Effect of Functional Group of Reactive Dye on Properties of Dyed Cotton Fabric

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Abstract: Cotton is a cellulosic fibre, which is most widely used for manufacturing different types of apparel. There are a variety of dyes for colouring cotton fabrics. Reactive dye is mostly used in the dyeing industries for dyeing cotton fabric. There are also a variety of reactive dyes on basis of their reactive groups. Two types of reactive dyes (bi-functional and mono-functional) are used in this research to find out the effects of functional groups on properties of knitted cotton fabric. It is observed that colour strength and fastness properties of the mono- and bi-functional reactive dyed fabrics are not same though the percentage of shade is same. The best result is found in terms of colour strength value (K/S value)-, when the fabric is dyed with bi-functional reactive dye. At the same time, the bi-functional reactive dyed fabrics have shown better colour fastness properties than mono-functional reactive dyed fabrics.

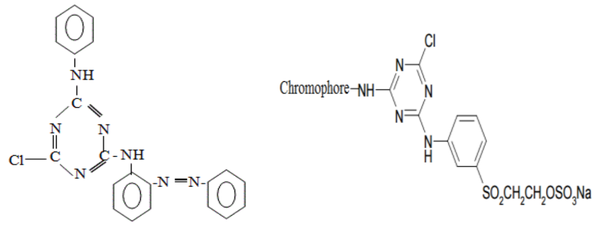
Key Words: **Mono functional reactive dye, Bi-functional reactive dye, dye exhaustion, colour strength.**

1. INTRODUCTION

Dyeing is the process of adding color to textile materials like fibers, yarns, fabrics etc. Dyeing is normally done in a solution containing dyes and auxiliaries chemicals. After dyeing, dye molecules are attached with fiber polymer by physical and/or chemical bonds. The temperature and time play an important role in the dyeing process [1]. Dyes are the chemical substances used to impart color to textiles, paper, leather, and other materials so that the color is not readily altered by washing, rubbing, heat, light, or other environmental factors to which the material is likely to be exposed [2].

Reactive dye is the most popular dye for the coloration of cellulosic fabrics. Reactive dyes attach themselves to the substrate by a chemical reaction that forms a covalent bond between the molecule of dye and that of the fiber [3,4]. The dyes have good fastness properties owing to the bonding that occurs during dyeing. There are two types of reactive dye on the basis of their functional groups such as; mono-functional and bi-functional reactive dyes [5]. The dyes can be termed as mono-functional reactive dyes, which have only one functional group in their structure. On the other hand, bi-functional dyes are the dyestuffs that contain two functional groups (i.e. halogen and vinyl-sulphone) in their structure as shown in figure 1.

The aim of the study is to dye the knitted cotton fabric with bi-functional and mono-functional reactive dyes so that the properties of the dyed cotton fabrics are compared.



Mono-functional Bi-functional

Fig. 1: Mono- & bi-functional reactive dye [1]

2. MATERIALS AND EXPERIMENTAL DETAILS

2.1 Fabric Used

The single jersey knitted cotton fabric of 160 GSM was used in this experiment.

2.2 Chemicals and Dyes Used

Caustic soda (NaOH), sequestering agent, soda ash (Na_2CO_3), leveling agent, detergent and acetic acid (CH_3COOH) are used in this experiment. Reactive dye (Drimarene yellow CL-2R as mono-functional and Drimarene yellow X-6BN as bi-functional) used in this experiment. The chemicals are collected from Sigma-Aldrich GmbH and Carl Roth GmbH, Germany. They were pure grade chemicals used for laboratory purposes. The dyes are collected from clariant Switzerland ltd.

2.3 Scouring and Bleaching of Cotton fabric

Scouring is the most important process in textile wet processing, which is also considered as one of the pretreatment processes for dyeing textile substrate. All the natural impurities (oil, wax, fat, pectin) of the cotton fabrics are removed by scouring. So, the water absorbency as well as dye exhaustion of the fabrics are increased, as there is no impurities present in the fabrics [1,6,7].

Dyeing is completed with scoured cotton fabrics, when the amount of dye is 1% (on the weight of fabric) or more. But bleached fabrics are used, if the amount of dye is less than 1%. 2 gm/L caustic soda (NaOH) is used in scouring. Other chemicals like detergent, sequestering agent are also added as auxiliaries. Scouring is carried out at the temperature of 100 ºC. 3gm/L H_2O_2 (50%) and 1gm/L stabilizer (pure) are used along with scouring chemicals to complete the bleaching. Scouring or scouring-bleaching is done in 60 minutes. After completing scouring or scouring-bleaching, neutralization is done with acetic acid. 1%, 2% and 3% shades are obtained by using scoured cotton fabrics. On the other hand, 0.2%, 0.4% and 0.6% shades are produced by using bleached cotton fabric.

