

Use of natural mordant in dyeing of wool

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Natural mordant was obtained by concentrating aqueous extract of banana flower petaloids under reduced pressure and evaporating it to dryness. Bharat Merino sheep wool yarn dyed with turmeric (*Curcuma longa*) was subjected to mordanting separately with natural mordant and chromium under the identical conditions. Out of the different concentrations of the mordants used, 3.5 % natural mordant and 1.5 % chromium (on the weight of yarn) showed similar colour fastness, reflectance, colour shade and *K/S* values. The chemistry of wool dyeing and the physico-chemical properties of dyed wool yarns are also discussed.

Keywords: Banana petaloids, *Curcuma longa*, Tensile behaviour, UB solubility, Wool

1 Introduction

The vegetable colourants are non-polluent, mainly consist of flavonoids, anthocyanins, quinines and carotenoids, and require a mordant in dyeing of textiles to enhance the binding forces between colourant and substrate. The use of mordant, especially metal ions, is found to produce the harmful effects on environment as well as to living organisms. This awareness was also probably in the mind of ancient workers as they were in use of natural mordants in the form of albumen from egg, ox-blood, urea, cowdung and rotten mud¹. Recently, the interest is further arisen in natural mordants which are ecofriendly and non-carcinogenic in nature. The natural mordants, such as myrobalon (*Terminalia chebula*), pomegranate rinds (*Punica granatum*), tannin, tannic acid, tartaric acid, guava and banana leaves ash, are being utilized for mordanting purpose²⁻⁹. The ashes of banana leaves, bark and fruit rinds have been reported to be in use for dyeing of textile and leather as mordanting agent. The cell sap of banana flower petaloids contains a considerable amount of tannin, which stains the cloth in almost dark black colour. The stain on the cloth is fairly permanent and very difficult to wash out¹⁰⁻¹¹. In this work, an attempt has been made to study the use of petaloids of banana flower as a natural mordant in place of chromium which is non-ecofriendly and non-

biodegradable for dyeing of wool yarn using turmeric (*Curcuma longa*) as colourant.

2 Materials and Methods

2.1 Natural Mordant

Fresh petaloids of the banana flowers were collected without sacrificing the proportionate banana production, dried under shade and crushed to get it in powder form. The powder (100 g) was boiled for about 30 min with 500 ml of distilled water, cooled at room temperature and then filtered. The filtrate was concentrated under reduced pressure on water bath at 60 °C. This concentrated mass was then treated with a mixture of alcohol: water (60:40 v/v) with constant shaking for 1 h to remove gum and mucilage. The contents were filtered and the filtrate so collected was dried under reduced pressure at 40 °C. The yield of the mass was found to be 25.07 g.

2.2 Colourant

Dry turmeric was crushed, soaked in water and boiled for nearly 30 min. The filtrate was concentrated and dried under reduced pressure. The stock solution was prepared by dissolving 1.0 g colourant per 100 ml of solution.

2.3 Substrate

Worsted yarn (2-ply) of Bharat Merino sheep wool, prepared at the Division of Textile Manufacture & Textile Chemistry, Central Sheep & Wool Research Institute, was used for dyeing. Scouring of yarn was done as per the BIS method IS: 1349:1964. The scoured yarn was treated with ethanol in soxhlet

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apparatus for 3 h at the rate of 6 siphons/h to ensure removal of residual soap. The yarn was then rinsed with distilled water and dried at room temperature.

2.4 Dyeing and Mordanting

Five samples of scoured wool yarn (weighing 5 g each) were pre-soaked in acidulated water (pH 4.5, acetic acid) for nearly 30 min at 30-40 °C and then put in separate dye bath marked with A, B, C, D and E. Each dye bath contained 25 ml of stock solution of colourant and 475 ml of acidulated water (pH 4.5), maintaining the material-to-liquid ratio at 1:100. The temperature of the dye bath solution was then slowly raised to 97.5°C and maintained as such for 60 min. The loss of water due to evaporation was maintained by adding hot acidulated water (pH 4.5) from time to time to the dye bath. After 60 min of dyeing, the contents were allowed to cool at about 60 °C and then 1.0 ml glacial acetic acid was added to each dye bath with stirring for about 2 min. The natural mordant of the concentrations 0.5, 1.0, 1.5, 2.5 and 3.5 % (on the weight of yarn) was added in dye bath marked A, B, C, D and E respectively. The temperature of the dye bath was then slowly raised to 97.5°C and maintained as such for next 60 min. The loss of water due to evaporation was maintained as described above. The contents of dye bath were allowed to cool at room temperature and the yarns were taken out, washed

with washing solution (2.0 g Na₂CO₃ and 1.0 ml non-ionic detergent per litre of solution), rinsed with distilled water and dried at room temperature.

