

Dyeing of cotton with eco-friendly natural dyes obtained from flower of *Plumeria* species using single mordants

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Abstract: Bleached cotton fabric was dyed with natural dyes obtained from the flower of *Plumeria* species. The colour fastness properties and colour strength of dyed cotton fabric were determined and compared. From the comparative study of fastness properties and colour strength of the dyed cotton samples, *Plumeria* species in simultaneous mordanting method with 3% mordant combination gives better results.

Keywords: Colour strength, Fastness, Mordant, Natural dye, *Plumeria* species.

Introduction

Until about 150 years ago all dyes were natural substances, derived mainly from plants and animals. The natural dyes present in plants and animals are pigmentary molecules¹ which impart colour to the materials. Upto the end of 19th century natural dyes were the main colourants for textiles. Recently, interest in the use of natural dyes has been growing rapidly due to the result of stringent environmental standards imposed by many countries in response to toxic and allergic reactions associated with synthetic dyes²

Environmental pollution due to the discharge of dyeing industry effluents is the matter of major concern now-a-days. With the world becoming more conscious towards ecology and environment, there is greater need today to revive the tradition of natural dye and dyeing techniques as an alternative of hazardous synthetic dyes is an extremely crude.

However, the common drawbacks of natural dyes are their non-reproducible and non-uniform shades, poor to moderate colour fastness and lack of scientific information on the chemistry of dyeing and standardised dyeing methods³. Many reports are available on application of natural dyes on silk and cotton^{4,5}.



Fig : *Plumeria* species

The present investigation deals with the extraction of natural dyes from the flower extract of the plant *Plumeria species*. *Plumeria species* grows as a spreading shrub or small tree to a height of 2–8 m (5–25 ft) and similar width. It has a thick succulent trunk and sausage-like blunt branches covered with a thin grey bark. The flowers are terminal, appearing at the ends of branches over the summer. Often profuse and very prominent, they are strongly fragrant, and have five petals. The colours range from the common pink to white with shades of yellow in the centre of the flower.

The aim of present work has been carried out to prepare eco-friendly natural dyes from the flower extract of the plant *Plumeria species* and apply them on cotton fabric. In the present work an attempt has been made to study the effect of mordanting and dyeing properties⁶ of cotton fabric such as, washing, rubbing, light fastness and perspiration^{7,8} and also to visualize the effect of myrobolan and metallic mordants have been undertaken.

2. Materials and Methods

2.1 Materials

Conventionally desized, scoured and H₂O₂ (1%) bleached plain weave cotton fabric (220 ends/ dm, 180 picks/dm, 120 g/m²) obtained from Gandhi Trust, Dindugal, were used for the study. Analytical reagents (AR) grade ferrous sulphate, aluminium sulphate, nickel sulphate, potassium dichromate, stannous chloride, commercial grade acetic acid, common salt, sodium carbonate were used. A natural mordant myrobolan (*Terminalia chebula*) powder was used for the study. Depending upon the mordant used, the colour obtained on textiles from the the flower extract of the plant *Plumeria species extract* may give different shades.

The myrobolan (harda) powder was soaked in water (1:10 volume) for overnight (12h) at room temperature to obtain the swelled myrobolan gel. It was then mixed with a known volume of water and heated at 80°C for 30 min. The resulting solution is cooled and filtered. The filtrate was used as final mordant solution for mordanting^{9,10}.

2.2 Methods

2.2.1 Extraction of colour component

For optimizing^{11,12} the extraction method the ethanol extraction of dye liquor was carried out under varying conditions, such as time of extraction, temperature of extraction bath and material-to-liquor ratio. In each case, the optical density or absorbance value at a particular maximum absorbance wavelength ($\lambda_{420\text{nm}}$) for the ethanol extract of plant parts were estimated by using Hitachi-U-2000 UV-VIS absorbance spectrometer.

2.2.2 Dyeing of cotton fabric with the extract of the flower extract of the plant *Plumeria species*

The wetted out cotton samples were entered into dye baths containing required amount of dye extract and water. After 10 minutes, required amount of sodium carbonate and sodium chloride were added. The dyeing was carried out for one hour at 60°C. The dyed samples were dried in air without washing to make them ready for pre, simultaneous and post-mordanting using myrobolan and metallic salts.