2.4 Dyeing of pre-treated cotton fabric with bi- and mono-functional reactive dye

Alkali scoured cotton fabrics are dyed with mono-functional reactive dye (Drimarine Yellow Cl-2R) and bi-functional reactive dye (Drimarene yellow X-6BN) at a liquor ratio of 1:10. To compare the effect of color strength, the fabrics are dyed with both the dyes at same shade% such as- 1, 2 and 3 on the weight of fabric. The experiments are carried out at 60 ^oC in alkaline condition. Dyeing is completed in 45 minutes. In after treatment process, the dyed fabrics are rinsed for 10 minutes and then neutralized. Then the dyed fabrics are washed with soap at 80 ^oC. Finally, the dyed fabrics are dried in dryer.

Bleached cotton fabrics are used to compare the color strength of dyed fabrics in case of light shade. The bleached fabrics are dyed with mono- and bi-functional reactive dyes with the shade% of 0.2, 0.4, and 0.6 in same dyeing method as discussed before.

2.5 Measurement of dye exhaustion by UV/VIS spectroscopy

Degree of exhaustion is the amount of dyestuff, which is diffused in the fibre from the dye bath during dyeing. UV/VIS spectrophotometer (DT A 01, Perkin Elmer, Singapore) is used to measure the exhaustion of the dyestuff. By measuring the concentration of dye bath before and after the dyeing process, the percentage of exhaustion is estimated using the equation (1).

$$E\% = \frac{C_1 - C_2}{C_1} x10 \quad (1)$$

Where, C_1 and C_2 are the concentrations of the dye bath before and after dyeing process respectively.

2.6 Estimation of color strength

Estimation of the colour strength of dyed fabrics is done by determining the K/S values using a Computer Color Matching System (CS-5, Applied color system, USA). The reflectance value (R) in the visible wave length region is measured by means of the ACS spectrophotometer. The value of reflectance (R) of a dyed fabric is measured at the wavelength of 650 nm and also the K/S value of the sample is found directly from the instrument. At first the original (scoured for 1% or more and bleached for less than 1% shade) fabric is set between the light sources and color detector. The light source illuminated the sample and the reflected light is collected on a detector and subsequently a graph of reflectance as a function of wavelength in the visible range is obtained. Then the dyed sample is illuminated by the light source and in the same way the reflectance is obtained in the same graph. Every dyed sample is measured in the same way and the K/S values are obtained directly from the instrument, which followed the Kubelka-Munk theory as in equation (2).

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

Where, K and S are the absorption and scattering co-efficient of the sample. R is the absolute reflectance.

2.6 Evaluation of fastness properties

Wash fastness of the dyed samples are tested according to the ISO-105 C01 method. ECE reference detergent is used for this purpose. Washing solution is taken with a liquor ratio of 1:50. The specimen is treated for 30 minutes at 60 ^oc in sample washing machine. IS (Indian Standard) test method 766-1988 is followed to measure the rubbing fastness. ISO test method 105-104 is used to measure the perspiration fastness. Color fastness of textile material to day light is of considerable importance to the consumer. The specimen is tested according to ISO 105-B02 test method. The fastness is assessed by comparing the fading of the specimen with that of blue wool patterns.

3. Result and Discussion

3.1 Result of colour strength of cotton dyed fabric

It is observed from figures 2 & 3 that the colour strength of the dyed fabrics depends significantly on the type of reactive dye. It is seen that colour strength of the dyed fabrics is not same though the percentage of dye is same. The results are found different for different shade% i.e. lighter and darker shade. The best result is found in terms of colour strength value (K/S value) for scoured and bleached cotton dyed fabrics, when the fabrics are dyed with bi-functional reactive dye. This is because of the functional groups of the reactive dyes. As the bi-functional reactive dyes contain two types of reactive groups, so more dye molecules are fixed with the fibre polymer. As a result, the colour strength of bi-functional reactive dyed cotton fabric is found more than that of mono-functional reactive dyed cotton fabrics.

