SOME STUDIES ON DYEING PROPERTIES OF COTTON FABRICS WITH CROCUS SATIVUS (SAFFRON) (FLOWERS) USING AN ULTRASONIC METHOD

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Abstract:

Cotton fabrics were dyed with natural colouring matter extracted from Crocus sativus (saffron) using a traditional heating method and a power ultrasonic method. Factors affecting the dyeing properties such as pH values, salt concentration, temperature, duration of dyeing bath, and ultrasonic power were studied. Environmentally friendly mordants were used in pre-mordanting, post-mordanting, and simultaneous-mordanting methods. The fastness properties including light, washing, and perspiration of dyed and mordanted fabrics were assessed. Colour strength (K/S) was measured for dyed and dyed mordanted cotton fabrics.

Key words:

Dyeing, cotton fabrics, saffron, ultrasonic energy

1. Introduction

There are only two or three places in the world where *Crocus sativus* (saffron) grows. Kashmir has the proud privilege of being one of these places. The *Crocus sativus* (saffron) plant is very small and its flower is the only part which is seen above the ground. The blooming time of this flower is autumn. *Crocus sativus* (saffron) has a unique sweet smell and it is used in dyeing and cooking [13].

In this work a natural dye was extracted from *Crocus sativus* powder [5–6]. The effects of concentration of colouring matter, salt, different mordant types with different methods, pH, temperature, duration of dyeing bath, and ultrasonic power were studied for both the traditional method and the ultrasonic energy method of dyeing. Also, the fastness properties of dyed and simultaneously, pre-, and post-dyed mordanted fabrics were evaluated [14–17].

2. Experimental

2.1. Materials

2.1.1. Natural colouring matter

The colouring substance used in this work was extracted from the *Crocus sativus* (saffron) plant.

2.1.2. Fabrics

Mill-scoured and bleached cotton fabrics (130 g/m^2) were kindly supplied by Misr El Beida Co. Egypt.

2.1.3. Mordants

The following mordants were used: potassium aluminium sulphate, copper sulphate, stannous chloride, ferrous sulphate, and tannic acid. They were pure grade chemicals [8, 9].

2.2. Methods

2.2.1. Extraction of natural colouring matter from Crocus sativus (saffron)

Crocus sativus (saffron) was crushed to the powder form and then the colouring matter was extracted using 2–12g of the powder in 100 ml water at the boil for one hour, after which the solution was filtered off and left to cool down.

2.2.2. Dyeing methods

Dyeing of cotton fabrics using traditional method

Cotton fabric samples (0.5 g each) were dyed with the natural colouring matter extracted from *Crocus sativus* (saffron) at a liquor ratio of 1:50. Dyeing was carried out at different pH values (3–8) using different concentrations of sodium chloride, dyeing durations, and temperatures as in the text. The fabric samples were immersed in the dyeing solution in a water bath at 40 °C. The fabrics were dyed for different lengths of time and the dyed samples were rinsed with cold water and washed for 30 minutes in a bath containing 3 g/L of non-ionic detergent at 45 °C. Finally, the fabrics were rinsed and air dried.

Dyeing of cotton fabrics using ultrasonic energy method

Cotton fabric samples (0.5 g each) were dyed with the natural colouring matter extracted from *Crocus sativus* (saffron) at a liquor ratio of 1:50. Dyeing was performed at different pH values using different concentrations of sodium chloride, dyeing durations, and temperatures as well as different power levels of ultrasonic energy as shown later. The fabrics were immersed in the dyeing solution and subjected to ultrasound at 40 °C for different lengths of time and power levels. Fixation of the *Crocus sativus* (saffron) colour was carried out as before. The samples were rinsed with cold water and then washed for 30 minutes in a bath containing 3 g/L of non-ionic detergent at 45 °C. Finally, the fabrics were rinsed and air dried.

