Impact of liquor ratio on color uptake and fastness properties of Reactive dyed cotton fabric

Md. Tofazzal Hossain[a,b], Manindra Nath Roy[a], Md. Tanjim Hossain[a], Palash Kumur Saha[a]

[a] Department of Textile Engineering, Northern University Bangladesh, Bangladesh
[b] Department of Textile Engineering, Dhaka University of Engineering and Technology, Gazipur-1700, Bangladesh

Abstract: This study shows the impact of liquor ratio on color strength, exhaustion, fixation, and various fastness properties of reactive dyed cotton fabric. Here, two reactive dye such as Reactive Yellow 145 and Reactive Blue 250 was used to dye cotton fabric at various liquor ratios (1:4, 1:6, 1:8, 1:10, 1:12, and 1:14). Then the color fastness was assessed against washing, rubbing, perspiration and light. It was found that the color strength, fixation, and exhaustion were higher at liquor ratio 1:6 for Reactive Yellow 145 and 1:8 for Reactive Blue 250. In most cases, the washing fastness, rubbing fastness, and perspiration fastness were better at a higher liquor ratio for lower dye adsorption. In the case of light fastness, a lower liquor ratio shows better results than a higher liquor ratio.

Keywords: Liquor ratio, Color strength, Reactive dye, Color fastness, Exhaustion, and Fixation

1. Introduction

Textile dyeing is based on a mixture of various dyes used in different percentages. Thus desired shades can be obtained by mixing them with specific proportions with water. Dyes that can react chemically, forming a covalent bond with the textile substrate are known as reactive dye. Reactive dyes are becoming increasingly popular for dyeing cellulosic fibers because of their wide range of shades, brilliant color, ease of application, and excellent wash fastness properties due to strong covalent bonds. In textile industries, reactive dyes are extensively used in the dyeing process because of their availability, affordability, a wide variety of colors, and high color fastness [1]. These are the most common type of dye used for cotton fiber dyeing. This dye can react with the hydroxyl group of cellulose to form a covalent bond [2]. It happens due to the specific addition or substitution reactions within the reactive groups of reactive dyes and the hydroxyl groups of cellulose fibers. Therefore, the dye can quickly fix with cellulosic fibers and gives superior fastness properties to other dyes [3]. The dyeing of reactive dyes is influenced by a number of factors, including the alkali, electrolyte, temperature, and liquor ratio [4]. The reactivity of dyes, salt concentration, dying time, and material to liquid ratio influence reactive dyes exhaustion and fixation percentages. A highly reactive dye has a more significant likelihood of reacting with fiber, but it also has a higher risk of hydrolyzing. However, to acquire the best results from the procedure, the behavior of dyestuff in various constraints should be investigated.

Many researchers have been studied the effect of various parameters during the dyeing of cotton fabric using reactive dyes [5]. Haque investigated the fixing of reactive colors into cotton fabric by varying the temperature and changing the alkali concentration [6]. Rahman et al. [7] studied the effect of color percentages on different factors such as CPI, GSM, WPI colorfastness properties of reactive dyed cotton fabric. Another researcher analyzed the influence of soda on the fastness properties of reactive dyed cotton fabric [8]. However, these investigations have described the impact of dyeing of cotton fabric with one reactive dye.

In this research, the impact of material to liquor ratio on different reactive dyed cotton fabric qualities, such as color strength, exhaustion, fixation, and various color fastness features, such as color fastness to washing, rubbing, and perspiration, and light fastness, was investigated.

2. Materials and methods

2.1 *Materials*

100% cotton knitted fabric of 160GSM was used for the experiment. C.I. Reactive Yellow 145 (RY 145) and C.I. Reactive Blue 250 (RB 250) dyes (Fig. 1 and Fig.2, respectively) in the commercial grade were collected from Colorchem Ltd. Bangladesh. Other chemicals such as Soda ash (Na_2CO_3), Caustic Soda (NaOH), Hydrogen peroxide (H_2O_2), Stabilizer, Glauber Salt anhydrous (Na_2SO_4), Leveling Agent, wetting agent, Sequestering Agent, Anti-creasing agent were purchased from a local market and used in this investigation without any further purification.