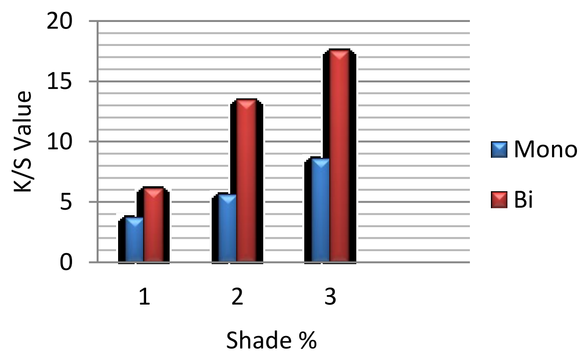


Fig. 2: Colour strength of mono- and bi-functional reactive dyed cotton fabrics in case of dark shade

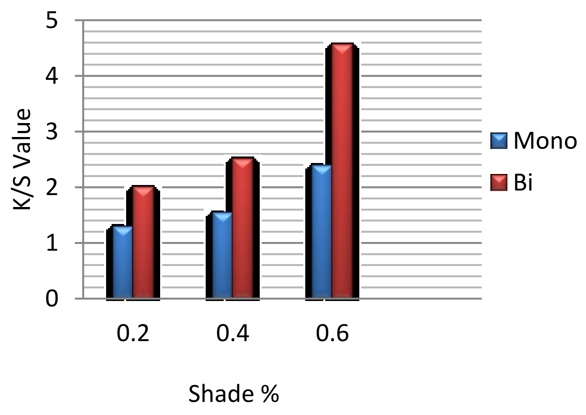


Fig. 3: Color strength of mono- and bi-functional reactive dyed cotton fabrics in case of light shade

3.2 Result of dye exhaustion

The highest degree of dye exhaustion of mono- and bi-functional reactive dyed cotton fabrics are shown in tables 1 & 2, which are determined by UV-Visible spectroscopy. The degree of exhaustion of bi-functional reactive dye is found higher than that of mono-functional reactive dye in case of both light and dark shade. As two types of reactive groups are present in bi-functional reactive dye, so more dye molecules are fixed with the fibre polymer. So the exhaustion% of bi-functional reactive dye is higher than mono-functional reactive dye. It is also demonstrated in the tables 1 & 2 that the exhaustion% of mono- and bi-functional reactive dye is reduced with the increase of shade%, as the bond forming functional groups in the fibre are decreasing when dye% is increased.

TABLE 1: Maximum exhaustion of bi- & mono-functional reactive dye (dark shade)

Type of reactive dye	Shade%	Dye exhaustion (%)
Mono-functional	1	79
Bi-functional	1	87
Mono-functional	2	78
Bi-functional	2	87
Mono-functional	3	76
Bi-functional	3	85

TABLE 2: Maximum exhaustion of bi- & mono-functional reactive dye (light shade)

Type of reactive dye	Shade%	Dye exhaustion (%)
Mono-functional	0.2	84
Bi-functional	0.2	92
Mono-functional	0.4	83
Bi-functional	0.4	90
Mono-functional	0.6	80
Bi-functional	0.6	89

TABLE 3: Result of wash fastness rating for bi- & mono-functional reactive dye (dark shade)

Type of reactive dye	Shade%	Colour change	Fastness rating					
			Staining					
			Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Bi-functional	1	5	5	5	5	5	5	5
Bi-functional	2	5	5	5	5	5	5	5
Bi-functional	3	5	5	5	5	5	5	5
Mono-functional	1	4-5	5	4-5	5	5	5	4-5
Mono-functional	2	4	5	4	5	5	5	4
Mono-functional	3	4	5	4	5	5	5	4

TABLE 4: Result of wash fastness rating for bi- & mono-functional reactive dye (light shade)

Type of reactive dye	Shade%	Colour change	Fastness rating					
			Staining					
			Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Bi-functional	0.2	5	5	5	5	5	5	4-5
Bi-functional	0.4	5	5	5	5	5	5	4-5
Bi-functional	0.6	5	5	5	5	5	5	4-5
Mono-functional	0.2	4-5	5	4-5	5	5	5	4-5
Mono-functional	0.4	4-5	5	4-5	5	5	5	4-5
Mono-functional	0.6	4-5	5	4-5	5	5	5	4-5

TABLE 5: Result of rubbing fastness properties of bi- & mono-functional reactive dye (dark shade)

Types of reactive dye	Shade%	Dry	Wet
Bi-functional	1	5	4-5
Bi-functional	2	5	4-5
Bi-functional	3	5	4-5
Mono-functional	1	5	4-5
Mono-functional	2	4-5	4-5
Mono-functional	3	4-5	4

TABLE 6: Result of rubbing fastness properties of bi- & mono-functional reactive dye (light shade)

