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Effect of Tannic Acid and Metallic Mordants on the Dyeing Properties of Natural Dye Extracted from *Acacia nilotica* Bark

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This study is aimed to investigate the effect of tannic acid and metallic mordants on the dyeing properties of natural dye extracted from *Acacia nilotica* bark. The alkaline extract of the dye was applied on the bleached cotton fabric without and with single and double pre-mordanting. It was found that pre-mordanting with tannic acid, ferrous sulphate, zinc sulphate and aluminum sulphate affect both the colour characteristics and fastness properties of the natural dye. Overall, double mordanting with tannic acid and ferrous sulphate gave the best results in terms of both colour depth and fastness properties.

Key Words: *Acacia nilotica*, Mordant, Tannic acid, Natural dyes, Fastness properties, Cotton.

INTRODUCTION

Textile industry, at present, almost exclusively uses synthetic dyes and pigments based on non-renewable petrochemicals. The use of natural organic dyes obtained from renewable resources such as plants and trees has the potential for not only preserving the precious petrochemicals but also the all-endangered environment for our coming generations.

Inspite of their inferior fastness properties, natural dyes can be employed in the colouration of natural as well as synthetic fibers[1]. Recently, the potentiality of using natural dyes in textile colouration with additional UV-protection and antimicrobial properties has also been reported[2-4]. Inspite of several advantages of natural dyes over synthetic dyes, the use of natural dyes is still very limited due to non-availability of standard shade cards and standard application procedures.

Cotton is one of the most commonly used textile fibers in the world having any desirable characteristics such as comfort, soft hand, good absorbency, colour retention, reasonable strength and machine washability. Environmental protection campaigns, particularly in the West, have once again revitalized the interest for dyeing cotton, a natural cellulosic fiber, with natural dyes. However, most natural dyes have little affinity for cotton[5] and are required to be used in conjunction with mordants (salts of various metals or tannins)[6].

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A textile fibre pretreatment with a mordant, in order to achieve dyeings of improved fastness and depth of shade, has been practiced since time immemorial. Tannins were used by Perkin as mordants to increase the uptake of cationic dyes[7]. Without mordants, most natural dyes have poor to moderate light fastness while synthetic dyes represent the full range of light fastness properties from poor to excellent[8]. The fastness properties of a mordant dye depends on the mordant and mordanting method because different metal or tannin dye complexes are formed, which may differ in their stability to washing, rubbing or light and also because the metal may have positive or negative catalytic effect on the photochemical degradation of the dye[9]. The combination of tannins with iron salts has enjoyed various applications over many centuries, such as the use of tannic acid and iron sulphate in the preparation of iron gall inks and from a dyeing perspective, the use of $FeSO_4 \cdot 7H_2O$ in conjunction with tannins to produce greyish-brown shades on cotton, silk and wool has been practiced since medieval time[10].

The present research work is undertaken to study the technical feasibility of dyeing cotton with alkaline extract of *Acacia nilotica* bark using single and double-pre-mordanting. Samples of cotton, dyed with and without mordanting, were compared in terms of colour characteristics and fastness properties.

EXPERIMENTAL

The bark of *Acacia nilotica* plant was collected from Southern Punjab (Pakistan). Sodium hydroxide, used for extraction of the dye in alkaline medium, was purchased from Merck. Sodium sulphate, used for promoting the dye exhaustion during dyeing of cotton with the extracted dye, was also obtained from Merck. Tannic acid, ferrous(II) sulphate heptahydrate and zinc(II) sulphate, used as mordants were purchased from Merck and aluminium(III) sulphate hexadecahydrate was purchased from Riedel-deHaen. All the chemicals were of analytical grade.

A laboratory scale exhaust-dyeing machine by Advance Logic Systems Pakistan was used for dyeing industrially bleached cotton fabric. Spectraflash SF-650 spectrophotometer by Datacolour International was used for colour measurement of the dyed samples. A Launder-*o*-meter and a Fadometer with xenon arc lamp were used for testing washing and light fastness properties of the samples, respectively. A crockmeter was used for testing the rubbing fastness.

Dye extraction: An alkaline extract of the dye was prepared by adding 10 g of *Acacia nilotica* bark to 125 mL 0.3 M sodium hydroxide solution in a flask. The mixture was heated, held at boil for 75 min, allowed to stand for cooling to room temperature and then filtered through a piece of filter cloth. The filtrate was then used for dyeing of cotton samples.

Dyeing without mordanting: A control sample of 2 g bleached cotton fabric was dyed in 100 mL of the dye extract using 50 g dm^{-3} sodium sulphate (Na_2SO_4), without adjusting the pH of the dye bath. The temperature of the dye bath was raised to 80 °C over 25 min (2 °C min^{-1}) and maintained at this level for 100 min in

the exhaust dyeing machine. Then, the fabric was removed from the dye bath and rinsed successively in cold, hot and cold water before drying in air.

Dyeing after single mordanting: In single-stage mordanting, samples of bleached cotton fabric were treated separately with tannic acid, ferrous(II) sulphate heptahydrate, zinc(II) sulphate and aluminium(III) sulphate hexadecahydrate, each at 4 % on the weight of fabric (o.w.f.) concentration using fabric to liquor ratio of 1:15 at 60 °C for 1 h. The mordanted samples were then rinsed in cold water and allowed to dry in air before dyeing at the same conditions as were used for dyeing the control sample.

