

Application of red natural colorants from *Rheum emodi* on wool fiber: Colorimetric and fastness properties

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-----ABSTRACT-----

Present study deals with aqueous extraction of natural red colorant from *Rheum emodi* and its potential application in coloration of woolen yarns by exhaustion dyeing process. A range of shades were developed with alum, ferrous sulfate and stannous chloride mordants as well as without mordants. To assess the effect of mordanting conditions, color characteristics of un-mordanted and mordanted samples were comparatively investigated in terms of CIELab (L^* , a^* , b^* , c^* and h^o) and color strength (K/S) values. With the application of metal mordants color characteristics were found prominently improved. Highest color strength values were obtained with tin mordant. Color fastness to light, washing and crocking of colored fibers were determined according to standard test methods and all the developed shades were found color fast towards light, wash and rubbing upto acceptable range. Alum mordant positively affected the fastness properties and in contrary, iron mordant negatively affected them. Ultimately *Rheum emodi* can be utilized as a natural colorant for textile coloration.

Keywords - *Rheum emodi*; dyeing; mordant; fastness; coloration.

I. INTRODUCTION

Color has always played an important role in the formation of different cultures of human being all over the world. It affects every moment of our lives, strongly influencing the clothes we wear, the furnishings in our homes. In the past, painters had used natural dyes extracted from plants, insects, animals and minerals for their paintings. The unique character of their works were the result of using different mixtures of dyes and mordants as varnishes and lacquers responsible for cohesion of the pigments and protection of the layers destroying by environmental effects. Natural dyes were used in clothings, as well as in cosmetic industry (Henna, Catechu), pharmaceutical industry (Kamala, Rhubarb) and in food industry (Annatto, Curcumin and Cochineal) also. The ability of natural dyes to color textiles has been known since ancient times [1-5].

Due to problems such as cost effectiveness, easy to use, color brightness and long shade range encountered with natural dyes accelerated development of synthetic dyes globally in 20th century. However, nowadays due to environmental benign, there are some major drawbacks to these synthetic dyes like toxicity, health hazards and environmental pollution. Thus it is not always acceptable to have only faster shades on the cost of nature's damage. This has resulted in the revival of natural dyes motivated by renewable resources, no chemical processing, no health hazards, biodegradable and compatibility with the environment, harmonized with nature and sometimes shows some biological activities also [6-14].

Rheum emodi belongs to the Polygonaceae family, prevalently known as buckwheat or rhubarb. Many plants belonging to the genus *Rheum*, including *Rheum emodi* are known as "Rhubarbs".

Rheum emodi is known to contain several secondary metabolites with medicinal properties. It is a perennial stout herb, 1.5-3.0 m. in height, distributed in the temperate and subtropical regions of Himalaya from Kashmir to Sikkim, between elevations of 2800m - 3800 m. In Garhwal Himalaya it is generally found between 2800m - 3600 m in an alpine zone on rocky soil, between boulders and near streams. Some trace elements such as Zn, Cu, Mn, Fe, and Co were found in the extract of leaves and roots of *R. emodi*. The roots contain a number of anthraquinone derivatives (Fig. 1) based on rhein (C₁₅H₁₈O₆), emodin (C₁₅H₁₀O₅), aloë-emodin (C₁₅H₁₀O₆), chrysophanol (C.I. 75400) and physcion (C₁₆H₁₂O₅). These occur free and as quinone, anthrone or dianthrone glycosides (Emodin 8- β -D-glucoside). The astringent principally consists of gallic acid, together with small amounts of tannin and possibly catechin. Chrysophanic acid (C₁₅H₁₀O₄), the main color component of dolo roots is present as the glycoside chrysophanein (C₂₁H₂₀O₉ yellow needles; M.P. 242-249) which occurs together with emodin, emodin-3-monomethyl ether and rhein [15-17]. Rheum emodi is an important medicinal plant, which finds an extensive use in Ayurvedic and Unani systems of medicine. A variety of biological properties of the compounds isolated from various Rheum species as antimicrobial potential. A review published on the anti-cancer properties with Rhubarb. Hepatoprotective activity of *R. emodi* extract has been studied in terms of in vitro and in vivo. Anti-diabetic actions of this plant were also reported [18-21].