The above procedure of dyeing and mordanting was repeated using 0.5, 1.0, 1.5, 2.5 and 3.5 % (on the weight of yarn) potassium dichromate in place of natural mordant.

2.5 Physico-chemical Studies

2.5.1 Colour Strength

The treated yarns were subjected to estimation of colour strength in terms of *K/S* values on Computer Colour Matching Instrument (Jaypak 2300). The results are given in Table 1.

2.5.2 Colour Fastness Tests

Light fastness test of dyed samples was carried out as per the BIS method IS: 686-1957. The samples were exposed to summer (May – June) daylight from 9.30 AM to 3.30 PM for a total period of 36 h as per the BIS method. The atmospheric temperature and relative humidity were recorded as 39-45°C and 3-35% respectively during the exposure period of the samples. The daylight exposed portion was compared for light fastness against un-exposed portion of sample on Computer Colour Matching Instrument (Jaypak 2300). The results are shown in Table 1.

The dyed yarn samples were knitted (10.0 cm × 4.0 cm) and then subjected to wash fastness test as per

Table 1— Physico-chemical properties of wool yarns

Type of yarn	Colour strength (<i>K/S</i>)	Colour fastness		U B solubility %	Tensile strength		
		Light	Wash		Tex	Tenacity g/tex	Elongation- at-break, %
Scoured	-	-	-	33.49	54.9	7.4	12.7
Dyed	5.001	1-2	1-2	30.82	55.4	6.3	14.8
Dyed yarn mordanted with natural mordant							
0.5 ^a	3.819	2	1-2	29.22	56.4	6.4	14.3
1.0 ^a	4.278	2	2	29.13	56.5	6.7	13.9
1.5 ^a	4.700	2-3	2-3	28.96	56.7	6.6	13.6
2.5 ^a	4.959	3	3-4	28.88	57.2	6.4	13.2
3.5 ^a	4.980	4	3-4	28.66	57.9	6.4	13.9
Dyed yarn mordanted with chromium							
0.5 ^a	4.498	4	2-3	28.69	56.2	5.95	14.2
1.0 ^a	5.131	3-4	2-3	26.44	57.2	5.48	14.7
1.5 ^a	4.675	4	3-4	24.28	58.6	5.37	15.6
2.5 ^a	4.870	4	3-4	19.35	58.8	4.96	15.8
3.5 ^a	5.236	3	4	17.98	59.15	4.52	17.9

^a Mordant concentration (%)

the BIS method in a Launder-O-meter using 5.0 g per litre of soap (Lisapol D paste) at $50 \pm 2^\circ\text{C}$ for 30 min. The sample was compared with gray scale rating (1-5) as per the BIS method IS: 687-1979. The results are shown in Table 1.

2.5.3 Urea-metabisulphite Solubility

The solubility of treated wool yarns (1.0g) in urea-metabisulphite solution (3.0 g sodium-metabisulphite and 50 g urea per 100 ml of solution) was determined for 60 min at $65 \pm 2^\circ\text{C}$ as per the BIS method IS: 3430:1966. The results are given in Table 1.

2.5.4 Tensile Behaviour

The experimental yarns were subjected to tensile testing on Uster automatic single yarn strength tester (Zewleger) with 600 g measuring load under the standard atmospheric conditions. The results are shown Table 1.

3 Results and Discussion

Turmeric is a vegetable dyestuff and classified as direct dye. Its constituents are diferuloyl-methane (m.p. 183°C), *p*-hydroxy cinnamoyl feruloyl-methane (m.p. 168°C) and bis-(*p*-hydroxy cinnamyl)methane (m. p. 224°C). It imparts yellow colour to the wool.

