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Performance of Formaldehyde-free Fixing Agents on the Shade and Fastness Properties of Cotton Fabric Dyed with Reactive Dye

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KEYWORDS

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Fastness
Reactive dye
Cotton fabric

ABSTRACT

Reactive dye, the most frequently used dye for cotton coloration due to its superior technical aspects, especially its uncut covalent bond with the fiber, show poor fastness properties because of unfixed or hydrolyzed dyes on the fabric surface. Several fixing agents were investigated to improve the fastness properties, while some are not eco-friendly. However, instead of harmful chemicals, the formaldehyde-free fixing agents Optifix RSL, Albafix FRD, Optifix EC, and Albafix ECO were used in this study to enhance the fastness properties. These agents were applied on reactive dyed cotton knit fabric at 0.5%, 1.0%, and 1.5% concentration, and different fastness properties of treated fabric were investigated, namely colorfastness to washing, rubbing, and perspiration. In most cases, treated fabrics showed better fastness properties than untreated ones, whereas 1% concentration yielded better than 0.5%, and no improvement was found with further increasing the concentration of the fixing agent. Moreover, the mentioned fixing agents had little effect on shade, and this phenomenon was also inspected in terms of ΔE and K/S values. Quaternary ammonium compounds (Optifix RSL and Albafix FRD) performed better stability regarding shade than aliphatic polyamine compounds (Optifix EC and Albafix ECO), and this change appeared slightly yellowish to blueish.

1. . INTRODUCTION

Cotton fiber is the most widely used textile fabric worldwide due to its softness. It currently holds almost 60 percent market share for all textiles used in clothing and home furnishings [1]. It is renowned for its breathability, strength, and versatility [2]. Abundantly, up to more than 50% consumption of textiles is made up of cellulose [3]. This cotton fabric is dyed with different types of dyes. Cellulosic fiber dyeing with reactive dyes is one of the most convenient and popular methods [4][5].

Reactive dyes are extensively used for the exhaustion dyeing of cotton fiber; they provide a wide range of shades of good light and wash fastness on cellulosic fibers. These dyes suffer the disadvantage that dye and fiber reaction is not 100% efficient [6]. Exhaustion of the dye is incomplete because the dyes react not only with the fiber nucleophile reactive sites but also with nucleophiles present in the dye bath for dye hydrolysis [5][6]. Due to the deposition of hydrolysis dyes onto the surface of cotton, the fastness properties of the dyed fabric are not so good. Different fixing agents are used to improve

the fastness properties of reactive dyes of cotton fabric [7][8][9].

Fixing agents are chemicals that prevent the dyed fabrics from bleeding during subsequent washing, rubbing, and perspiration. Fixing agents are used to improve the different color fastness properties of dyed fabrics by bonding chemically with unfixed excess dye on the fabric surface [10]. In most cases of reactive dyeing, the complete removal of the hydrolyzed dyestuff portion by soaping is not possible, so an after-treatment is carried out with a fixing agent to improve the wet fastness properties of reactive dyed cotton fabrics [11]. Burkinshaw and Katsarelias improved the fastness properties of cotton using Matexil FC-ER and Matexil FC-PN cationic fixing agent at 40^0C for 30 minutes [8]. In 2014, Mohsin et al. examined the performance of formaldehyde-based cross-linker (DMDHEU) and BTCA - zero formaldehyde cross-linker fixing agent- on reactive dyed cotton fabric and reported that DMDHEU exhibited excellent results [12]. Liu studied a novel formaldehyde-free fixing agent likely dimethyl diallyl ammonium chloride and ammonium persulfate, as a binary polymer with outstanding fastness properties [13].

This study investigated the effect of formaldehyde-free fixing agents on shade and various color fastness features, such as colorfastness to washing, rubbing, and perspiration.

2. MATERIALS AND METHODS

2.1 Materials

100% cotton knitted fabric of 130 GSM with 28Ne was used in this study. Bi-functional reactive dyes (Red Sunfix S3B 150%, Sunfix Navy Blues SBF SP, and Sunfix Yellow S3R 150%), 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.