Present study is carried to investigate the coloration ability of natural dye (*Rheum emodi*) on woolen yarn and the color characteristics and fastness properties are evaluated with the effect of varying dye concentration and mordants. This study successfully enhances the past and present study of natural dyes application in dyeing of textiles.

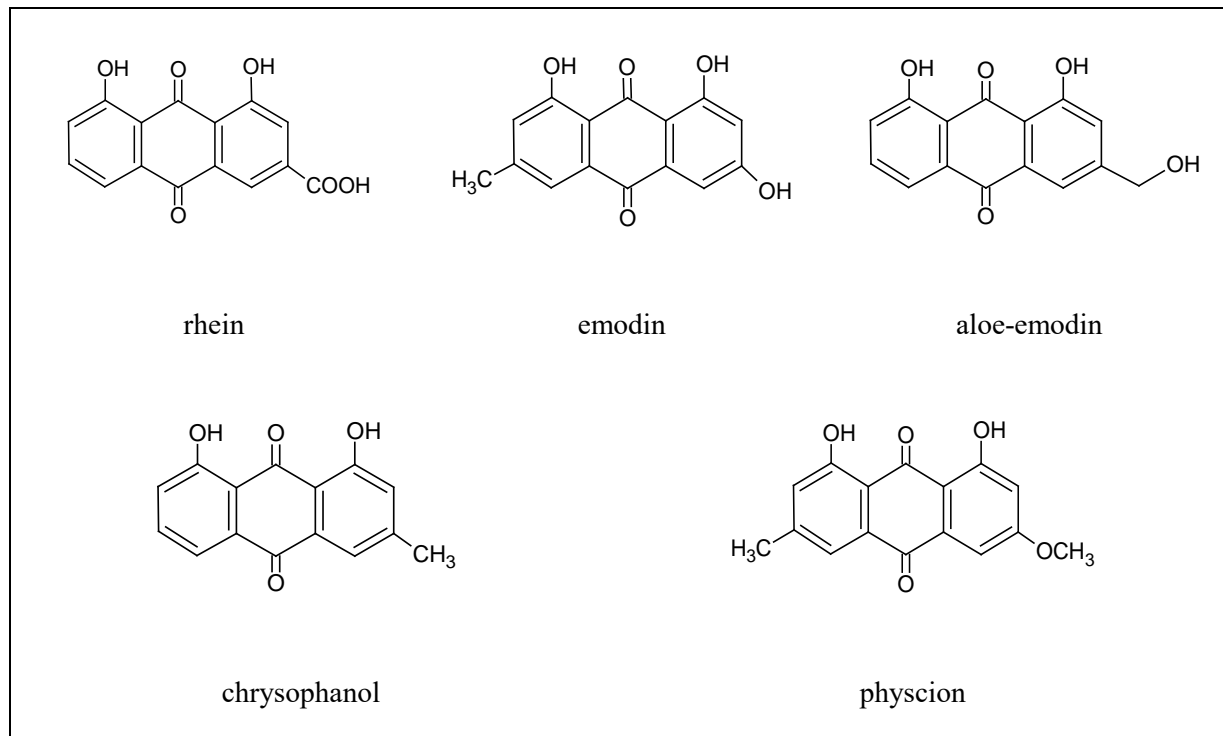


Figure 1: Coloring compounds of *Rheum emodi* natural dye

II. MATERIALS AND METHODS

Materials

Commercially available 100% pure 60 count NZ semi-worsted wool yarns were purchased from MAMB Woolens Limited, Jamunipur, Bhadohi (UP), India. Commercially available powdered Rheum emodi used for dyeing were purchased from SAM Vegetable Colours Pvt. Ltd. Moradabad (UP), India. All other chemicals used were of Laboratory grade.

