INFLUENCE OF ELECTROLYTE AND LIQUOR RATIO ON EXHAUSTION AND COLOR COORDINATES OF COTTON FABRIC DYED WITH MONO-FUNCTIONAL AND BI-FUNCTIONAL REACTIVE DYES

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ABSTRACT. *Effects of electrolyte and liquor ratio were observed on dyeing of cotton fabric with bi-functional Fluoro Chloro Pyrimidene (FCP), bi-functional Monochlorotriazine-Vinyl Sulphone (MCT-VS) and mono functional Monochlorotriazine (MCT) reactive dyes. For this experiment single joursey knitted fabrics were taken. The selected dyestuffs were Drimarene Yellow K-2R (FCP), Drimarene Red CI-5B (MCT-VS) and Drimarene Navy X-GN (MCT). 1% on the weight of fabric (owf) of each dye was considered for producing 15 single shades by varying the electrolyte amount and liquor ratio. Gluaber salt was used in each dye bath as electrolyte. The post dye liquors were tested in absorbance spectrophotometer (UV 1800) to measure the absorbance of those solutions. Beer-Lambert law was used to get concentration from absorbance and then the exhaustion% was calculated. The dyed fabric samples were tested in a reflectance spectrophotometer (datacolor 650) to get the color coordinates (L*, a*, b*, c*, h*). The results show that FCP dye exhaustion was the best among these three and MCT dye exhaustion was the least but it can be improved by increasing the electrolyte. MCT-VS dye has a tendency to changing its hue in higher electrolyte amount or higher liquor ratios.*

KEYWORDS. Electrolyte, liquor ratio, chroma, hue, exhaustion.

INTRODUCTION

Reactive dye is the only class of dyes which makes covalent bond with the fiber and becomes an integral part of it (Chinta & Vijaykumar, 2013). Exhaustion of This dye largely depends upon its substantivity towards fabric. Different reactive group has different degree of substantivity. The substantivity of a bi-functional dye normally ranges from medium to good (Dalal & Desai, 1996) as it has two reactive groups and better probability of attraction towards fabric than a mono-functional dye. Salt and even liquor ratio in a dye bath can have an influence on the substantivity as well as exhaustion of the dye. Salt works as electrolyte on the negatively charged surface of cotton fabric so that dye uptake can be higher (Gamal *et al.*, 2010). On the other hand low liquor in dye bath can hinder the perfect dispersion of dyes and high liquor can push away the dye molecules from the fabric surface.

Three types of dyes are considered in this experimental work. First one Drimarene Yellow K-2R is a bi-functional Fluoro Chloro Pyrimidene (FCP) dye with two halogen group fluorine and chlorine; each of one is responsible for nucleophilic substitution reaction with cellulose. The reactivity of FCP dye lies between Monofluorotriazine (MFT) and Dichlorotriazine (DCT) dyes (Aspland, 1997). The second dye, Drimarene Red CI-5B is a hetero bi-functional dye contains both monochlorotriazine (MCT) and vinyl sulphone (VS) as its reactive group, one responsible for nucleophilic substitution but another for addition reaction (Iqbal, 2008). The third dye considered here was Drimarene Navy X-GN is a mono-functional dye (MCT) with only a chlorine group. This dye needs higher temperature for its dyeing as it is a lower reactive dye (Renfrew, 1999).

Several researchers studied on the influence of dyeing parameters on dyeing with reactive dye. Miljkovic *et al* (2007) studied on the effect of dyeing parameter on dyeing with vinyl sulphone dyes. They measured the color coordinates of the dyed samples and in conclusion suggested that cutting of dyeing time with a diminution of salt can give a better yield. Dalal and Desai (1996) studied with some bi-functional reactive dyes and found them in a range of medium to good substantivity in dye bath. Sultana and Uddin (2007) had observed good exhaustion and fixation properties for Drimarene dyes.

This paper tried to describe the influence of two dyeing parameters (electrolyte and liquor ratio) on three types of reactive dye exhaustion. They were compared by their exhaustion% and also analyzed with the color coordinates found from reflectance spectrophotometer. It helped to understand the lightness/darkness variations, color saturation or change in chroma and variations in hue (redness/greenness or blueness/yellowness) due to the change of electrolyte amount and liquor ratio.