Mordanting of cotton fabrics

The three methods of mordanting (pre-, simultaneous, and post-mordanting) were used to dye cotton fabric with natural colouring matter extracted from *Crocus sativus* (saffron) [7, 11, and 12]. Different common mordant salts were used with permitted concentrations which are given in the literature [8] for environmentally friendly textiles.

2.3. Testing

2.3.1. Colour measurements of the dyed fabrics [10]

The colour yields of both the dyed and mordant samples were evaluated by the light reflectance technique using a Perkin-Elmer UV/V Spectrophotometer (model Lambda 3B). The colour strength (K/S value) was assessed using the Kubelka-Munk equation.

2.3.2. Fastness properties

The washing, dry and wet rubbing, acid and alkaline perspiration, and light fastness were evaluated according to standard methods [1–4].

3. Results and discussion

3.1. Factors affecting dyeing of cotton with a natural dye extracted from *Crocus sativus* (saffron) in the powder form

3.1.1. Concentration of the dye

The coloured solutions were extracted by boiling different amounts of *Crocus sativus* (flowers) in powder form in a fixed amount of water (100 ml) and used at different pH values for dyeing cotton fabrics according to traditional and ultrasonic methods. The colour strengths (K/S) of the dyed cotton samples were dependent on the concentration of the natural colouring matter.

From the results in Fig. 1, it was shown that the colour strength, expressed as K/S, increases with increasing concentration of the natural colouring matter in the dyeing solution within the range studied. These results were observed with traditional and ultrasonic methods after the dyed fabrics were subjected to washing at 45 °C.

Also, from Fig. 1 it was found that the colour strength of the fabrics dyed using the ultrasonic method was higher than the colour strength achieved using the traditional method. The extra vibration and agitation conferred on the dyeing system by use of the ultrasonic energy method may account for this. It is understandable that vibration and agitation along with inducing cavitations in the cotton structure enhance dyeing by promoting exhaustion and better dissociation of the dye molecules within the cotton structure. Second, for a given dye concentration, the decrease in K/S values is more striking with the traditional than with the ultrasonic energy method, suggesting that the latter affords better dye fixation and diffusion than the traditional method.

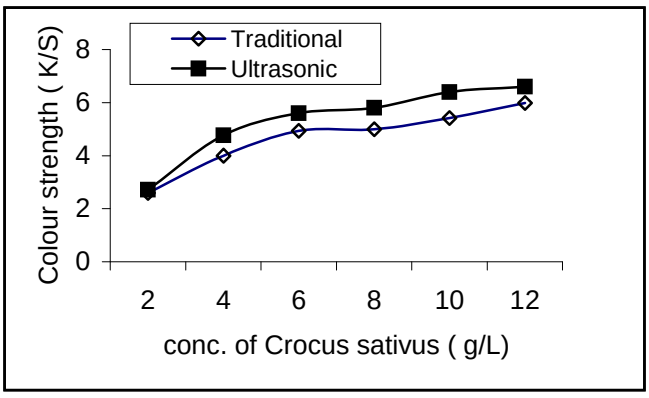

Figure 1. Effect of concentration of natural colouring matter extracted from *Crocus sativus* (flowers) (2–12gm/100 ml H_2O) on the colour strength of cotton fabrics dyed by traditional and ultrasonic methods.

Dyeing conditions: Traditional method: boiling for 60 min at pH 6. Ultrasonic method: 80 °C for 60 min at power level 9 and pH 6.

3.1.2. Effect of pH values

Figure 2 shows that the colour strength (K/S) exhibits a gradual increase with increases in the pH value of the dyeing bath from pH 3 to pH 8 irrespective of the method of dyeing; it is certain that higher K/S values are achieved with the ultrasonic method. Increasing the pH from 3 to 8 is accompanied by higher colour strength until pH 8 is reached.