Methods

Scouring & Mordanting

Prior to pre-mordanting the wool yarns were immersed in aqueous solution of non-ionic detergent (5 mL/L) for 30 min to get unwanted dirt away and to enhance surface wet ability. Wool samples were washed with water before used for mordanting or dyeing in the experiment.

Premordanting method was applied to study the effect of alum, iron and tin metal mordants on wool with Rheum emodi natural dye. Analysis of the influence of pre-mordanting on the shades produced with different concentrations of Rheum emodi on wool yarns was executed through comparison with un-mordanted samples. Desired percentages of mordants (i.e. 1% & 5% of Iron, 0.1% & 1.0% of Tin, 5% & 10% of Alum o.w.f.), were added to water in separate baths and the temperatures of the mordant solutions were raised to 30 oC and then water soaked wool yarns were added to the baths. The temperatures of the mordanting baths were brought to simmering point (90 oC) for 1 h with continuous stirring. Mordant baths were cooled and mordanted samples were taken out of the mordanting baths and rinsed with tap water.

Dyeing with Rheum emodi

The wool yarns were dyed at dye bath pH i.e. 7, in a bath containing Rheum emodi dye solution at 1:40 M:L ratio. The dyeing was started at 30 oC and temperature was gradually raised till simmering point (90 oC) and dyeing was continued for 1 h at this temperature with stirring at regular intervals. The dyed woolen yarn samples were washed with 5 mL/L non-ionic detergent, and thereafter, rinsed with tap water and dried in shade at room temperature.

Color Measurements

The colorimetric properties of the dyed wool yarn samples were obtained with Gretag Macbeth Color-Eye 7000 A Spectrophotometer integrated with a computer in terms of CIELab color coordinates (L^*, a^*, b^*, c^*, h_o) and color strength values (K/S). The color strength value (K/S) in the visible region of the spectrum (400–700 nm) was calculated based on the Kubelka–Munk equation:

$$\frac{K}{S} = \frac{(1 - R)^2}{2R}$$

where K is the absorption coefficient, R is the reflectance of the dyed sample, and S is the scattering coefficient.

Fastness Tests

Light fastness

The light fastness of the dyed wool yarn samples was conducted on Digi light NxTM, having water cooled Mercury Blended Tungsten lamp as per Test method AATCC 16e-2004 similar to ISO

105-B02:1994 (Amd.2:2000), which has nearest approach to that of sunlight. Light fastness ratings have been done on gray scale as per ISO 105-B02:1994 (Amd.2:2000).

Wash fastness

The wash fastness of the dyed wool yarn samples was measured in Digi wash SSTM (Launder-ometer) as per the ISO 105-C06:1994 (2010) specifications. The wash fastness of the dyed specimens was assessed, both in terms of alteration of shades and the degree of staining on white adjacent fabrics (cotton and wool) against the standard five-point gray scale. A grade of 5 is the best and the grade of 1 is the poor. Color fastness rating of less than grade 3 indicates considerable alteration in color after washing.

Rub fastness

Dry and wet rub fastness of the dyed wool yarn samples was tested using a Digi crock™ (Crockmeter) as per Indian standard IS 766:1988 (Reaffirmed 2004) based on ISO 105-X12:2001 by mounting the fabric on panel and giving ten strokes for both dry and wet rub fastness tests .

III. RESULTS AND DISCUSSION

Color characteristics

Developed shades with the application of *Rheum emodi* natural dye with or without mordants were tested in terms of CIEL*a*b*c*h° and color strength (K/S) values (Table 1&2). a*-b* plot of control (Fig 2) and mordanted (Fig 3) dyed samples were found in red-yellow quadrant and all distinguished points justifies all different shades obtained in the study.

