

Dyeability and Light Fastness Properties of Onion Scale Dye on Different Fabric Types for Conservation Applications

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ABSTRACT

The present work is aimed at producing variety of colored samples of wool, silk and cotton from natural dye extracted from onion scales for the application in the field of conservation of archaeological textiles. Thus, wool, silk and cotton fabrics were dyed at three dye concentrations using five mordants, namely alum, tin chloride, potassium dichromate, copper sulfate and ferrous sulfate. Different strong bright fast colors were obtained. The dyeability, i.e. color and light fastness ratings were found to depend on the fabric type, dye concentration as well as the mordant used. Wool samples showed the best dyeability and light fastness rating followed by silk then cotton samples. High dye concentration gave the highest dyeability and stability to light. Also it was found that light fastness of the onion scales dye on the three fabrics is very good on using copper sulphate mordant. The least values were obtained with tin chloride mordant, especially on cotton samples. Unmordanted wool and silk fabrics samples gave medium values, while cotton samples recorded low light fastness ones.

Keywords: Natural dye, Onion scales, mordants, post-mordant, premordant, cotton, silk, wool

I. INTRODUCTION

Technological, scientific and industrial progresses have been pronounced and diverse during the last decade in all fields of modern life. As a result, the increases in population density, industrial, urban and transportation activities that consume huge amounts of fuel have produced enormous amount of pollutant gasses. These noticeable negative effects created many environmental

issues leading to an imbalance in ecology. In recent years, there have been international calls for returning back to the nature for protecting the environment and the human race [5]-[8], [10].

Compared with synthetic dyes, the natural dyes are eco-friendly, biodegradable, non-pollutant, and known to pose less health hazard. They also often provide more brilliant, more harmonizing and colors and

automatically while they are easy for extraction and applications [2], [4]-[8], [13],[14].

The aim of this work is to produce completely natural fabrics of different colors to be used as mimic samples for conservation and consolidation of archaeological fabrics.

II. EXPERIMENTAL WORK

Fabrics

Three fabrics were used in this study namely wool, silk and cotton. The fabrics were purified by scouring in a solution containing 2g/L of detergent for 30 minutes at 40°C for wool and silk fabric samples and at 60°C for cotton. Then the samples were thoroughly rinsed with distilled water and finally dried at ambient conditions [12],[13].

Natural Dye

The dye used was the *Natural Yellow 10* [18]. which was extracted from the outermost onion's scales by boiling 20g in 1L distilled water for 1 hour till the complete extraction then the solution was filtered till a clear solution was obtained [7],[8].

Mordants

Five different mordants were used to stabilize the natural dye on the tested samples, namely: alum potassium aluminium sulfate, stannous chloride, potassium dichromate, copper sulphate and ferrous sulphate.

Pre-mordanting

Set of all examined samples were pre-mordanted by soaking separately for 12 hours in (5g/L) for alum, and (1.6 g/L) for each of potassium dichromate and stannous chloride [5],[6],[14].

Post-mordanting

All examined samples were post-mordanted separately in a solution of CuSO_4 of (1.2g/L) added to it 40 ml of 5% acetic acid. Also, solutions of each of other

mordants (1.6g/L) of FeSO_4 , SnCl_2 and $\text{K}_2\text{Cr}_2\text{O}_7$ were used. The mordants were dissolved in distilled water, the temperature was raised to 80°C. The dyed samples were then immersed in the solution and the liquor ratio (LR) was (1:50). The samples were kept for one hour then rinsed and dried at the ambient conditions.

Dyeing

Three dye concentrations were prepared from onion dye solution. The optical density (OD) ($\text{Log } I_0/I$) of the mother solution was recorded then the solution was diluted to two other concentrations. The fabrics were dyed by the exhaustion method at 80°C for one hour with continuous stirring at liquor ratio (1:50). The samples were transferred to the mordant bath for one hour at 80°C at same LR.

Light fastness assessment

This test was performed according to the standard method [1] using Tera light fastness tester [21], where the dyed mordanted samples were exposed in the tester alongside with the standard blue scale. The light fastness was assessed visually against the blue scale under the standard light cabinet equipped with D65 illuminant.

III. RESULTS AND DISCUSSIONS

Natural Yellow 10 dye (of the color index) [18] of the onion's scales used in this work is an acid dye. When wool, silk and cotton fabrics were dyed with it, several bright colors with different shades were obtained depending on the nature of the substrate used, the concentration of the dye in the dyeing bath, and the type of the mordant used.