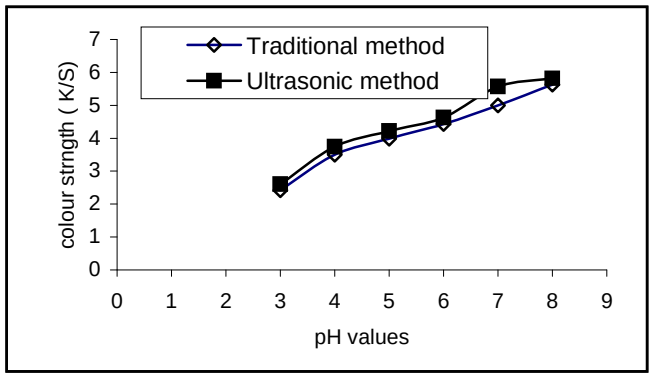

Figure 2. Effect of pH values on the colour strength (K/S) of cotton fabrics dyed by traditional and ultrasonic methods with natural colouring matter extracted from *Crocus sativus* (flowers) (12gm/ 100 ml H_2O).

Dyeing conditions: Traditional method: boiling for 60 min, pH 3–8. Ultrasonic method: 80 °C for 60 min, power level, pH 3–8.

3.1.3. Effect of salt concentration

The colour strengths of dyed and washed samples were measured and the results are shown in Fig. 3. The figure also shows that the colour strength increases as the salt concentration increases and the colour strength of the fabric dyed using the ultrasonic method is higher than the colour strength achieved by the traditional method.

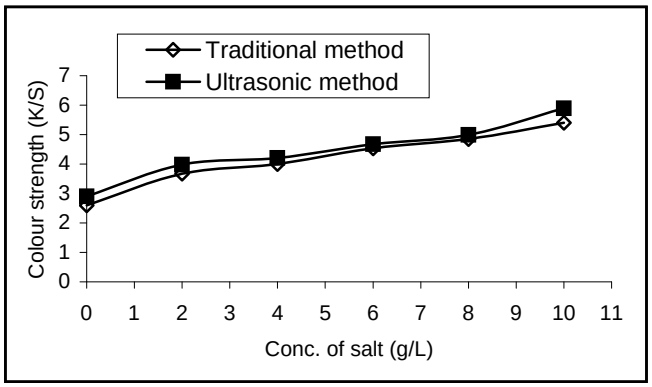

Figure 3. Effect of salt concentration on the colour strength (K/S) of cotton fabric dyed by traditional and ultrasonic methods with natural colouring matter extracted from *Crocus sativus* (flowers) (12gm/ 100 ml H_2O).

Dyeing conditions: Traditional method: boiling for 60 min, pH 8, salt (2–10g/l). Ultrasonic method: 80 °C for 60 min, salt (2–10g/l), power level 9, pH 8.

3.1.4. Effect of temperature

The dyeing procedure was continued for one hour at a temperature varying from 40 to 100 °C in the case of the traditional method and from 40 to 80°C in the case of the ultrasonic method.

From Fig. 4, it can be seen that the colour strength increases with increasing dyeing temperature in both the ultrasonic and traditional methods, with a pronounced increase achieved by the ultrasonic method compared to the traditional method.

Generally, the increase in dye-uptake can be explained by swelling and hence enhanced dye diffusion. Also, the ultrasonic power provides other additional factors such as de-aggregation of dye molecules, leading to further enhancement of dye diffusion and better dye uptake than that achieved by the traditional method.

From Table 4, it is observed that better results are obtained at 80 °C with the ultrasonic method and at 100 °C with the traditional method.