2.2 Scouring and bleaching recipe

Table 1: Recipe for scouring and bleaching

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	4.5 g/L
Caustic Soda	4.25 g/L
M:L	1: 10
Temperature	95^0C
Time	50 min

The cotton fabric was scoured and bleached at high-temperature exhaust method. 4.50 g/L hydrogen peroxide was used for bleaching (to remove natural color/grey color), and 4.25 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) for 50 minutes was used to scoured and bleach. Finally, neutralized the material, washed, and dried in a dryer [14].

2.3 Dyeing and fixing recipe

Cotton fabric was dyed in a laboratory dyeing machine at 60^0C for 50 minutes. After dying, the fabric was neutralized, washed with soaping agent in a shaker bath at 80rpm on 80^0C for 20 minutes, and thoroughly rinsed in tap water. Finally, fixing was used to improve the fastness properties of reactive dyed fabric [15][16].

Table 2: Recipe for reactive coloration of cotton

Chemicals	amount
Leveling agent	1.0 g/L
Sequestering agent	0.7 g/L
Anti-creasing agent	0.8 g/L
Sunfix Red S3B 150%	2.94 %
Sunfix Yellow S3R 150%	0.058 %
Sunfix Navy Blue SBF SP	0.002 %
Salt	50 gm/L
Soda Ash	15 gm/L
Temperature	60^0C
Time	50 min

Table 3: Recipe for fixation of dyed cotton fabric

Fixing	amount

agents			
Optifix RSL	0.5%	1.0%	1.5%
Albafix FRD	0.5%	1.0%	1.5%
Optifix EC	0.5%	1.0%	1.5%
Albafix ECO	0.5%	1.0%	1.5%

Fixing agent was used a laboratory dyeing machine at 40^{0}C for 20 minutes to improve the fastness properties of reactive dyed fabric [15].

2.4 Measurement of Color strength

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 [17]. 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)) [18]. Three measurements were taken for each sample [19] [20].

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

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

2.5 Assessment of color fastness

Colorfastness was evaluated using a variety of established testing procedures. According to ISO 105-C03 (2010), the Atlas LEF Lander-Omitter (Atlas, USA) measured color fastness to washing. Color Fastness to Perspiration (Acid, Alkali) was investigated using an AATCC Per spirometer **(**Atlas, USA**)** following ISO 105 E04 (2013). The color fastness to rubbing was tested using an AATCC Crock meter (Atlas, USA) following ISO 105-X12 (2016). All colorfastness was rated using greyscale ratings from 1 to 5, where 5 implies no shade change [21].

3. RESULTS AND DISCUSSION

3.1 Effect on Shade Change

Generally, fixing agents do not change the shade of dyed fabric. It is used to improve the fastness properties of dyed fabric. However, some types of fixing agents have little effect on the shade. Shades of dyed fabric may be changed tonally.

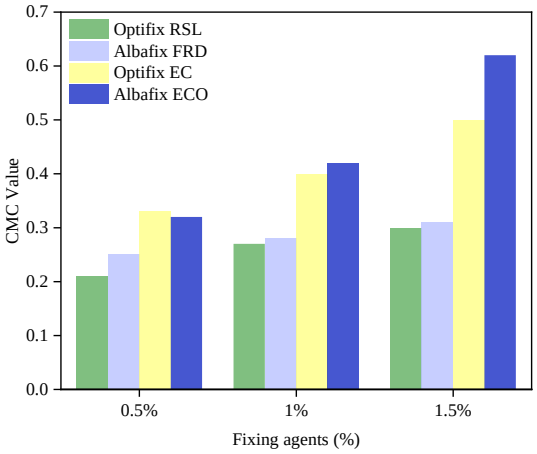

Fig. 1: CMC Value of various samples.

The fig. 1 shows that the CMC value was higher after using different fixing agents for aliphatic derivatives (Optifix EC and Albafix ECO) compared with quaternary ammonium compounds (Optifix RSL and Albafix FRD). It is observed that with the increase of the treated fixing agent's amount, the shade of dyed fabric also changed respectively.

3.2 Color Difference Value

3.2.1 Color Difference Value for DL* (D65, 10^0)

Table 4 shows the lightness or darkness of the dyed fabric after using different fixing agents. In most cases, the dyed fabric's shade does not have a significant effect. However, some fixing agents have little effects on shade, such as aliphatic derivatives fixing agents DL* decreased or slightly darker shade.