Effect of substrate nature on dyeability

Comparing the results in Table 1 showing the obtained colors of the three different examined fabrics dyed by onion's scales dye at three different concentrations taken as OD values and mordanted with different mordants. It was noticed that the wool samples had acquired darker shades than that of silk or cotton. The color strength followed the order wool>silk>cotton. This is

in full agreement with the chemical structures of these examined samples. This finding may be attributed to the hygroscopic nature of wool fabrics which absorbs more water due to the presence of many amorphous regions in its molecular chains and this leads to swelling of the fiber [4,9] and hence the diffusion of the dye solution increased considerably. Moreover, wool is characterized by high polarity of (2.1) and also silk while that of cotton is only (1.2). Nevertheless, wool fabric has high porosity equal (18) comparing to silk (11) and cotton (7). It is well known fact that the dyeability increases by the increase of porosity [3,9]. Moreover, wool molecules are present in a flexible chains and bind together with natural cross-linkages and salt bridges that help the attraction of more dye molecules to the vicinity of the fibers micelles, and hence increasing the dyeability [11].

In case of silk fabric samples, the molecules are present in fully extended chains and are arranged next to each other and hence the amorphous regions are considered less than those of wool, also silk's porosity is less than that of wool (11) which leads to less dyeability of silk fabric although it is characterized by high polarity equivalent to that of wool.

As for the cotton fabric, the observed low dye susceptibility and color strength relative to wool and silk fabric samples were attributable to its low porosity (7), as well as polarity (1.2) which in turn lowers the diffusion of dye molecules to the cotton fibers [9],[11]. In addition, the onion scale dye is an acid dye which dyes the protein fabrics at high efficiency, and hence it has low affinity towards cellulose fibers. These findings explain the low color strength of the onion dye on the cotton fabric samples.

Effect of dye concentration on dyeability

The results in the Table 1 show that by increasing the dye concentration darker shades were observed. This means the color strength and affinity of the dye had increased with the rise of the dye concentration in the solution for all studied

samples. This is because the dyeing process is the availability of the dye molecules in the vicinity of fibers in the dyeing solution, and this in turn increases with increasing dye concentration in the solution [3],[20],[22]. On the other side, the chemical nature of each of the dye and fiber and the nature of the links existing between them play a key role in the adsorption and the complex formation. It is known that for wool and silk protein fibers there are electrostatic attraction forces between the molecules of side chains having positive charges and the dye molecules with negative charges. Whereas in the case of cotton fiber chains the nature of attraction is through "Van der Waals" linkages with weak hydrogen bonding. These bonds are responsible for the adsorption in cotton dyeing [17], leading to lower dye-ability of cotton samples with dye concentrations than their mates of wool and silk ones.

Effect of mordant on the produced color

It is known that natural dyes need metal ion for fixing the dye to the fiber by forming an insoluble composition precipitate on the surface of fiber and this is the role of metallic mordant ion which gives a range of bright colors depending on the type of metal ion used [19]. Comparing the data in Table 1, a several strong bright colors ranging from brown oblique reddish color of cinnamon, burnt orange with brown tint on both control fabric sample of wool and silk. These colors were observed at high dye concentration, while for low dye concentration dark beige and light cuprous orange were observed. Mordanting with chrome gave degrees of dark brown to beige - gray colors on wool while it gave dark yellow with brown tint to yellow with the used dye concentrations. Tin chloride mordant gave dark mustard color at high dye concentration on both materials and shades of light golden yellow at low dye concentration. Copper sulfate mordant gave degrees of dark brown khaki to olive khaki color on wool at the different concentrations, while on the silk it gave copper to light beige color shades. Ferrous sulfate gave greenish dark brown to buff

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color on wool, while on silk it gave very dark to light khaki colors at high and low dye concentrations respectively. Alum mordant gave almost the same colors on both wool and silk ranged from dark coppe to light color shades with yellow tint at the concentrations used.

Cotton control samples dyed with onion's scale and also mordanted with chromium gave reddish cinnamon beige colors to beige and light beige. While those mordanted with copper mordant gave brownish dark beige to brown and light beige. While with iron it gave dark to light khaki color shades. Alum gave shades of burnet to beige-orange. Tin chloride mordant gave coppe, earth yellow and finally fawn colors with cotton samples dyed at three dye concentrations respectively.