Table 1: Control (*Rheum emodi*) dyed wool color characteristics and fastness properties

Dye %	L*	a*	b*	c*	h°	K/S	L.F.	W.F.	R.F.	
									dry	wet
1	66.92	6.17	20.10	21.02	72.93	1.5878	4-5	3	5	4
2	59.91	8.46	24.54	25.95	70.97	2.9571	4-5	3	5	4
3	57.41	9.76	27.38	29.06	70.38	3.8346	4	4-5	4-5	4
4	57.05	9.39	28.94	30.42	72.02	4.2365	4	5	4-5	4
5	54.43	10.21	28.04	29.84	69.99	4.8936	4	5	4-5	4

Table 2: Mordanted dyed wool color characteristics and fastness properties

Dye %	Mordant	L*	a*	b*	c*	h°	K/S	L.F.	W.F.	R.F.	
										dr	we
2% dye	1% Iron	59.40	5.78	29.69	30.24	78.98	3.758	4-5	3-4	4-5	3-4
	5% Iron	50.21	5.40	16.97	17.80	72.34	4.114	4	3	3-4	4
	0.1% Tin	65.17	9.60	25.76	27.49	69.56	2.413	4	3-4	4-5	4
	1% Tin	62.94	8.07	31.06	32.09	75.43	3.448	4-5	4	4-5	3-4
	5% Alum	59.15	4.33	25.65	26.01	80.41	3.499	4-5	3	4-5	4
	10% Alum	64.76	12.96	27.89	30.75	65.07	2.640	4-5	4	4-5	4
4% dye	1% Iron	54.16	8.60	23.19	24.73	69.65	3.959	4-5	4	4-5	3-4
	5% Iron	46.96	5.61	18.15	18.99	72.82	5.518	4-5	3-4	3	2
	0.1% Tin	62.79	11.36	34.47	36.29	71.75	3.872	4	2	4-5	4
	1% Tin	50.58	8.57	29.78	30.98	73.94	6.399	4-5	4	4-5	3-4
	5% Alum	52.21	6.26	26.64	27.36	76.77	5.469	4	3	4	3-4
	10% Alum	62.45	14.53	31.83	34.98	65.46	4.579	4	4	4	3-4