MATERIALS AND METHODS

Single jersey scoured and bleached cotton fabric was taken for this experiment which was supplied by Impress-Newtex Composite Textiles Limited, Mirzapur, Tangail, Bangladesh. The specifications of the fabric are listed in Table 1.

Table 1. Specification of the fabric.

Parameters	Scoured-Bleached Cotton fabric
Structure	Single joursey
Course per inch	46
Wales per inch	38
Yarn count	26 Ne
Stitch length	2.48 mm
GSM (gram/m^2)	162

From Beer-Lambert law we get that-

$$A(\lambda)= \varepsilon (\lambda) \times l \times c \quad (1)$$

Where, A is the absorbance at wavelength λ, c is the concentration of the absorbing substance in a solution, l is the length of the light path through the solution and ε is the extinction coefficient at wavelength λ (Broadbent, 2001).

Firstly different known concentrations were taken for three of the dyes. Their absorbance values were measured in absorbance spectrophotometer (UV 1800) and that wavelength was considered where the highest pick (λ_{max}) of absorbance was observed. The obtained data are shown in Table 3. As the length of the light path through the solution was constant 1 cm for the tests, the dye extinction coefficients were calculated as the slopes of the absorbance-concentration curves by least square method (Cantrell, 2008).

15 pieces of fabric samples were taken for dyeing, each one weights 5 gram. The samples were divided into three groups for dyeing with three different dyes (5 samples in each group). The first group was named as group Y. It was selected for dyeing with Drimarene Yellow K-2R. The second group was named as group R which was selected for dyeing with Drimarene Red CI-5B. Third group was named as group N and selected for dyeing with Drimarene Navy X-GN. First sample of each group was taken as standard and named as Y1, R1 and N1 respectively. They were dyed with 1% owf (on the weight of fabric). The dyeing recipe followed for the standards are mentioned in Table 2.

Table 2. Recipe for dyeing of standards.

Description	Y1	R1	N1
Dye% owf	1% Yellow K-2R	1% Red CI-5B	1% Navy X-GN
Glauber salt	50 g/L	50 g/L	55 g/L
Soda Ash	7.5 g/L	16.2 g/L	5 g/L
Caustic Soda 36°Be (Baume)	---	---	1.10 ml/L
Time	60 minutes	50 minutes	80 minutes
M:L	1:10	1:10	1:10
Temperature	60°C	60°C	95°C

The second sample of group Y was named YS2 and was dyed with the same recipe of Y1 but only the salt amount used there was double (100 g/L) of the standard Y1. And the third sample of group Y was dyed with a triple amount of salt (150 g/L) than Y1 and named as YS3. For the fourth and fifth sample of Y group only the liquor ratio were doubled and tripled (1:20 and 1:30) than Y1 but other parameters were kept constant and they were named as YL2 and YL3. Thus Y1, YS2 and YS3 were compared for understanding the influence of salt and Y1, YL2 and YL3 were compared for understanding the influence of liquor ratio. Same procedure was applied for the other two groups R and N and sample RS2, RS3, RL2, RL3 and NS2, NS3, NL2, NL3 were dyed accordingly. After the completion of dyeing the post dye liquors were 3 times diluted and tested in absorbance spectrophotometer (UV 1800) to measure the remaining dye concentration. The dilution was done because the instrument had shown better accuracy in lower concentrations. Here, a reformed Beer Lambert law can be shown as-

$$c = A/(\varepsilon \times l) \quad (2)$$

Where c is the concentration, A is the absorbance, ε is extinction coefficient that was calculated previously and l is the length of light passed through which was 1 cm constant for each test. As the solution was 3 times diluted so the actual value of dye concentration was calculated by using the following formula-

$$c = 3 \times A/(\varepsilon \times l) \quad (3)$$

The exhaustion percentages of dyes were then calculated by the following formula-

$$E\% = \frac{I-P}{I} \times 100 \quad (4)$$

Where, E is the exhaustion, I is initial concentration of dye liquor and P is the concentration of post dye liquor. (Sultana and Uddin, 2007). The results obtained from this calculation for 15 different dye baths are listed in Table 4.