2.2.3 Pre-Mordanting of cotton fabrics with myrobolan and metallic salts

Bleached cotton fabrics with or without pre-mordanting were further mordanted prior to dyeing using 1-3% of any one of the chemical mordants, such as aluminium sulphate, nickel sulphate, potassium dichromate, stannous chloride, copper sulphate and the myrobolan, at 60°C for 30 min with material-to-liquor ratio of 1:20. The samples treated with metal salts were dyed with the dye extract.

2.2.4 Simultaneous -Mordanting of cotton fabrics with myrobolan and metallic salts.

Bleached cotton fabrics were treated with both dye extract and metal salts simultaneously, using 1-3% of any one of the chemical mordants, such as aluminium sulphate, nickel sulphate, potassium dichromate, stannous chloride, copper sulphate and the myrobolan, at 60°C for 30 min with material-to-liquor ratio of 1:20.

2.2.5 Post-Mordanting of cotton fabric with myrobolan and metallic salts.

Bleached cotton fabrics were dyed with dye extract. The wetted out cotton samples were entered into different dye baths containing required amount of dye extract and water. After 10 minutes required amount of sodium sulphate was added. After 20 minutes required amount of sodium chloride was added. The dyeing was carried out for one hour at 50°C. The dyed samples were taken out, squeezed and used for treatment with metal salts process without washing. The dyed cotton samples were treated with different metal salts using 1-3% of any one of the chemical mordants, such as aluminium sulphate, nickel sulphate, potassium dichromate, stannous chloride, copper sulphate and the myrobolan, at 60°C for 30 min with material-to-liquor ratio of 1:20.

In all the above three methods, after the dyeing is over, the dyed samples were repeatedly washed with water and then dried in air. Finally, the dyed samples were subjected to soaping with 2gpl soap solution at 50°C for 10 min, followed by repeated water wash and drying under sun.

2.2.6 Determination of surface colour strength¹⁴(K/S value)

The K/S value of the undyed and dyed cotton fabrics was determined by measuring surface reflectance of the samples using a computer-aided Macbeth 2020 plus reflectance spectrophotometer, using the following Kubelka Munk equation with the help of relevant software:

$$K/S = \frac{(1 - R_{\lambda, \max})^2}{2R_{\lambda, \max}} = \alpha C_d$$

where K is the coefficient of absorption; S the coefficient of scattering; C_d , the concentration of the dye and $R_{\lambda, \max}$ the surface reflectance value of the sample at a particular wavelength, where maximum absorption occurs for a particular dye/colour component.

2.2.7 Evaluation of Colour Fastness:

Colour fastness to washing of the dyed fabric samples was determined as per IS: 764 – 1984 method using a Sasmira launder-O-meter following Is-3 wash fastness method. The wash fastness rating was assessed using grey scale as per ISO-05-A02 (loss of shade depth) and ISO-105-A03 (extent of staining) and the same was cross-checked by measuring the loss of depth of colour and staining using Macbeth 2020 plus computer-aided colour measurement system attached with relevant software. Colour fastness to rubbing (dry and wet) was assessed as per IS: 766-1984 method using a manually operated crock meter and grey scale as per ISO-105-A03 (extent of staining).

Colour fastness to exposure to light was determined as per IS: 2454-1984 method. The sample was exposed to UV light in a Shirley MBTF Microsal fade-O-meter (having 500 watt Philips mercury bulb tungsten filament lamp simulating day light) along with the eight blue wool standards (BS 1006: BOI: 1978). The fading of each sample was observed against the fading of blue wool standards (1-8). Colour fastness to perspiration assessed according to IS 971-1983 composite specimen was prepared by placing the test specimen between two adjacent pieces of fabrics of cotton and stitched all among four sides. The sample was soaked in the test solution (acidic /alkaline) separately with MLR 1:50 for 30 minutes at room temperature. The sample was then placed between two glass plates of perspirometer under load of 4.5kgs (10 lbs). The apparatus was kept in the oven for four hours at 37±2°C. At the end of this period the specimen was removed and dried in air at a temperature not exceeding 60°C. The test samples were graded for change in colour and staining using grey scales.

3. Results and Discussion

The colour strength values of cotton fabrics dyed with the flower extract of the plant *Plumeria species* obtained in this study by using single mordanting method are presented and compared in Tables 1, 2 and 3.