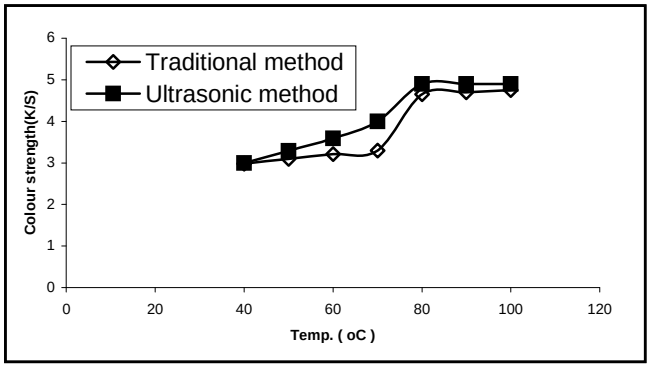

Figure 4. Effect of temperature on the colour strength of cotton fabric dyed with natural colouring matter extracted from *Crocus sativus* (flowers) (12gm/100 ml H_2O) by the traditional and ultrasonic methods.

Dyeing conditions: Traditional method: 40–100 °C for 60 min, pH 8, salt 10 g/l. Ultrasonic method: 40–80 °C for 60 min, salt 10 g/l, power level 9, pH 8.

3.1.5. Effect of time

From Fig. 5 it is observed that the colour strength increases with increasing duration of dyeing time, (to 50 min/60 min) in both methods. Then the colour strength levels off, and better results are obtained after 60 min with the traditional method. In the case of the ultrasonic method it was found that 50 min duration of dyeing is good because it gives better colour strength.

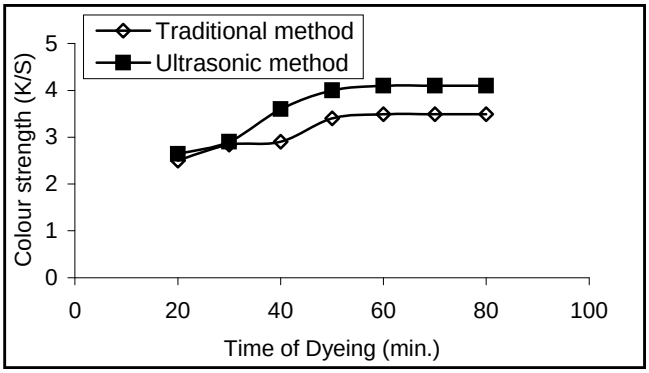

Figure 5. Effect of duration of dyeing of cotton fabric with natural colouring matter extracted from *Crocus sativus* (flowers) (12 gm/ 100 ml H_2O) on the colour strength using the traditional and ultrasonic methods.

Dyeing conditions: Traditional method: 100 °C for 40–80 min, pH 8, salt 10 g/l. Ultrasonic method: 70°C for 40–80 min, salt 10 g/l, power level 9, pH 8.

3.1.6. Effect of ultrasonic power

The effect of ultrasonic power on the dyeability of cotton fabrics with *Crocus sativus* (flowers) dye was investigated at different power levels. As shown in Fig. (6), the colour strength of dyed fabrics seemed to be directly proportional to the power supplied.

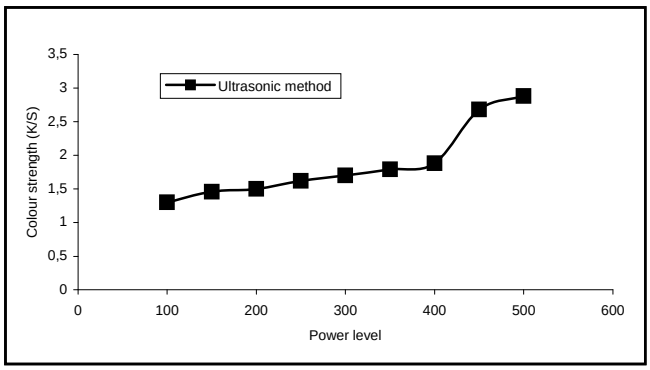

Figure 6. Effect of ultrasonic power levels on the colour strength of cotton fabric dyed with natural colouring matter extracted from *Crocus sativus* (flowers) (12 gm/100 ml H_2O) by the traditional and ultrasonic methods.