Types of reactive dye	Shade%	Dry	Wet
Bi-functional	0.2	5	5
Bi-functional	0.4	5	4-5
Bi-functional	0.6	5	4-5
Mono-functional	0.2	5	4-5
Mono-functional	0.4	4-5	4
Mono-functional	0.6	4-5	4

TABLE 7: Result of Perspiration fastness rating for bi- & mono-functional reactive dye (dark shade)

Types of reactive dye	Shade%	Colour change	Fastness rating					
			Staining					
			Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Bi-functional	1	5	5	5	5	5	5	5
Bi-functional	2	5	5	5	5	5	5	5
Bi-functional	3	5	5	5	5	5	5	5
Mono-functional	1	4-5	5	4-5	5	5	5	5
Mono-functional	2	4	5	4	5	5	5	5
Mono-functional	3	4	5	4	5	5	5	5

TABLE 8: Result of Perspiration fastness rating for bi- & mono-functional reactive dye (light shade)

Types of reactive dye	Shade%	Colour change	Fastness rating					
			Staining					
			Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Bi-functional	0.2	5	5	5	5	5	5	5
Bi-functional	0.4	5	5	5	5	5	5	5
Bi-functional	0.6	5	5	5	5	5	5	5
Mono-functional	0.2	4-5	5	4-5	5	5	5	5
Mono-functional	0.4	4-5	5	4-5	5	5	5	5
Mono-functional	0.6	4-5	5	4-5	5	5	5	5

3.3 Result of fastness properties

From the table 3 and 4 it can be said that wash fastness properties of bi-functional reactive dyed fabric is better than mono-functional dyed fabrics. So, wash fastness rating depends on the type of functional group of reactive dyes greatly. The staining properties of the bi-functional reactive dyed fabric are also better. Mono-functional reactive dyed fabrics have problem of staining in case of wool and cotton fabric. So, wool fabrics should be washed separately in case of mono-functional reactive dyed products, but no precaution is required if bi-functional reactive dye is used. It is seen in the table 5 and 6 that rubbing fastness properties of bi-functional reactive dyed fabric is better than mono-functional cotton dyed fabrics. It is because of the chemical bonding between dye and fibre polymer. Two different reactive groups of the dye helped to fix with the fibre firmly. So, rubbing fastness rating depends on the interaction between fibre and type of reactive dyes greatly. From the table 7 and 8 it can be said that perspiration fastness properties of bi-functional reactive dyed fabric is better than mono-functional cotton dyed fabrics. So, perspiration fastness rating also depends on the type of functional group of reactive dyes greatly. The staining properties of the bi-functional reactive dyed fabric are also better. Mono-functional reactive dyed fabrics have problem of staining in case of cotton fabric.

3.4 Comparison of costing between alkali scouring and bio-scouring

Though the costing with bi-functional dye is a little bit more than mono-functional reactive dye as shown in table 11, but the quality of the bi-functional reactive dyed fabrics is much better. So, the market demand of the product must be increased, when the fabric dyed with bi-functional reactive dye. As a result, bi-functional reactive dye should be number one choice to the industries for dyeing cotton fabrics.

TABLE 9: Result of light fastness properties of bi- & mono-functional reactive dye (dark shade)

Types of reactive dye	Shade%	Rating
Bi-functional	1	5
Bi-functional	2	4-5
Bi-functional	3	4-5
Mono-functional	1	4-5
Mono-functional	2	4
Mono-functional	3	4

TABLE 10: Result of light fastness properties of bi- & mono-functional reactive dye (light shade)

Types of reactive dye	Shade%	Rating
Bi-functional	0.2	5-6
Bi-functional	0.4	5-6
Bi-functional	0.6	5
Mono-functional	0.2	5-6
Mono-functional	0.4	4-5
Mono-functional	0.6	4-5

TABLE 11: Costing of dyeing with mono- & bi-functional reactive dye (3% shade).

Chemical / Dyes	Amount in gm/l	Total taka	
		Bi-	Mono-
Salt	70	15	15
Soda	17	30	30
Dyes	0.3	70	55
Total tk / kg		115	100

4. CONCLUSIONS

Various dyes can be used for dyeing cotton fabrics. Mostly used dye for dyeing cotton fabric is reactive dye. Two types of reactive dyes (bi-functional and mono-functional) are used for dyeing cotton knitted fabric. In this study the color strength, dye exhaustion, fastness properties of bi-functional reactive dyed fabrics are compared with mono-functional dyed cotton fabrics. It is seen that all the properties of bi-functional reactive dyed fabrics are better than the mono-functional dyed fabrics.

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