From the results, it was observed that, among all the three dyeing methods, simultaneous method gave excellent results. In all the three methods of dyeing, the mordants ferrous sulphate and aluminium sulphate show excellent results. For dyeing of cotton, 1%, 2% and 3% mordant concentrations were used for the present study. Among these three concentrations 3% mordant concentration gave better results.

Table 1 Surface colour strength of the flower extract of the plant *Plumeria* species dyed cotton fabric after pre, simultaneous and post mordanting methods by using 1% mordant concentration (K/S value without mordant : cotton-2.72)

Mordant concentration:1%	K/S($\lambda=420$ nm)		
	Pre mordanting	Simultaneous mordanting	Post mordanting
Nickel sulphate	2.12	2.41	2.29
Aluminium sulphate	2.44	2.77	2.60
Potassium dichromate	1.68	1.89	1.81
Ferrous sulphate	2.49	2.81	2.69
Stannous chloride	2.37	2.55	2.46
Myrobolan	1.86	2.06	1.98

Table 2 Surface colour strength of the flower extract of the plant *Plumeria* species dyed cotton fabric after pre, simultaneous and post mordanting methods by using 2% mordant concentration (K/S value without mordant : cotton-2.72)

Mordant concentration:2%	K/S($\lambda=420$ nm)		
	Pre mordanting	Simultaneous mordanting	Post mordanting
Nickel sulphate	2.18	2.46	2.31
Aluminium sulphate	2.48	2.81	2.66
Potassium dichromate	1.70	1.91	1.85
Ferrous sulphate	2.55	2.83	2.71
Stannous chloride	2.39	2.58	2.49
Myrobolan	1.88	2.09	2.00

Table 3 Surface colour strength of the flower extract of the plant *Plumeria* species dyed cotton fabric after pre, simultaneous and post mordanting methods by using 3% mordant concentration (K/S value without mordant : cotton-2.72)

Mordant concentration:3%	K/S($\lambda=420$ nm)		
	Pre mordanting	Simultaneous mordanting	Post mordanting
Nickel sulphate	2.21	2.49	2.36
Aluminium sulphate	2.54	2.88	2.71
Potassium dichromate	1.71	1.94	1.87
Ferrous sulphate	2.61	2.85	2.75
Stannous chloride	2.41	2.60	2.52
Myrobolan	1.92	2.14	2.07

Table 4 Colour fastnesses of *flower of Plumeria* species dyed cotton fabrics with selective mordants using pre, simultaneous and post mordanting methods

Mordants	Method of mordanting	Mordant concentration (%)	Washing		Rubbing				Sun light	Perspiration				
			CC	C	Dry		Wet			Acidic		Alkaline		
					CC	CS	CC	CS		CC	CS	CC	CS	
														C
Nickel sulphate	Pre-mordanting	1	4	4	5	5	5	5	4	5	5	5	4	
		2	5	4	5	5	5	4	5	5	5	5	5	
		3	5	5	5	5	5	5	5	5	4	5	5	5
	Simultaneous mordanting	1	4	4	5	5	5	5	5	5	5	5	5	5
		2	5	4	5	4-5	5	5	4	5	5	5	5	5
		3	5	4	5	5	5	5	4	4	5	4	5	5
Post-mordanting	1	4	4	5	5	5	5	4	5	5	5	5	5	
	2	4	5	4	5	5	5	4	5	5	5	5	5	