The dyed samples were not washed and were dried at 60°C for 30 minutes and then tested in a reflectance spectrophotometer (datacolor 650). The L^*, a^* and b^* values were obtained from the instrument. Higher value of L^* means greater lightness of the shade. Higher a^* indicated greater redness or lesser greenness, higher b^* indicates greater yellowness or lesser blueness of the shade. The chroma or saturation coordinate c^* and coordinate for the hue h^* was calculated from the following formulas (Broadbent, 2001)-

$$c^* = \sqrt{a^{*2} + b^{*2}} \quad (5)$$

$$h^* = tan^{-1}\frac{b^*}{a^*} \quad (6)$$

After that how much the coordinates (L^*, c^* and h^*) varied from the standard was calculated by using the following formula-

$$V\% = \frac{R-Q}{Q} \times 100 \quad (7)$$

Where, V is the variation, R is the value of a particular coordinate of standard and Q is the value of same coordinate of the sample. The results found from these calculations are listed in Table 5.

RESULTS AND DISCUSSION

The absorbance values obtained from the instrument for different dye concentrations at highest pick (λ_{max}) point and calculated dye extinction coefficients are listed in Table 3.

Table 3. Absorbance values for different dye concentrations and extinction coefficient.

Concentration	Absorbance		
	Yellow K-2R λ_{max} = 415 nm	**Red CI-5B** λ_{max} = 529 nm	**Navy X-GN** λ_{max} = 567 nm
5 mg/L	0.008	0.010	0.004
10 g/L	0.080	0.110	0.067
20 mg/L	0.420	0.510	0.382
30 mg/L	0.980	1.040	0.734
50 mg/L	1.680	1.760	1.410
Dye extinction coefficient (L mg^{-1} cm^{-1}**)**	**0.0389**	**0.0404**	**0.0321**

The absorbance values of post dye liquors at highest pick (λ_{max}) point and calculated dye concentrations of post dye liquors are listed in Table 4.

Table 4. Absorbance values and concentrations of post dye liquors.

Sample	Absorbance (3 times diluted)	Calculated concentration (mg/L)
Y1	1.271	98.02
YS2	0.947	73.03
YS3	0.921	71.03
YL2	1.245	96.02
YL3	1.660	128.02
R1	1.831	135.97
RS2	1.643	122.01
RS3	1.603	119.03
RL2	1.966	145.99
RL3	2.262	167.97
N1	2.022	188.97
NS2	1.798	168.04
NS3	1.669	155.98
NL2	2.279	212.99
NL3	2.696	252.06

Influence on Exhaustion

Figure 1 shows that Yellow K-2R has greater value of exhaustion always. Red CI-5B also has good exhaustion but lower than Yellow K-2R. Navy X-GN had shown the least value of exhaustion here. These are because the FCP dye has higher potential to be attracted by the fiber but MCT dye's substantivity is lower than other two. Exhaustion% was clearly increasing for all the dyes with the increase of electrolyte amount. The close value of YS2 and YS3 indicates that the FCP dye was becoming saturated at that salt level.

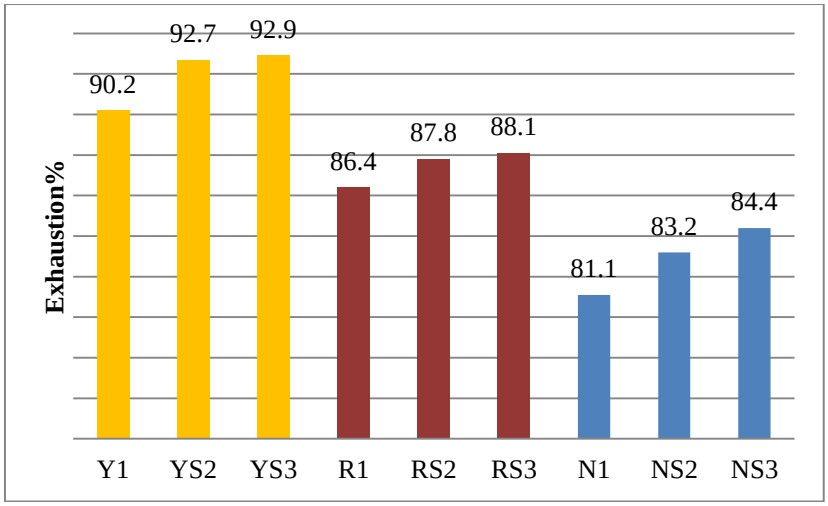

Figure 1. Influence of electrolyte on exhaustion.