Dyeing condition: Traditional method: 100 °C for 60 min, salt 10 g/L, pH 8. Ultrasonic method: 70°C for 50 min, salt 10 g/L, power level 9, pH 8.

This behaviour emphasises again the assisting effect of ultrasonic power on the dyeability of cotton fabrics dyed with *Crocus sativus* (flowers). This assistance can be explained by dispersion, which is the breaking up of micelles and high molecular weight aggregates into uniform dispersions in the dye bath, and by degassing, which is the expulsion of dissolved or entrapped gas or air molecules from fibre capillaries and interstices at the crossover points of fabric into the liquid and removal by cavitations, thus facilitating dye–fibre contact. The rate of diffusion of dye inside the fibre is also accelerated by piercing the insulating layer covering the fibre and accelerating the interaction or chemical reaction between dye and fibre [18–22].

3.1.7. Effect of using different types of mordants

Three mordant methods: pre-mordanting, simultaneous mordanting, and post-mordanting are used to dye cotton fabrics. Different common mordant salts such as copper sulphate, ferrous sulphate, potassium aluminium sulphate, stannous chloride, and tannic acid are used.

Pre-mordanting method

Table 7 shows the use of different pH values with different kinds of mordants. Better colour strength results are dependent on the metal salt used.

Table 1. Effect of using different pH values of mordants on the colour strength of cotton fabric dyed by traditional and ultrasonic methods using Crocus sativus (pre-, simultaneous, and post-dyeing and mordanting methods).

Mordant Type	pH value	Colour strength (K/S)					
		Traditional method			Ultrasonic method		
		Pre-mordanting and dyeing method	Simultaneous mordanting and dyeing method	Post-mordanting and dyeing method	Pre-mordanting and dyeing method	Simultaneous mordanting and dyeing method	Post-mordanting and dyeing method
Copper sulphate	**3**	2.60	2.60	2.91	2.98	2.98	3.00
	4	2.79	2.96	2.99	3.00	3.00	3.33
	5	2.84	2.96	3.00	3.10	3.00	3.38
	6	3.11	3.26	3.04	3.30	3.35	3.42
	7	3.37	3.33	3.48	3.50	3.42	3.63
	8	**3.47**	**3.40**	**3.57**	**3.69**	**3.44**	**3.68**
Potassium aluminium sulphate	**3**	2.51	2.57	3.50	2.73	2.73	3.73
	4	2.82	2.60	3.62	2.97	2.99	3.80
	5	2.98	2.81	3.71	3.00	3.11	3.87
	6	3.11	2.98	3.83	3.31	3.26	3.98
	7	3.35	3.00	3.90	3.48	3.30	4.10
	8	**3.43**	**3.20**	**3.97**	**3.58**	**3.43**	**4.32**
Tannic Acid	**3**	2.43	2.42	3.51	2.67	2.50	3.67
	4	2.55	2.47	3.57	2.70	2.59	3.77
	5	2.76	2.54	3.70	2.98	2.63	3.80
	6	2.89	2.60	3.72	3.00	2.70	3.83
	7	3.18	2.67	3.75	3.30	2.74	3.87
	8	**3.29**	**2.70**	**3.80**	**3.55**	**2.83**	**3.91**
Ferrous sulphate	**3**	1.90	2.37	2.87	2.50	2.48	2.93
	4	2.00	2.44	2.99	2.55	2.54	3.00
	5	2.40	2.53	3.01	2.73	2.70	3.10
	6	2.63	2.64	3.08	2.78	2.73	3.25
	7	2.75	2.71	3.33	2.90	2.77	3.58
	8	**2.78**	**2.99**	**3.57**	**3.00**	**3.15**	**3.63**
Stannous chloride	**3**	**3.00**	**2.97**	**2.73**	**3.40**	**3.16**	**2.85**
	4	3.11	2.40	2.70	3.38	2.67	2.82
	5	2.40	2.30	2.58	2.57	2.69	2.67
	6	2.63	2.08	2.42	2.70	2.57	2.58
	7	2.68	2.03	2.40	2.74	2.37	2.47
	8	2.74	1.98	2.33	2.78	2.28	2.38

From Table 8, it can be observed that the colour strength of dyed fabrics increases when the concentration of mordant used is increased. It was found that ultrasonic dyeing of cotton samples gave a deeper shade (higher K/S) than the traditional method did.

