and 2 are completely soluble in methanol while in the case of extract-3, only 68% of the extracted colouring matter is dissolved in methanol.

3.2 Spectral Analysis
The UV spectra of the extracts (Figs 2-5) show that these dyes have strong absorption in UV region ($\lambda_{max}$ = 288nm). The visible spectra of the extracted dyes (extracts 1, 2 and 3) at different pH are shown in Figs 3, 4 and 5 respectively. The maximum absorption ($\lambda_{max}$)

![UV spectra of red sandalwood extracts](image)

![Visible spectra of red sandalwood extract 1 at different pH](image)

<table>
<thead>
<tr>
<th>Property</th>
<th>Raw material</th>
<th>Extract 1</th>
<th>Extract 2</th>
<th>Extract 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture, %</td>
<td>3.96</td>
<td>12</td>
<td>13.12</td>
<td>13.19</td>
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<tr>
<td>pH of 1% aqueous dispersion</td>
<td>6.9</td>
<td>4.76</td>
<td>4.7</td>
<td>2.9</td>
</tr>
<tr>
<td>Hot water-soluble fraction, %</td>
<td>14</td>
<td>38</td>
<td>45</td>
<td>31</td>
</tr>
<tr>
<td>Methanol-soluble fraction, %</td>
<td>21</td>
<td>100</td>
<td>100</td>
<td>68</td>
</tr>
</tbody>
</table>
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pH: 4
pH: 7
pH: 7.67
pH: 9
pH: 10

Fig. 4 – Visible spectra of red sandalwood extract 2 at different pH

Fig. 5 – Visible spectra of red sandalwood extract 3 at different pH

Table 2 — L*, a* and b* values of undyed and dyed fabrics

<table>
<thead>
<tr>
<th>Mordant</th>
<th>Dye extract No.</th>
<th>Pre-mordanting</th>
<th>Post-mordanting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L*</td>
<td>a*</td>
<td>b*</td>
</tr>
<tr>
<td>Dyed wool fabrics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alum</td>
<td>35.005</td>
<td>31.895</td>
<td>28.122</td>
</tr>
<tr>
<td>Alum + T.A.</td>
<td>35.461</td>
<td>34.942</td>
<td>25.848</td>
</tr>
<tr>
<td>Pot. dichromate</td>
<td>22.800</td>
<td>22.493</td>
<td>11.775</td>
</tr>
<tr>
<td>Ferrous sulphate</td>
<td>27.010</td>
<td>13.073</td>
<td>04.254</td>
</tr>
<tr>
<td>Ferrous sulphate + T.A.</td>
<td>17.446</td>
<td>11.834</td>
<td>01.411</td>
</tr>
<tr>
<td>Copper sulphate</td>
<td>23.301</td>
<td>16.961</td>
<td>12.199</td>
</tr>
<tr>
<td>Alum</td>
<td>39.729</td>
<td>29.938</td>
<td>23.706</td>
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<tr>
<td>Alum + T.A.</td>
<td>38.680</td>
<td>30.700</td>
<td>22.194</td>
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<tr>
<td>Pot. dichromate</td>
<td>25.103</td>
<td>23.542</td>
<td>08.182</td>
</tr>
<tr>
<td>Ferrous sulphate + T.A.</td>
<td>20.131</td>
<td>12.675</td>
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<tr>
<td>Copper sulphate</td>
<td>28.816</td>
<td>17.166</td>
<td>12.730</td>
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<tr>
<td>Alum</td>
<td>59.513</td>
<td>17.833</td>
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<td>Pot. dichromate</td>
<td>22.365</td>
<td>21.566</td>
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<td>Ferrous sulphate + T.A.</td>
<td>29.729</td>
<td>15.064</td>
<td>00.343</td>
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<tr>
<td>Copper sulphate</td>
<td>30.786</td>
<td>20.816</td>
<td>09.304</td>
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<tr>
<td>Dyed without mordant</td>
<td>41.358</td>
<td>26.542</td>
<td>30.269</td>
</tr>
<tr>
<td>Undyed</td>
<td>87.000</td>
<td>-0.423</td>
<td>11.849</td>
</tr>
</tbody>
</table>

Dyed nylon fabrics

<table>
<thead>
<tr>
<th>Mordant</th>
<th>Dye extract No.</th>
<th>Pre-mordanting</th>
<th>Post-mordanting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L*</td>
<td>a*</td>
<td>b*</td>
</tr>
<tr>
<td>Dyed nylon fabrics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alum</td>
<td>53.076</td>
<td>31.653</td>
<td>32.344</td>
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<tr>
<td>Alum + T.A.</td>
<td>57.576</td>
<td>32.641</td>
<td>35.905</td>
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<tr>
<td>Pot. dichromate</td>
<td>42.627</td>
<td>22.896</td>
<td>01.862</td>
</tr>
<tr>
<td>Stannous chloride + O.A. + T.A.</td>
<td>44.079</td>
<td>32.767</td>
<td>15.310</td>
</tr>
<tr>
<td>Dyed without mordant</td>
<td>58.099</td>
<td>33.384</td>
<td>39.474</td>
</tr>
<tr>
<td>Undyed</td>
<td>94.015</td>
<td>-0.516</td>
<td>01.780</td>
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</tbody>
</table>

O.A. — Oxalic acid and T.A. — Tartaric acid
at 504 and 474 nm are almost same for all extracts up to pH 10 in methanol solution. After that at pH 11, the $\lambda_{\text{max}}$ changes to 488 nm and gives one maxima only, the colour of the solution changes (not shown in figure). This change may be due to the decomposition of the dye or modification of the dye at this pH.