On the other hand exhaustion percentages were decreasing with the increase of liquor ratio except Yellow K-2R. In case of this dye the exhaustion was very close to the standard for 1:20 liquor ratio and actually higher also. Low liquor in dye bath can hamper the perfect distribution of dyes or can produce heterogeneous distribution and high liquor can push away the dye molecules from the fabric surface. So for Yellow K-2R may be the 1:20 liquor ratio is more suitable for the dyestuffs for homogeneous distribution and after this ratio the dyes are more widely spread out so got less chance to attract by the fabric. For the other dyes exhaustion percentages was less for higher liquors. Navy X-GN the MCT dye was found with the least uptake capability.

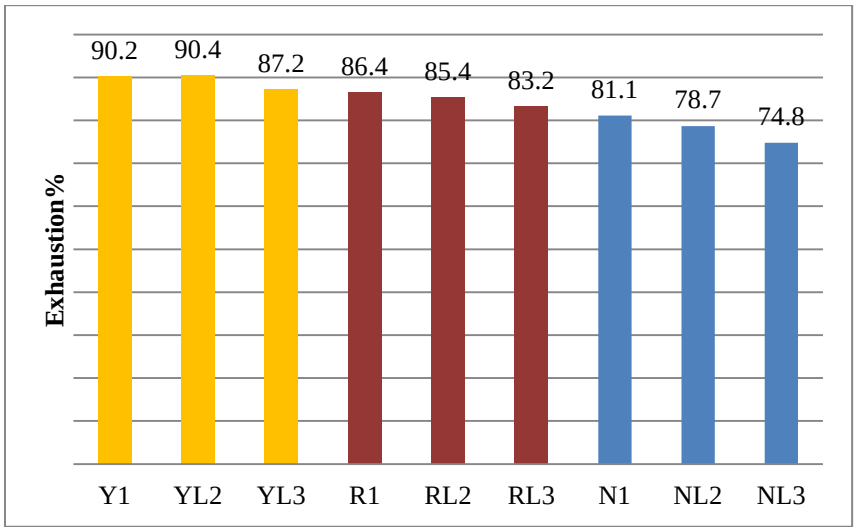

Figure 2. Influence of liquor ratio on exhaustion.

Influence on Color Coordinates

Figure 3 shows the changes occurred in the color coordinates due to different electrolyte concentration. The variation in chroma value of Yellow K-2R was increased for higher salt amounts. That indicates the increasing amount of dye molecules in the fabric for this dye. Other dyes had little effect on chroma due to salt increasing though MCT dye had greater effect than MCT-VS. Significant change was found in hue of Red CI-5B which is actually abnormal. Chroma should increase with color depth as salt had increased the exhaustion but changing a hue is not much acceptable for dyeing. From Table 5 the value of a^* and b^* for

RS2 and RS3 suggest that this change was a combination of reddish and yellowish. And the other dye Navy X-GN was getting Darker significantly in the effect of electrolyte. As the substantivity of MCT group is less than other two, salt was clearly increasing its uptake there so the shade became darker.

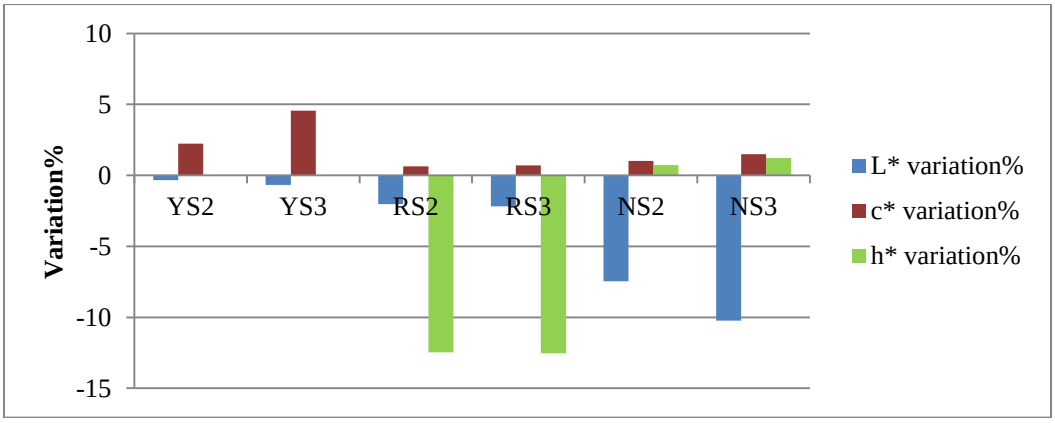

Figure 3. Influence of electrolyte to the color coordinates.