It can be observed that the colour strength of dyed mordant cotton samples for the different mordant salts follows the order copper sulphate > potassium aluminum sulphate > tannic acid > stannous chloride > ferrous sulphate in the case of pre-mordanting.

Simultaneous dyeing and mordanting method

Table 9 shows the use of different pH values with different kinds of mordants. Better colour strength results are dependant on the metal salt used. On the other hand, from Table (10) it can be observed that the colour strength (K/S) of dyed fabrics increases when the concentration of mordant used is increased. Ultrasonic dyeing of mordanted cotton samples gave a deeper shade (higher K/S) than the traditional method did. It can be observed that the colour strength in dyed mordant cotton fabric for different mordant salts follows the order potassium aluminum sulphate > copper sulphate > ferrous sulphate > stannous chloride > tannic acid when the simultaneous mordanting and dyeing method is used.

Post-mordanting method

Table 11 shows the effect of using different pH values (3–8) with different kinds of mordants. Better colour strength results are obtained using different pre-mordants and are dependent on the metal salt used. From Table 12, it can be observed that the colour strength (K/S) of dyed fabrics increases when the

Table 2. Effect of using different concentrations of mordants on the colour strength of cotton fabric dyed by traditional and ultrasonic methods using Crocus sativus (pre-, simultaneous, and post-mordanting and dyeing methods).

Mordant Type	Mordant Conc. (g/L)	Colour strength (K/S)					
		Traditional method			Ultrasonic method		
		Pre-mordanting and dyeing method	Simultaneous Mordanting and dyeing method	Post-mordanting and dyeing method	Pre-mordanting and dyeing method	Simultaneous mordanting and dyeing method	Post-mordanting and dyeing method
Copper sulphate	**0.2**	3.10	3.05	2.80	3.25	3.19	3.00
	0.6	3.33	3.20	3.10	3.33	3.33	3.27
	1.0	3.57	3.47	3.40	3.69	3.60	3.44
	1.4	3.60	3.53	3.46	3.79	3.70	3.52
	1.8	**3.79**	**3.70**	**3.57**	**3.85**	**3.73**	**3.60**
Potassium aluminium sulphate	**0.2**	3.52	3.00	2.73	3.81	3.16	3.97
	0.6	3.52	3.19	2.80	3.81	3.26	3.00
	1.0	3.97	3.43	3.20	3.32	3.58	3.43
	1.4	3.97	3.45	3.32	4.32	3.60	4.43
	1.8	3.97	**3.45**	**3.41**	**4.40**	**3.61**	**4.45**
Tannic acid	**0.2**	3.42	2.60	1.55	3.55	2.80	2.64
	0.6	3.47	2.73	2.05	3.62	3.00	2.90
	1.0	3.80	**3.00**	3.29	3.77	**3.55**	3.10
	1.4	3.80	3.35	3.13	3.82	3.60	3.30
	1.8	**3.80**	3.35	**3.16**	**3.87**	3.61	**3.60**
Ferrous sulphate	**0.2**	2.99	2.89	2.50	3.05	3.00	2.63
	0.6	3.00	2.98	2.61	3.15	3.07	2.87
	1.0	3.17	2.99	2.78	3.18	3.15	3.00
	1.4	2.99	3.12	2.99	3.33	3.20	3.15
	1.8	**3.20**	**3.17**	**3.10**	**3.38**	**3.30**	**3.20**
Stannous chloride	**0.2**	3.00	2.74	2.33	3.30	3.00	2.43
	0.6	3.06	2.94	2.48	3.32	3.09	2.59
	1.0	3.13	3.00	2.97	3.40	3.37	3.16
	1.4	3.23	3.07	3.00	3.40	3.38	3.23
	1.8	**3.27**	**3.07**	**3.10**	**3.43**	**3.45**	**3.40**

Table 3. Fastness properties of pre-mordanting dyeing of cotton fabrics dyed with natural colouring matter extracted from *Crocus sativus* (flower) using the traditional method.