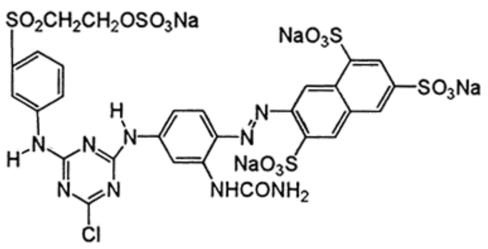

Figure 1. Chemical structure of C.I. Reactive Yellow 145

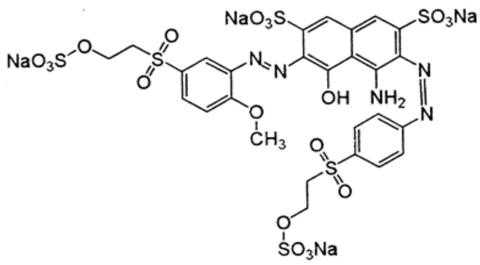

Figure 2. Chemical structure of C.I. Reactive Blue 250

2.2 Scouring and bleaching of cotton fabric

Table 1. Scouring and bleaching Recipe for cotton fabric

Chemicals	amount
Wetting agent	1.0 g/L
Sequestering agent	0.7 g/L
Anti-creasing agent	0.8 g/L
Stabilizer	0.3 g/L
Hydrogen peroxide	2.5 g/L
Caustic soda	2.25 g/L
Temperature	95^0C
Time	50 min

The cotton fabric was Scoured and bleached at high-temperature exhaust method. 2.5 g/L hydrogen peroxide was used for bleaching (to remove natural color/grey color), and 2.25 g/L Caustic was used for scouring (to remove fat, oil, and wax) in this study. Other chemicals were used as per recipe amount, which has given in table 1. High temperature (95^0C) was used for 50min to scour and bleach the fabric. Finally, neutralized the material, washed, and dried in a dryer [9].

2.3 Dyeing of cotton fabric

Table 2. Recipe of dyeing cotton fabric

C.I. Reactive Yellow 145		C.I. Reactive Blue 250	
Chemicals	Amount	Chemicals	Amount
Wetting agent	0.8 gm/L	Wetting agent	0.8 gm/L
Sequestering	0.5 gm/L	Sequestering	0.5 gm/L
Anti-creasing	0.5 gm/L	Anti-creasing	0.5 gm/L
C.I. Reactive Yellow 145	1.0%	C.I. Reactive Blue 250	3.0%
Leveling agent	1.0 gm/L	Leveling agent	1.0 gm/L
Glauber Salt	40.0 gm/L	Glauber Salt	70.0 gm/L
Soda ash	10.0 gm/L	Soda ash	15.0 gm/L
Temp.	60°C	Temp.	60°C
Time	60min	Time	60min

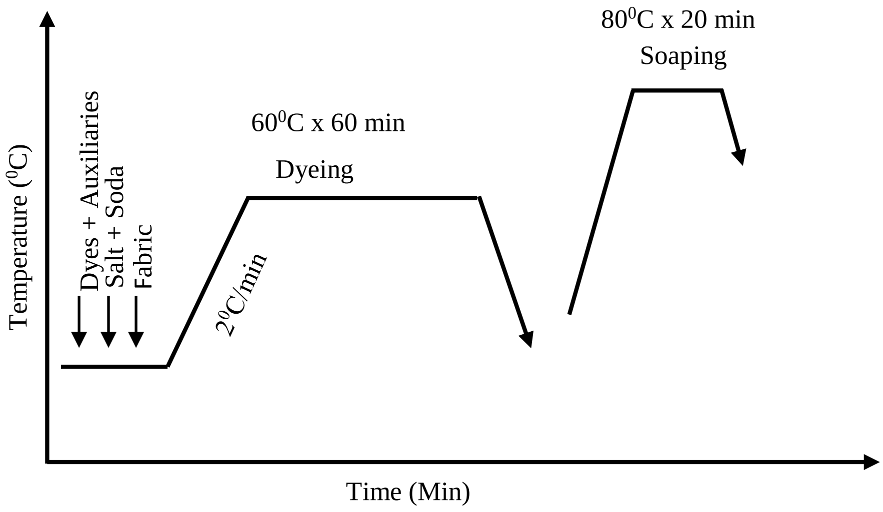

Figure 3. Dyeing process curve

Cotton fabric was dyed in a rotary infrared laboratory dyeing machine at 60^{0}C for 60 minutes with two different reactive dyes (CI Reactive Yellow 145 and C.I. Reactive Blue 250) at various liquor ratios (1:4, 1:6, 1:8, 1:10, 1:12, and 1:14). After dying, the fabric was neutralized, washed with soaping agent in a shaker bath at 80rpm on 80^{0}C for 20 minutes, and thoroughly rinsed in tap water. Finally, the dyed fabric was dried in a hot air oven dryer.