		3	4	5	5	5	5	5	5	4	4	5	4	5	
Aluminium sulphate	Pre-mordanting	1	5	4	4	5	5	5	5	4	5	5	5	5	5
		2	5	4	5	4-5	5	5	5	5	5	5	5	5	5
		3	5	5	5	5	5	5	5	5	4	5	5	4	5
	Simultaneous mordanting	1	5	5	5	4	4	5	4	5	5	5	5	5	5
		2	4	4	5	4-5	5	5	5	5	5	5	5	5	5
		3	5	4	5	5	4	5	5	5	4	5	5	4	5
	Post-mordanting	1	4	4	5	5	5	5	5	4	5	5	5	5	5
		2	5	5	5	5	5	5	5	4	5	5	5	5	5
		3	5	5	5	5	5	5	5	4	4	5	5	4	5
Potassium dichromate	Pre-mordanting	1	4	4	3	3	3	3	3	4	5	4	5	5	
		2	3	4	3	3	3	4	3	3	5	4	5	5	
		3	4	4	3	3	3	3	4	3	5	4	5	5	
	Simultaneous mordanting	1	3	4	5	4	5	4	3	3	5	3	5	5	
		2	3	3	5	4-5	5	4-5	3	3	5	3	5	5	
		3	4	4	5	5	5	5	4	3	5	4	5	5	
	Post-mordanting	1	4	4	3	3	3	3	3	3	5	3	5	5	
		2	3	3	3	3	4	3	3	3	5	3	5	5	
		3	4	4	3	3	3	4	4	4	5	4	5	5	
Ferrous sulphate	Pre-mordanting	1	4	4	5	5	5	5	4	4	5	4	5	5	
		2	4	4	5	5	5	5	4	4	5	4	5	5	
		3	4	5	5	5	5	5	4	4	5	4	5	5	
	Simultaneous mordanting	1	5	4-5	5	4	5	5	4	4	5	4	5	5	
		2	5	4	5	4-5	5	5	5	5	5	4	5	5	
		3	5	5	5	5	5	5	4	4	5	4	5	5	
	Post-mordanting	1	5	5	5	5	5	5	4	4	5	5	5	5	
		2	5	4	5	5	5	5	5	5	5	5	5	5	
		3	5	4	5	5	5	5	4	4	5	4	5	5	
Stannous chloride	Pre-mordanting	1	4	4	5	5	5	5	4	4	4	4	5	5	
		2	4	4	4	4	5	4	4	4	4	4	5	5	
		3	5	5	5	5	5	5	4	4	5	4	5	5	
	Simultaneous mordanting	1	5	4	5	4	5	4-5	4	4	5	4	4	4	
		2	4	4	4	4-5	5	4-5	4	3	4	4	5	5	
		3	5	5	5	5	5	5	4	4	5	4	3	5	
	Post-mordanting	1	4	4	5	5	5	5	4	4	4	5	4	4	
		2	4	3	4	4	3	4	3	5	5	5	4	4	
		3	5	5	5	5	5	5	4	5	5	4	4	4	
Myrobolan	Pre-mordanting	1	3	4	3	5	5	5	4	5		4	5		
		2	3	4	3	4	4	4	3	3		4	5		
		3	4	4	3	5	5	5	4	4		4	5		
	Simultaneous mordanting	1	3	4	3	4	5	5	4	4	4	4	4		
		2	3	3	3	4	5	5	4	5	5	4	5		
		3	4	4	3	5	5	5	4	4	5	4	5		
	Post-mordanting	1	3	4	3	5	5	5	4	4	5	4	5		
		2	3	3	3	5	5	5	4	5	5	4	5		
		3	4	4	3	5	5	5	4	4	5	4	5		
Control	-	-	4-5	4-5	5	5	5	5	4	4	5	4	4		

CC-Colour change, CS – Colour staining, C-Cotton

The colour fastness values of cotton fabrics dyed with flower extract of the plant *Plumeria species* obtained in this study by using single mordanting method are presented and compared in Table 4.

From the results, it was observed that all the samples showed better light fastness properties. Similar rub fastness and perspiration fastness values were obtained. Flower extract of the plant *Plumeria species* showed better wash fastness for the dyed cotton fabrics.

In all the three dyeing methods, simultaneous method gave excellent results. In all the three methods of dyeing, ferrous sulphate and aluminium sulphate show excellent results. For dyeing of cotton, 1%, 2% and 3% mordant concentrations were used for the present study. Among these three concentrations 3% mordant concentration gave better results. Similar results were obtained in the previous study reported by Das et al

(2008). The present study shows excellent wash fastness (GS : 4) and light fastness (GS :4) when compared with Das et al (2007) study (WF : 2-3 and LF : 3). A better light fastness (GS : 8) was reported by Sharada devi et al (2002) in pre mordanting method.

4. Conclusion

From the comparative study of fastness properties and colour strength of the dyed cotton samples, flower extract of the plant *Plumeria* species in simultaneous mordanting method with 3% mordant combination gives better results as compared to the other concentrations 1% and 2%

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