The wool fibre morphology, chemical constituents and its complex histological structure play a major role in dyeing. The wool in its protofibrils contains two or three polypeptide chains with different R groups of amino acids. These groups have both acidic and basic characteristics. On immersion of wool yarn in dye bath solution, it gets wetted and swells due to the breaking of hydrogen bonds and weakening of ionic linkage. Wool protein gets half ionized at their pK (corresponding to pH 4.5), resulting in dissociation of carboxyl and ammonium groups and these ionized groups become equal so that the net charge on wool is zero. As the dyeing process goes on, the pH of the dye bath solution increases due to the loss of hydrogen ions which combine with ionized carboxylic groups of aspartic and glutamic acid residues and hence the formation of un-ionized aspartic and glutamic acid residues increases while the lysine and arginine residues remain ionized, resulting in increase in positive charge on the wool. These positive charges ($-\text{NH}_3^+$) serve as attraction forces for colourants having negative charges ($-\text{OH}^-$). The turmeric colourant molecule migrates from the solution by means of transport energy and then

reaches on the fibre surface where it gets adsorbed on the surface. The adsorbed turmeric colourant molecules diffuse through swollen pores into the interior of the fibre by means of activation energy obtained from thermal molecular motion of the dye bath solution at boil temperature. The turmeric colourant molecules have negative charge ($-\text{OH}^-$) and hence these remain loosely held with positively charged wool and also by polar and non-polar interaction between polypeptide chains and protofibrils. In addition to inter-ionic attraction, non-polar van der Waal's forces also exist between hydrophobic turmeric colourant and hydrophobic parts of the wool.

The banana flower cell sap contains both coloured and colourless glycosides. The brown red colour of bract is due to the presence of diglycosides of delphinidin and cyanidin. The colourless cell sap which is due to the leucotannin, leucodelphinidin and leucocyanidin turns into brown and finally black on exposure of light and air.

When natural mordant is added in the dye bath solution, its molecules migrate from dye bath solution, get adsorbed on the surface of the fibre and diffuse into the interior of the dyed fibre. Natural mordant possibly serves as a protective layer through its binding sites which acts as a cover for both the wool protein and turmeric colourant.

With the increase in percentage of natural mordant in dyeing process from 0.5 to 3.5 (on the weight of yarn), the binding forces of natural mordant become stronger due to the increase in numbers of available binding sites and this improves light and wash fastness properties. This increase in concentration of natural mordant dose not cause any loss to the wool as can be observed by physico-chemical tests, namely urea-metabisulphite solubility and tensile strength (Table 1).

In case of dyed yarn mordanted with Cr(VI), the dichromate ion diffuses into the interior of the fibre and gets attached with the positively charged lysine/arginine residue of keratin where it gets reduced to Cr(III) via Cr(IV) and Cr(II) with simultaneous oxidation of disulphide bonds. The trivalent metal interacts with carboxylic groups of glutamic/aspartic acid residue and with turmeric colourant to form metal chelates which have stronger attraction for both wool protein and turmeric colourant, resulting in better light and wash fastness of dyed yarn.

The increase in concentration of chromium in the dye bath from 0.5% to 3.5% (on the weight of yarn) not only increases the light and wash fastness but also increases damage in physico-chemical properties of wool due to the increase in oxidation of disulphide bonds. These damages in wool yarn are reflected in solubility of wool in urea-metabisulphite solution and tensile behaviour (Table 1).

Table 1 shows that 3.5 % concentration of natural mordant gives just similar results in terms of appearance in colour shade/ tone, light and wash fastness and *K/S* values to that of dyed yarn mordanted with 1.5% chromium.

4 Conclusions

The dried aqueous extract of petaloid of banana flower can be used as mordant. It is observed that 3.5 % (on the weight of yarn) concentration of natural mordant provides just similar results to that of 1.5% (on the weight of yarn) chromium in terms of colour fastness, colour shade/tone and *K/S* values. The natural mordant does not cause damage to wool. Since the nature of turmeric colourant and banana petaloids

is ecofriendly, their use in dyeing and mordanting will not cause any harm to the environment.

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