2.4 Measurement of Color strength, exhaustion and fixation percentages

The reactive dyed cotton fabric's color strength (K/S) was determined using a Datacolor 650 reflectance spectrophotometer (USA). The experiments were carried out on a machine using a D_{65} light source and a 10^o viewing geometry [10]. The reflectance of each specimen was taken in the 400–700 nm range by folding it twice, and by using the Kubelka–Munk equation, the reflectance (R) at the wavelength of maximum absorption (λ_{max}) was measured (Eqn. (1)) [11]. Three measurements were taken for each sample [12, 13].

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

Where K and S are absorption and scattering coefficients of the dyed fiber. R is the reflectance of the dyed fabric at λ_{max}.

After every dyeing, the exhaustion rate E(%) was measured by the following equation Eqn.(2)

$$E\ (\%) = \frac{A_0 - A_1}{A_o} \times 100 \tag{2}$$

and the fixation rate F(%) was calculated by the following equation Eqn.(3)

$$F\ (\%) = \frac{A_0 - A_1 - A_2}{A_o} \times 100 \tag{3}$$

Where A_0 is the initial dye bath concentration, A_1 is dye concentration in the dye bath after dyeing, and A_2 is concentration of dye in the finish baths (mgL^{-1}).

2.5 Assessment of color fastness

Color fastness was evaluated using a variety of established testing procedures. According to ISO 105-C03 (2010), color fastness to washing was measured using the Atlas LEF Lander-Omitter (Atlas, USA). Color Fastness to Perspiration (Acid, Alkali) was investigated using an AATCC Perspirometer (Atlas, USA) in accordance with ISO 105 E04 (2013). To assess staining, a multifiber was attached to each sample in the case of their wash, perspiration fastness. The color fastness to rubbing was tested using an AATCC Crockmeter (Atlas, USA) following ISO 105-X12 (2016). Atlas-150S+ was used to test color fastness to light by ISO 105-B02 (2013) standards (Atlas, USA). For all color fastness tests without light, shade change and staining were evaluated using greyscale ratings from 1 to 5, where 5 implies no shade change. Whereas the light fastness ratings are from 1 to 8 [14].

3. Results and Discussion

3.1 Impact of liquor ratio on color strength

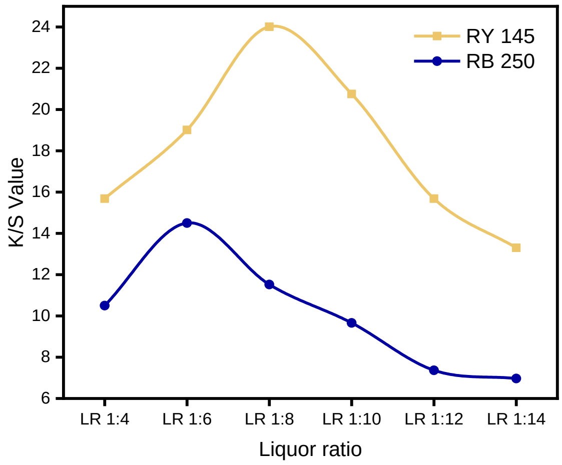

Figure 4. Impact of Liquor ratio on color strength

Color strength is the ratio of the co-efficient of absorption and co-efficient of scattering measured by a color matching system. **Fig.4** represented that the color strength value increased with increasing the liquor ratio up to 1:6 and 1:8 respectively for RY 145 and RB 250. After that, it decreases gradually with a higher liquor ratio and the highest MLR 1:14 it explicit the K/S value is 8 and 13 for RY 145 and RB 250. In lower liquor ratio means higher concentration dyes become aggregate and unable to diffuse into the fiber. As a result, after soaping the unboned dyes are removed from the fiber surface and its yields a lower color strength value. Reversely with a higher liquor ratio means a lower concentration of dye molecule in bath, there is a chance of hydrolysis and lack of absorption due to the higher distance of each dye molecule [15]. In this investigation, 1:6 and 1:8 is the effective concentration for RY 145 and RB 250 dyes.