L.F. = Light fastness, W.F. = Wash fastness, R.F.= Rub fastness

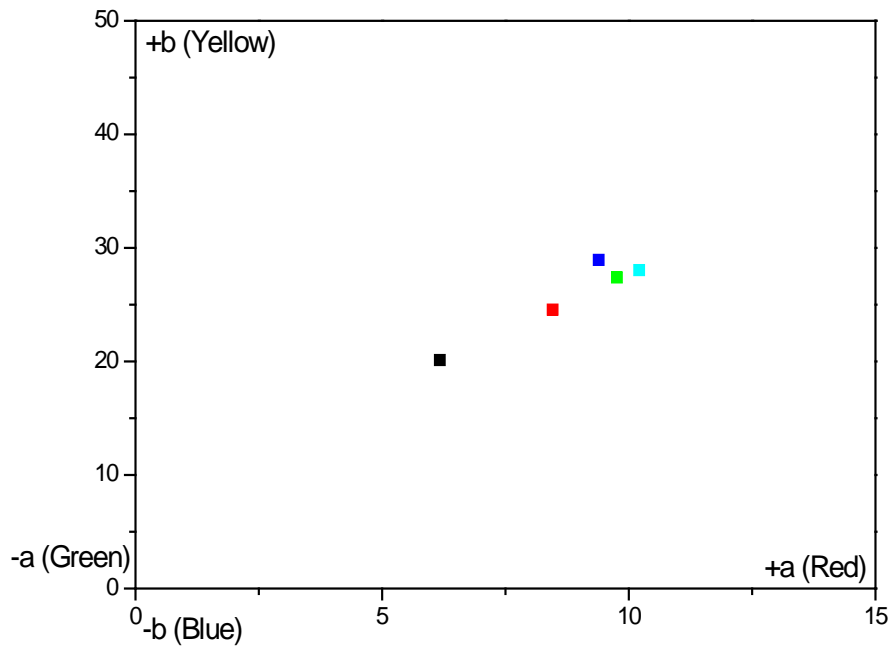


Figure 2: a*-b* plot for control dyed woolen yarn samples

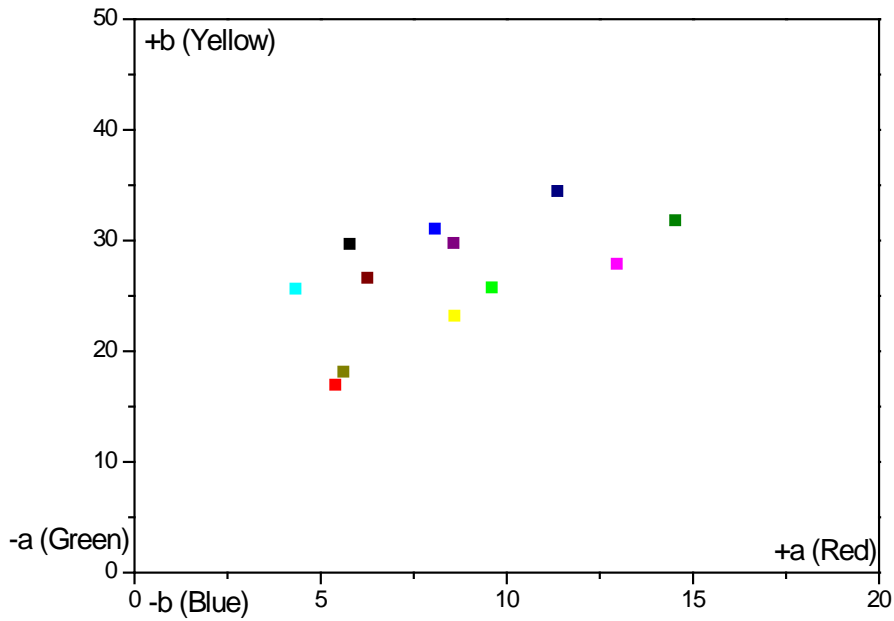


Figure 3: a^*-b^* plot for mordanted dyed woolen yarn samples

From the figure 4 it is concluded that with increase in concentration of dye an increase in color strength, responsible for more dye adsorption on the surface of woolen yarn.