3.3 Dyeing Studies

The reflectance spectra of the dyed samples were recorded and the $L^* a^* b^*$ values were calculated by CIELAB (1976) equations and are reported in Table 2. The low $L^*$ values of the samples dyed without mordant as compared to the $L^*$ values of undyed samples show that the dye is substantially absorbed by wool and nylon. The sorption of the dye by these fibres may be via hydrogen bonds, van der Waal’s forces or hydrophobic interactions.

It can be inferred from the $L^* a^* b^*$ values that on mordanting the hue of the dyed fabrics is changed distinctly. This change can be attributed to the

<table>
<thead>
<tr>
<th>Table 3 — Fastness ratings of wool fabrics dyed with different dye - mordant combinations</th>
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</table>

WF – Wash fastness; SC – Staining on cotton; SW – Staining on wool; and LF – Light fastness.

<table>
<thead>
<tr>
<th>Table 4 — Fastness rating of nylon fabrics dyed with different dye-mordant combinations</th>
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</table>

WF – Wash fastness; SW – Staining on wool; SN – Staining on nylon; and LF – Light fastness.
formation of metal-complex between dye, metal ions and fibres. It is further observed that the post-mordanting gives slightly deeper colour as compared to pre-mordanted dyed samples, irrespective of the applied dye extract.

Mordants like alum, alum + tartaric acid mixture, stannous chloride, and stannous chloride + tartaric acid + oxalic acid mixture give light colour with more yellowish to reddish tone, whereas ferrous sulphate, and ferrous sulphate + tartaric acid mixture give deep colour with violet to moderate reddish tone. Mordanting with potassium dichromate gives deep colour with brown tone, and copper sulphate too gives deep colour with yellowish tone.

Furthermore, the dye extracts obtained by different extraction procedures give different shades on wool and nylon. This may be because of the different proportions of the colouring components present in these extracts.

3.4 Light Fastness

The light fastness rating of the wool and nylon samples dyed with the various dye extracts are given in the Tables 3 and 4 respectively. A comparison between the light fastness of dyed wool and nylon shows that some of the wool samples show a light fastness in the range of 3-4, but all nylon samples show a very low light fastness (1 or 1-2). It is apparent from the tables that all the un-mordanted samples and the samples mordanted with alum as well as alum + tartaric acid show a low light fastness of 1-2, while most of the dyed wool samples mordanted with ferrous sulphate show a light fastness of 3-4. Furthermore, the light fastness rating of wool dyed with extracts 1 and 2 is good with some mordants, while the samples dyed with extract 3 show comparatively low light fastness. May be the extract 3 has a higher fugitive colouring component. Moreover, it is observed from TLC that the colouring components of extract 3 are different from those of the other extracts.

Copper sulphate gives the best fastness followed by ferrous sulphate, in both the dyeing methods, on wool with dye extracts 1 and 2. Potassium dichromate gives good results for extract 2, particularly in post-mordanting method of dyeing.

Since the dye has strong absorption at 287.6 nm, it increases the susceptibility of the dye towards UV fading. Hence, the poor light fastness with some mordants on wool and with all mordants on nylon may be attributed to the light-induced change in quinone structure of the dye. Comparatively higher light fastness of some dyed - mordanted wool samples may be attributed to the formation of dye-metal and dye-metal-fibre complexes.

3.5 Wash Fastness

The wash fastness rating of dyed wool and nylon samples is also reported in Tables 3 and 4 respectively. There is not much difference in the fastness ratings of pre-mordanted and post-mordanted samples. Mordanting with copper sulphate gives poor fastness. Alum gives better fastness than alum + tartaric acid mixture. Ferrous sulphate + tartaric acid mixture performs better than only ferrous sulphate, whereas potassium dichromate gives moderate results. In case of stannous chloride + tartaric acid + oxalic acid mixture, the reddish tone decreases slightly and becomes brown on washing. Dyeing without mordanting does not give acceptable results. The low wash fastness as well as the change in colour on washing can be attributed to the breaking of the dye-mordant complex during washing, resulting into the presence of complex and free dye in different proportions.

4 Conclusions

4.1 It is possible to extract the colouring matter from the wood with organic as well as aqueous alkali medium. All the extracts give the same absorption maxima up to pH 10 in the methanol solution.

4.2 The dye extracts can be applied directly on wool and nylon as well as with different mordants. The colour tone changes with different metal ions in both wool and nylon.

4.3 The light fastness of wool and nylon samples dyed with sandalwood extract is poor than that of those dyed with synthetic dyes. It is good with some mordants like copper sulphate, ferrous sulphate and potassium dichromate (post-mordanting) but poor with alum and alum + tartaric acid. Dyeings with extracts 1 and 2 on wool give more or less same results while dyeing with extract 3 gives in general poor fastness properties. In the case of nylon, the light fastness is very poor.

4.4 Wash fastness of all the samples dyed and treated with mordants, except copper sulphate, is good for both wool and nylon.
References
1 Gulrajani M L & Gupta D, Natural Dyes and their Application to Textiles (Department of Textile Technology, Indian Institute of Technology, Delhi), 1992.