3.2 Impact of liquor ratio on exhaustion and fixation of dye

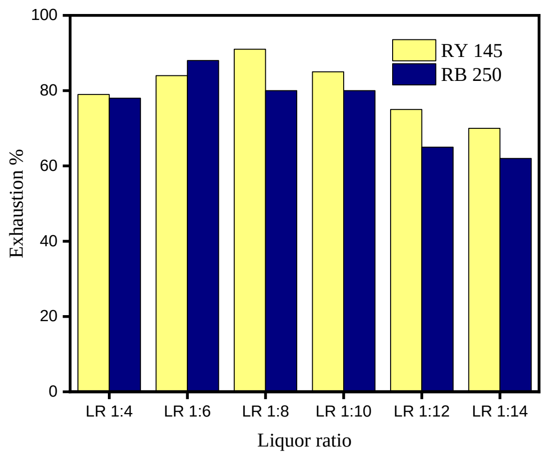

Figure 5. Liquor's impact on Reactive Dye Exhaustion in Cotton Fabric

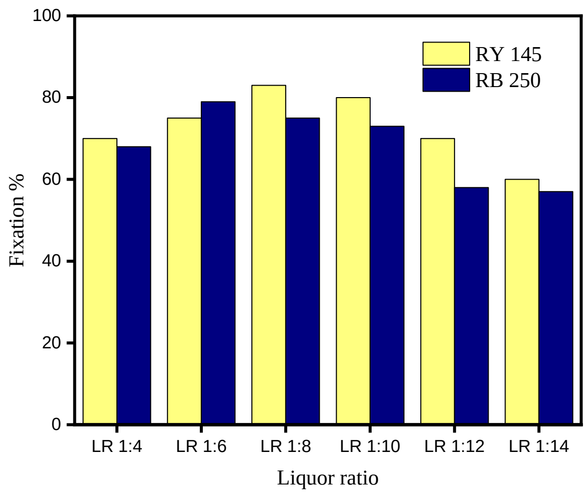

Figure 6. Liquor's impact on Reactive Dye Fixation in Cotton Fabric

Dye exhaustion indicates the amount of dye molecules transferred dye bath to the materials while fixation refers to the amount of dye bonded with the fiber. The exhausted dyes are not caused 100% fixation. Both are affected by different dyeing parameters like time, temperature, pH, material to liquor ratio, and auxiliary chemicals. Regarding this exhaustion and fixation liquor ratio is a crucial factor in dyeing. This investigation concludes that for RY 145 and RB 250 two reactive dyes liquor ratios 1:6 and 1:8 yield the best result. In the same conditions, RB 250 showed better exhaustion (90%) and fixation (80%) than RY 145 (exhaustion 85% and fixation 77%) due to their inherent properties. This result indicates that at lower liquor ratio dye exhaustion is hindered due to the high concentration of dyes and their self-attraction results aggregation. Also, the solubilization of huge amounts of dyes and auxiliary chemicals affects exhaustion. This hampered exhaustion causes a lower fixation of dyes. After effective concentration, the higher liquor ratio also showed poor exhaustion and fixation for both RY 145 and RB 250 dyes. In the higher liquor ratio, the space between dye molecules is increased and causes lower exhaustion. It happened more for low-affinity dye. Besides this, the higher liquor ratio causes hydrolysis of reactive dye and this greatly affects exhaustion and fixation of dyes [15, 16].

3.3 Impact of liquor ratio on color fastness to washing

Table 4. Color fastness to washing

Dyes		Liquor Ratio					
		1 : 4	1 : 6	1 : 8	1 : 10	1 : 12	1 : 14
C.I. Reactive Yellow 145	Change in color	4	4	4	4	4-5	4-5
	Staining	3-4	4	4	4	4	4
C.I. Reactive Blue 250	Change in color	4	3-4	3-4	4	4	4
	Color Staining	3-4	3-4	3	3-4	4	4

The fastness properties of dyed materials depend on the dye fiber bond formation. Regarding this physical theory of dyeing state that Stronger bonds have higher fastness properties will exhibit. Also, the larger size and lesser the solubility of dye yields better fastness. According to **Table 4**, the consequence of all fabric's color staining and color change value is nearly the same but the values of a higher liquor ratio showed a slightly better result than liquor ratio 1:6 or 1:8. This happened due to there is not enough dye to be stained or reduced in lighter shade yields at higher liquor ratio.

3.4 Impact of liquor ratio on color fastness to rubbing

Table 5 shows that the color staining and color change values of all textiles are approximately similar for colorfastness to the rubbing test. Dye molecules that are adhered to the fabric surface with a less strong bond or without chemical bond cause staining. At a lower liquor ratio dyes molecule become aggregated and adhere to the surface of the fabric without proper bonding. Aggregated dye molecules are unable to diffuse into the fiber which leads to poor rubbing fastness. But higher liquor ratios give better results both for dry and wet rubbing fastness because the dyed surface contains fewer dye particles.