The light fastness

It is known that the color fastness of the dyes of different textiles is affected by the photochemical interaction of the dye-metal complex, or to the pronounced tendency of the dye molecules to aggregate inside the

fiber [22], and this in turn depends on the type of the fabric, and the dye used and also the mordant. When comparing the effect of the substrate nature on the light fastness of the mordanted dyed samples of table (2) it was observed that 'LF' followed the order: Wool>Silk>cotton. This order agreed well with their porosity values (which are 18,11,7 respectively). Higher porosity values increase LF rating. The higher porosity values lead to higher swell-ability of the fiber, greater penetration and aggregation of the dye particles inside the fibers pores. Besides, the presence of cystin linkages in wool encourages the formation of complex with the metal in the fiber's pores. It was also observed that increasing the dye concentration lead to greater ability for dyeing and high aggregation and hence higher LF values [3],[9],[20],[22]. The results of table (2) showed also that LF of the onion's scales dye used with the three substrates and the different mordants followed the order:

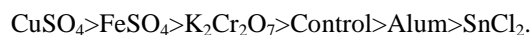


Table 1. The obtained colors on wool, silk and cotton fabrics at the different onion dye concentrations taken as OD values with the different mordants

Fabric	Mordant	Color produced at different concentrations (taken as optical density =)		
		0.840	0.410	0.159
Wool	Control	Brown oblique reddish color of Cinnamon	Reddish dark beige	Dark beige
	K ₂ Cr ₂ O ₇	Dark brown	Brown-beige	Grey beige
	CuSO ₄ .5H ₂ O	Dark khaki-brown	Dark khaki	Olive khaki
	FeSO ₄ .7H ₂ O	Greenish dark brown	Yellowish light yellow	Beige - buff
	KAl(SO ₄) ₂ . 24H ₂ O	Dark coppe	Light coppe	Pale yellowish coppe
	SnCl ₂ .5H ₂ O	Dark mustard color	Medium golden yellow	Pale golden yellow
Silk	Control	Burnet orange - brown	Cuprous orange	Pale cuprous orange
	K ₂ Cr ₂ O ₇	Dark yellow- brown	Dark yellow	Yellow
	CuSO ₄ .5H ₂ O	Fawn	Dark beige	Light beige
	FeSO ₄ .7H ₂ O	Dark khaki	Medium dark khaki	Light khaki
	KAl(SO ₄) ₂ . 24H ₂ O	Dark coppe	Medium coppe	Earth yellow
	SnCl ₂ .5H ₂ O	Dark mustard	Light mustard	Earth yellow
Cotton	Control	Reddish beige – cinnamon	Beige- cinnamon color	Beige
	K ₂ Cr ₂ O ₇	Dark beige	Medium beige	Light beige
	CuSO ₄ .5H ₂ O	Dark beige – brown	Beige	Light beige
	FeSO ₄ .7H ₂ O	Dark khaki	Medium khaki	Light khaki
	KAl(SO ₄) ₂ . 24H ₂ O	Burnet orange	Medium burnet orange	Orange- beige
	SnCl ₂ .5H ₂ O	Coppe	Earth yellow	Fawn

Table 2. Light fastness values of the three examined fabrics dyed with onion dye at three dye concentrations taken as Optical Density (OD) values with the different mordants

Fabric	Mordant type	Mordanting Method	Light fastness at different concentrations (taken as optical density =)		
			0.840	0.840	0.840
Wool	Control	Without	4	4	3-4
	K ₂ Cr ₂ O ₇	Post Mordanting	5	4	4
	CuSO ₄ .5H ₂ O	Post Mordanting	6	6	6
	FeSO ₄ .7H ₂ O	Post Mordanting	6	6	5-6
	KAl(SO ₄) ₂ . 24H ₂ O	Pre Mordanting	4	3-4	3
	SnCl ₂ .5H ₂ O	Pre Mordanting	3-4	3-4	3
Silk	Control	Without	4	3-4	3-4
	K ₂ Cr ₂ O ₇	Post Mordanting	4-5	4	3-4
	CuSO ₄ .5H ₂ O	Post Mordanting	6	6	6
	FeSO ₄ .7H ₂ O	Post Mordanting	6	5-6	5
	KAl(SO ₄) ₂ . 24H ₂ O	Pre Mordanting	4	3-4	3
	SnCl ₂ .5H ₂ O	Pre Mordanting	3-4	3	2-3
Cotton	Control	Without	3	3	2
	K ₂ Cr ₂ O ₇	Post Mordanting	4	3-4	3
	CuSO ₄ .5H ₂ O	Post Mordanting	5	4-5	4
	FeSO ₄ .7H ₂ O	Post Mordanting	4	3-4	3
	KAl(SO ₄) ₂ . 24H ₂ O	Pre Mordanting	3	3	2
	SnCl ₂ .5H ₂ O	Pre Mordanting	2-3	2	1

IV. CONCLUSION

Silk, wool and cotton fabrics of different colors were produced to be used as mimic samples for conservation and consolidation of archaeological fabrics. Several strong bright colors were obtained by varying the mordant used. Copper sulfate mordant showed the better light fastness rating.

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