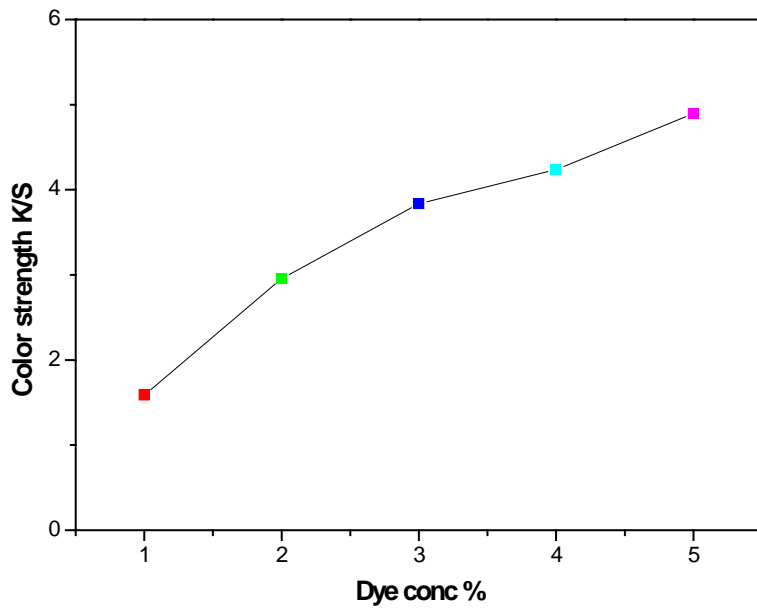


Figure 4: Effect of dye concentration on color strength

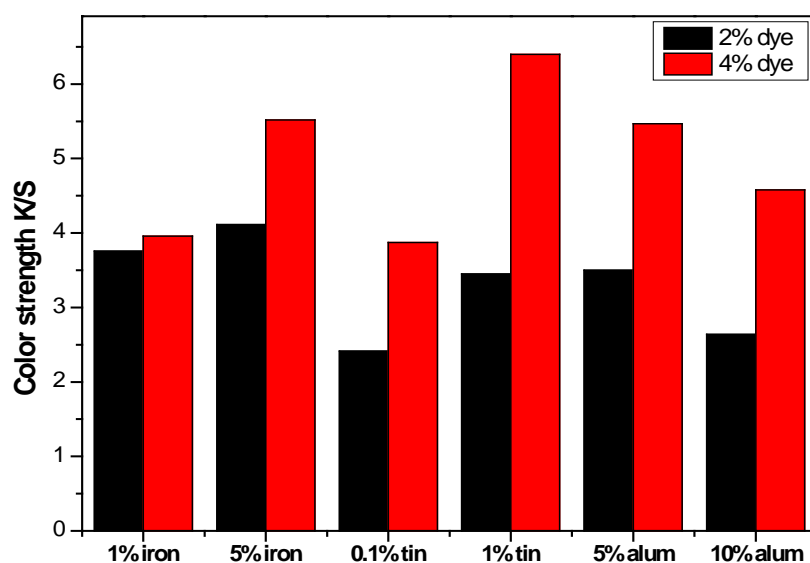


Figure 5: Effect of dye and mordant conc. simultaneously on color strength

After 3% of dye concentration a less increment in color strength observed and optimum dye concentration reached after which no more dye can be adsorbed. When the color strength of mordanted dyed woolen samples were compared with respect to different dye and mordant concentrations, it was observed that increase in dye concentration always increases the color strength simultaneously but mordant concentration in case of iron and tin increased the color strength and alum mordant affected adversely the color strength values (fig 5). Thus from these results it was observed that more dye and mordants make the shade more dark but alum mordant lightens the shades color.

Fastness properties

Color fastness properties were tested in terms of light, washing and rubbing, and rated on grey scale in 1-5 range with 1 as worst and 5 as excellent (Table 1&2).

Light fastness

For the light fastness, it was observed that all woolen yarn dyed with *Rheum emodi* showed very good fastness results to the light. Mordanted dyed woolen yarns were also found having good tolerance towards light. This is due to strong coordination bonding of mordants with dye molecule and the photolytic degradation prevented.

Wash fastness

From wash fastness data in Table 1&2, all the *Rheum emodi* dyed woolen yarn (un-mordanted as well as mordanted) showed good to excellent wash fastness rating of 3–5 and negligible staining on adjacent fabrics (cotton and wool) was observed. Good fastness to washing for un-mordanted dyed woolen yarn is attributed to the affinity of coloring components to the yarn in form of H-bonding,

ionic bonding and van der waals forces. Metal mordants also enhanced the fastness results appreciably attributed to coordination complexation.

Rub fastness

Un-mordanted and mordanted dyed woolen yarn were tested for dry and wet rub fastness properties and were found more or less same (4-5 on grey scale) for both un mordanted and mordanted dyed samples. Rub fastness of mordanted samples were found somewhat less than un-mordanted was due to weak coordination complexation with metal ions.

IV. CONCLUSION

The purpose of this study was to evaluate the colorimetric property of woolen yarn dyed with *Rheum emodi*, natural dye. The effect of mordants on dyeing properties and color fastness (light, wash and rub fastness) of woolen yarn dyed with *Rheum emodi* were investigated. It was found that the K/S values of dyed woolen yarn were found higher in case of mordants and lightness was increased with alum and tin mordants. It was found that alum mordant affected negatively the color strength. *Rheum emodi* natural dye can provide bright hues with good colour fastness properties with different type of mordants.

ACKNOWLEDGEMENT

The authors are grateful to Dr B. S. Butola, Department of Textile Technology, IIT Delhi, for extending the facility of recording CIELab values and UGC New Delhi, India for providing BSR fellowship for Mohd Shabbir.

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