Table 5. Color fastness to Rubbing

Dyes		Liquor Ratio					
		1 : 4	1 : 6	1 : 8	1 : 10	1 : 12	1 : 14
C.I. Reactive Yellow 145	Dry	4-5	4-5	4-5	4-5	4-5	4-5
	Wet	3-4	3-4	3-4	3-4	4	4
C.I. Reactive Blue 250	Dry	4-5	4-5	4-5	4-5	4-5	4-5
	Wet	2-3	2-3	2-3	2-3	3	3

3.5 Impact of liquor ratio on color fastness to perspiration

Table 6. Color fastness to perspiration (Acid and Alkali)

Dyes	LR ratio	Acid		Alkali	
		Color change	Color staining	Color change	Color staining
C.I. Reactive Yellow 145	1:4	4	3	4	3
	1:6	4-5	3-4	4-5	3-4
	1:8	4-5	3-4	4-5	3-4
	1:10	4-5	3-4	4-5	3-4
	1:12	4-5	3-4	4-5	3-4
	1:14	4-5	3-4	4-5	3-4
C.I. Reactive Blue 250	1:4	3-4	3	3-4	3
	1:6	3-4	3	3-4	3
	1:8	3-4	3	3	2-3
	1:10	4	3-4	4	3-4
	1:12	4	3-4	4	3-4
	1:14	4	3-4	4	3-4

The perspiration fastness of both acids and alkalis for RY 145 and RB 250 are almost the same except 1:4 of RY 145. Additionally, **Table 6** provides a micro indication of lower value of color change and staining at lower liquor ratio due to higher exhaustion than higher liquor ratio. In the case of both dyes, RB 250 showed perspiration fastness to acid and alkali lower than C.I Reactive Yellow 145 due to the higher shade percentage of RB 250. More dye in the fabric surface with less strong bond has the possibility of poor perspiration fastness.

3.6 Impact of liquor ratio on color fastness to light

Color fastness to light depends on the structure of the dye. The unsaturated loosely held electron in the dye molecule causes poor results. But regarding liquor ratio, the strong bond yields better results. Also, the higher exhaustion and fixation comparatively lower liquor ratio without aggregation produce deeper shade and the lighter fading seems negligible while the little change in the light shade has great impact. In this study liquor ratios, 1:6 and 1:8 for RY 145 and RB 250 showed better results. Between them, the light fastness of RY 145 was higher than that of RB 250, as seen in **Fig. 7** RY 145 provides the best light fastness at a liquor ratio of 1:6, whereas RB had a light fastness of 6 at a liquor ratio of 1:8.

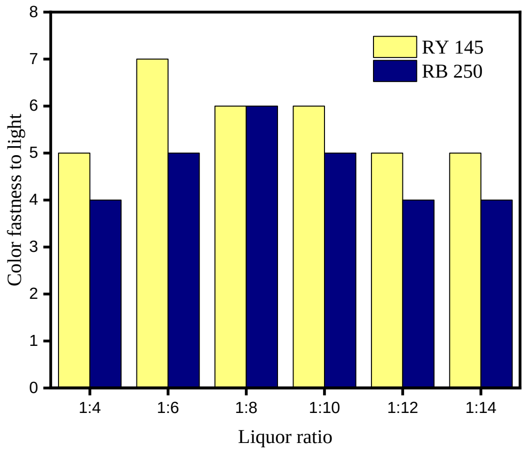

Figure 7. Impact of liquor ratio on light fastness

Color fastness to light depends on the structure of the dye. The unsaturated loosely held electron in the dye molecule causes poor results. But regarding liquor ratio, the strong bond yields better results. Also, the higher exhaustion and fixation comparatively lower liquor ratio without aggregation produce deeper

shade and the lighter fading seems negligible while the little change in the light shade has great impact. In this study liquor ratios, 1:6 and 1:8 for RY 145 and RB 250 showed better results. Between them, the light fastness of RY 145 was higher than that of RB 250, as seen in Fig. 7. RY 145 provides the best light fastness at a liquor ratio of 1:6, whereas RB 250 had a light fastness result is 6 at liquor ratio of 1:8.

4.Conclusion

This research investigates the impact of liquor ratio on two reactive dyes (C.I. Reactive Yellow 145, C.I. Reactive Blue 250) dyed cotton fabric. The optimal liquor ratio has been determined according to the color strength and different fastness properties. Color strength, exhaustion, and fixation were increased with increasing liquor ratio 1:6 for C.I. Reactive Yellow 145 and 1:8 for C.I. Reactive Blue 250. The improvement of the color strength can explain this phenomenon at a high liquor ratio and the adsorption of dyes in the fabric. The color fastness to washing, rubbing, and perspiration better resulted in a nearly higher liquor ratio. The color fastness to light was the best result at a lower liquor ratio than a higher liquor ratio.

Conflict of interest

All authors are confirming that there is no conflict of interest of this work

Acknowledgements

The authors are grateful to the Northern University Bangladesh. The author also wishes to thanks to the anonymous reviewers and editor for their helpful suggestions and enlightening comments.

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