Type of mordant	Crocking		Acidic Perspiration		Alkaline perspiration		Washing fastness		Light fastness
	Dry	Wet	St.*	St.**	St.*	St.**	St.*	St.**	40 hr
Without mordant	3–4	2	2–3	2	2–3	2	2	2	2
Ferrous sulphate	3–4	3	2–3	2–3	2–3	2	3	2–3	3–4
Aluminium sulphate	3–4	2	2–3	2	2	2–3	3	2–3	2–3
Stannous chloride	3–4	3	2–3	3	2–3	2–3	2–3	3	3–4
Copper sulphate	4	3–4	3	2–3	2–3	2–3	3	3	3
Tannic acid	4	3	2–3	2–3	3	2	3	3	3–4

St.* = staining on cotton
St.** = staining on wool

concentration of mordant used increases. Ultrasonic dyeing of mordanted cotton samples gave a deeper shade (higher K/S) than the traditional method did. It can be observed that the colour strength of dyed mordanted cotton fabric for different mordant salts follows the order potassium aluminium sulphate > tannic acid> copper sulphate > ferrous sulphate > stannous chloride when the post-mordanting method is used.

3.1.8. Colour fastness of cotton fabric dyed with natural colouring matter extracted from Crocus sativus *(saffron)*

From Tables (3–8) it can be seen that the fastness properties of pre-, simultaneous and post-mordanted dyed fabrics were assessed using traditional and ultrasonic methods. Comparing the fastness properties from all these tables, it is

Table 4. Fastness properties of pre-mordanting dyeing of cotton fabrics dyed with natural colouring matter extracted from *Crocus sativus* (flower) using the ultrasonic method.

Type of mordant	Crocking		Acidic perspiration		Alkaline perspiration		Washing fastness		Light fastness
	Dry	Wet	St.*	St.**	St.*	St.**	St.*	St.**	40 hr
Without mordant	3–4	3–4	3	3	3	2	2–3	3	4
Ferrous sulphate	3–4	3–4	2–3	2–3	3	2–3	3	3	3–4
Aluminium sulphate	4	3–4	3	2–3	3	2–3	3	3	3–4
Stannous chloride	3–4	3–4	3	3	2–3	2–3	3	3–4	4–5
Copper sulphate	3–4	3	3	3	3	2–3	3	3–4	4–5
Tannic acid	4	3–4	3	3	3	2–3	3	3–4	4

St.* = staining on cotton
St.** = staining on wool

Table 5. Fastness properties of simultaneous dyeing and mordanting of cotton fabrics dyed with natural colouring matter extracted from *Crocus sativus* (flower) using the traditional method.

Type of mordant	Crocking		Acidic perspiration		Alkaline perspiration		Washing fastness		Light fastness
	Dry	Wet	St.*	St.**	St.*	St.**	St.*	St.**	40 hr
Without mordant	3	2–3	2	2	2	2–3	3	2	3
Ferrous sulphate	3–4	3	3	2–3	2–3	3	3	2–3	4
Aluminium sulphate	3–4	3	2	2–3	2–3	3	3	2–3	3–4
Stannous chloride	3	3	2	3	2–3	2	3–4	3	4
Copper sulphate	3	2–3	3	2	2	2	3	3	3–4
Tannic acid	3	2–3	2	2	2	2–3	3	2–3	4

St.* = staining on cotton
St.** = staining on wool

Table 6. Fastness properties of simultaneous dyeing and mordanting of cotton fabrics dyed with natural colouring matter extracted from *Crocus sativus* (flower) using the ultrasonic method.