Dyeing after double-mordanting: In two-stage mordanting three bleached cotton fabric samples, mordanted with tannic acid were mordanted once again separately with ferrous(II) sulphate heptahydrate, zinc(II) sulphate and aluminium(III) sulphate hexadecahydrate, each at 4 % o.w.f. (on the weight of fabric) concentration using fabric to liquor ratio of 1:15 at 60 °C for 1 h. The double-mordanted samples were then rinsed in cold water and allowed to dry in air before dyeing at the same conditions as were used for dyeing the control sample.

Colour difference measurement: Colour measurement of all the dyed samples was performed using a Spectraflash SF-650 spectrophotometer, according to BS EN ISO 105-J03:2009.

Testing of colour fastness properties: Washing fastness of the dyed samples was tested according to BS EN ISO 105-C10:2007 at 60 °C for 0.5 h. Light fastness of the dyed samples was tested according to BS EN ISO 105-BO2:1999 using Xenon Arc lamp. Rubbing fastness of the dyed samples was tested according to BS EN ISO 105-X12:2002[11].

RESULTS AND DISCUSSION

Effect of mordanting on colour characteristics of dyed cotton: Table-1 gives the colour characteristics of cotton fabric dyed with *Acacia nilotica*, without and with mordanting. Tannic acid results in the highest increase in colour depth ($\Delta L^* = -6.33$), followed by ferrous sulphate ($\Delta L^* = -1.27$), zinc sulphate ($\Delta L^* = -0.55$) and aluminum sulphate ($\Delta L^* = 0.26$). The sample dyed without mordanting has less colour strength than all samples dyed with mordanting. This could be attributed to the affinity of mordant with colour and fabric[12,13]. The highest increase in colour depth is achieved by double mordanting with tannic acid and ferrous sulphate ($\Delta L^* = -10.04$). Overall, double mordanting results in greater increase in colour depth as compared to single mordanting. The higher dye uptake value of double mordanting could be explained to involve more population effect of mordants which possibly bound the maximum number of molecule of natural dye to the fabric[14].

Effect of mordanting on colour fastness properties of dyed cotton: Table-2 gives fastness properties of cotton fabric dyed with *Acacia nilotica*, without and with mordanting. Washing fastness, in terms of colour change, increase up to 1/2 grade when ferrous sulphate and zinc sulphate are used in mordanting while washing

fastness in terms of staining to cotton increases up to 1/2 grade when all mordants are used alone and in case of tannic acid and ferrous sulphate used together. This could be attributed to the formation of insoluble colour complex on fabric. Furthermore sample without mordanting also had good washing fastness, because *Acacia nilotica*'s extract containing tannins/polyphenols which also act as mordant[15].

TABLE-1
COLOUR CHARACTERISTICS OF COTTON FABRIC DYED WITH *Acacia nilotica*, WITHOUT AND WITH MORDANTING

Sample	ΔL*	Δa*	Δb*	ΔC*	ΔH*	ΔE_{cmc}	Description
Control sample[a]	–	–	–	–	–	–	Dyed without mordanting
Tannic acid	-6.33	1.26	1.60	2.01	-0.33	6.65	Darker, brighter
Ferrous sulphate	-1.27	0.23	0.55	0.38	0.46	1.41	Darker, brighter
Zinc sulphate	-0.55	0.17	0.41	0.45	0.04	0.71	Darker, brighter
Aluminum sulphate	0.26	0.04	0.37	0.34	0.21	2.05	Lighter, brighter
Tannic acid + ferrous sulphate	-10.04	0.20	-2.36	-1.92	-1.38	10.32	Darker, duller
Tannic acid + zinc sulphate	-6.28	1.22	1.20	1.64	-0.48	6.51	Darker, brighter
Tannic acid + aluminum sulphate	-6.40	4.59	-1.30	1.63	-4.49	7.98	Darker, brighter

[a]$L^* = 50.08$, $a^* = 8.27$, $b^* = 15.46$, $C_{ab}^* = 17.53$, $h_{ab} = 61.87$.

TABLE-2
FASTNESS PROPERTIES OF COTTON FABRIC DYED WITH *Acacia nilotica*, WITHOUT AND WITH MORDANTING

Sample	Wash fastness		Rubbing fastness		Light fastness
	Colour change	Staining to cotton	Dry	Wet	
Without mordanting	3-4	3-4	4	3-4	3-4
Tannic acid	3-4	4	4-5	2-3	4
Ferrous sulphate	4	4	4-5	3	5
Zinc sulphate	4	4	4-5	3	4
Aluminum sulphate	3-4	4	5	3	4-5
Tannic acid + ferrous sulphate	4	4	5	3	5-6
Tannic acid + zinc sulphate	3-4	3-4	4-5	3-4	4-5
Tannic acid + aluminum sulphate	3-4	3-4	4-5	3	4

Dry rubbing fastness improves up to 1 grade when mordanting is done with aluminium sulphate alone and tannic acid and ferrous sulphate used together. There is no improvement in wet rubbing fastness properties due to mordanting. It rather decreases in all cases except when tannic acid and zinc sulphate is used together.

As far as light fastness in concerned, it increases due to mordanting in all cases. Light fastness is improved in most of the cases the double mordanting with tannic acid and ferrous sulphate, followed by single mordanting with ferrous sulphate.

Conclusion

Bleached cotton fabric was successfully dyed with natural dye extracted from *Acaicia nilotica*, with and without mordanting, achieving reasonably good overall colour fastness properties. Mordanting results not only improve the colour depth and brightness in some cases but also leads to improvement in colour fastness properties. While mordanting with tannic acid enhances the colour depth the most, mordanting with ferrous sulphate best results in the improvement of colour fastness properties. Double mordanting with tannic acid and ferrous sulphate gives the best overall results, both in terms of colour depth and fastness properties.

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