Table 5. Color coordinates of the dyed fabric samples.

Sample Name	*L**	*a**	*b**	*c**	*h**
Y1	79.9	20.35	72.01	74.83	0.9983
YS2	79.64	20.80	73.63	76.51	0.9983
YS3	79.36	21.41	75.26	78.25	0.9982
YL2	79.82	20.70	73.47	76.33	0.9983
YL3	79.79	20.11	74.11	76.79	0.9987
R1	51.55	56.62	-4.29	56.78	-0.0756
RS2	50.51	57.02	-3.78	57.15	-0.0662
RS3	50.43	57.06	-3.78	57.19	-0.0662
RL2	52.60	56.37	-4.68	56.56	-0.0828
RL3	52.25	56.32	-4.76	56.52	-0.0843
N1	43.87	-9.55	-19.19	21.44	0.9647
NS2	40.60	-9.23	-19.59	21.66	0.9717
NS3	39.38	-8.95	-19.83	21.76	0.9765
NL2	43.18	-9.63	-19.36	21.62	0.9648
NL3	43.58	-9.83	-19.19	21.56	0.9605

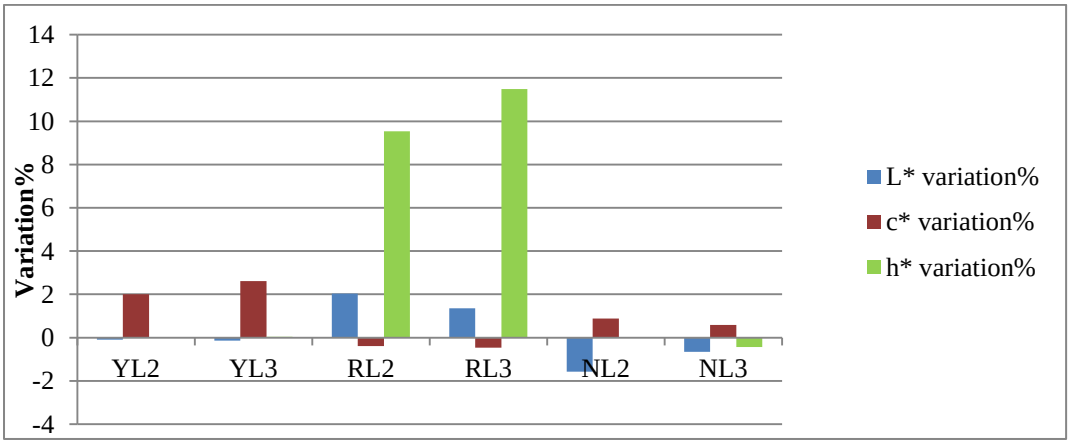

Figure 4. Influence of liquor ratio to the color coordinates.

Figure 4 shows the changes occurred in the color coordinate due to increase of liquor ratio or decrease in dye concentration. The variation in chroma or saturation value of for Yellow K-2R was found increasing even increase of water. But again the significant change in hue of Red CI-5B was found. This time the hue variation% was in positive direction and from Table 5 the value of *a** and *b** for RL2 and RL3 suggest that this change was a combination of greenish and bluish tone. And the shades of Navy X-GN were found darker than the standard but not so much dark as salt influence.

CONCLUSION

In conclusion, it can be said that the exhaustion order of these dyes according to reactive group is FCP>MCT-VS>MCT. Exhaustion was increasing with electrolyte amount and was mostly decreasing with liquor ratio. Electrolyte and liquor ratio had increased the chroma or saturation value of FCP dye. But the MCT-VS dye had shown a tendency in changing its hue which is abnormal. And about MCT dye, increasing the amount of electrolyte can produce better results for it.

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