Type of mordant	Crocking		Acidic perspiration		Alkaline perspiration		Washing fastness		Light fastness
	Dry	Wet	St.*	St.**	St.*	St.**	St.*	St.**	40 hr
Without mordant	3–4	3	2–3	2–3	2–3	2–3	3	2–3	3–4
Ferrous sulphate	3–4	3	3	2–3	2–3	3	3	2–3	4–5
Aluminium sulphate	3–4	3	2–3	3	3	3	3	2–3	4
Stannous chloride	4	3	2–3	3	2–3	2–3	3–4	3	4–5
Copper sulphate	3–4	3	3	2–3	2–3	2–3	3	3	4
Tannic acid	4	3	2–3	2–3	3	3	3	3	4

St.* = staining on cotton
St.** = staining on wool

Table 7. Fastness properties of post-mordanting dyeing of cotton fabrics dyed with natural colouring matter extracted from Crocus sativus (flower) using the traditional method.

Type of mordant	Crocking		Acidic perspiration		Alkaline perspiration		Washing fastness		Light fastness
	Dry	Wet	St.*	St.**	St.*	St.**	St.*	St.**	40 hr
Without mordant	1–2	1	2	1–2	2	1–2	2–3	1–2	1
Ferrous sulphate	1–2	1–2	2–3	2–3	2–3	2–3	3	3	1
Aluminium sulphate	1–2	2–3	2	2–3	3	2–3	3	3	2
Stannous chloride	1–2	1	1–2	2–3	2–3	2–3	3	2–3	3
Copper sulphate	3	2–3	2	1–2	2	2–3	3	2–3	1
Tannic acid	2	2–3	1–2	2	2	2–3	3	2–3	1–2

St.* = staining on cotton
St.** = staining on wool

Table 8. Fastness properties of post-mordanting dyeing of cotton fabrics dyed with natural colouring matter extracted from *Crocus sativus* (flower) using the ultrasonic method.

Type of mordant	Crocking		Acidic perspiration		Alkaline perspiration		Washing fastness		Light fastness
	Dry	Wet	St.*	St.**	St.*	St.**	St.*	St.**	40 hr
Without mordant	2–3	2–3	2	3	3	2	3	2	1–2
Ferrous sulphate	1–2	2	3	2	2–3	3	3	2–3	2
Aluminium sulphate	1–2	3	2–3	2–3	3	3	3	2–3	1–2
Stannous chloride	2–3	2–3	2–3	3	2–3	2–3	3–4	3	2–3
Copper sulphate	3	2–3	3	2–3	2–3	2–3	3	3	2–3
Tannic acid	2–3	2–3	2–3	2–3	3	3	3	3	2

St.* = staining on cotton
St.** = staining on wool

found that for all mordants, the dry and wet crocking fastness is almost good when the traditional and ultrasonic methods are used. Acid and alkaline perspiration values are fair to good. Also, the washing fastness is between good and very good. The light fastness is good to very good.

Conclusion

- The colour strength of cotton fabrics dyed with natural colouring matter extracted from *Crocus sativus* (Saffron) by the ultrasonic method is better than the colour strength for cotton fabric dyed by the traditional method.
- The optimum conditions for dyeing methods (traditional and ultrasonic) such as concentration of dye, pH of dye bath, temperature and duration of dyeing, and ultrasound power level were studied.
- Colour data were evaluated such as colour strength (K/S) and L, a, b.
- Using different mordants as well as different methods of mordanting dyed cotton fabrics gives a wide range of beautiful colourful hues.
- The pre-mordanting method gives higher colour strength than simultaneous mordanting and post-mordanting methods.
- Fastness properties were assessed for dyeing and mordanting dyeing methods.

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