Table 4: Color Difference Value for DL*

Fixing agents	DL*		
	0.5%	**1.0%**	**1.5%**
Optifix RSL	0.10	0.07	0.03
Albafix FRD	0.12	0.09	0.05
Optifix EC	-0.03	-0.22	-0.27
Albafix ECO	0.04	-0.20	0.03

3.2.2 Color Difference Value for Da* (D65, 10^0)

Table 5: Color Difference Value for Da*

Fixing agents	Da*		
	0.5%	**1.0%**	**1.5%**
Optifix RSL	0.77	0.77	1.02
Albafix FRD	0.82	0.84	0.95
Optifix EC	0.23	0.34	0.66
Albafix ECO	0.30	0.39	0.50

Table 5 shows the effects on the tone of the dyed sample after using different types of fixing agents. The red tone of dyed samples was decreased due to the use of aliphatic derivatives fixing agents (Optifix EC and Albafix ECO). It is stated that aliphatic derivatives and non-formaldehyde fixing agents generally reduce the red tone of reactive dyed fabric. However, it may not be well-established due to the different functional groups of reactive dye.

3.2.3 Color Difference Value for D6* (D65, 10^0)

Table 6: Color Difference Value for Db*

Fixing agents	Db*		
	0.5%	**1.0%**	**1.5%**
Optifix RSL	0.37	0.28	0.49
Albafix FRD	0.37	1.01	0.31
Optifix EC	-0.36	-0.32	-0.42
Albafix ECO	-0.16	-0.44	-1.13

Table 6 shows the effects on the tone of the dyed sample after using different types of fixing agents. Most of the cases different fixing agents have no remarkable difference but some fixatives have very little effect on the shade of dyed fabric. The figure is showing that aliphatic derivatives slightly reduce the yellowish tone.

3.3 K/S Value

Application of fixings agents usually fixed the unfixed dye on the dyed fabric. As a result, the amount of dye on the dyed fabric is increased and hence K/S value also increased, exception has been found if fixing is not done after the dyeing process.

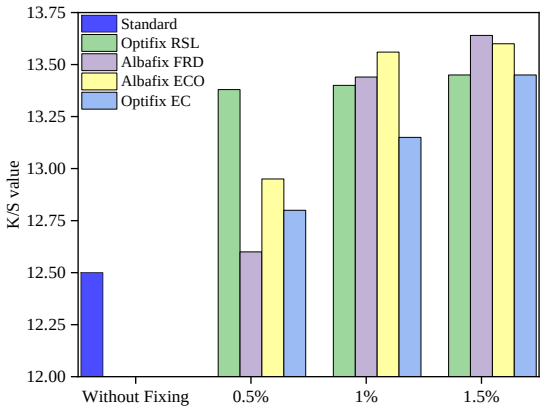

Fig. 2: K/S Value of various samples.

The fig. 2 shows that the K/S value is increased in greater amount after using different fixing agents in the case of quaternary ammonium compound (Optifix RSL and Albafix FRD) compare to aliphatic derivatives (Optifix EC and Albafix ECO). Most of the cases with the increase of concentration of different fixing agents increased the K/S value of the fabric

3.4 Color fastness

3.4.1 Color fastness to wash

Generally fixing agents are used to improve the wash-fastness properties of dyed fabric. It usually reacts with unfix dye on the dyed fabric as a result fixing agents prevent to dye from bleeding from dyed fabric for this reason fixing agents gave better wash fastness quality.

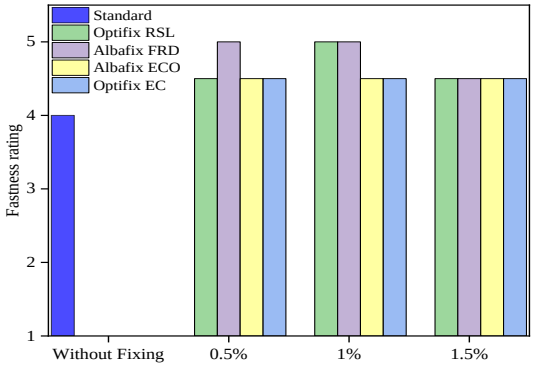

Fig. 3: Wash Fastness for Color Change (Grey Scale Rating)

Fig. 3 presents the color fastness results of the dyed fabrics with 3% of the reactive (Sunfix red S3B, Navy Blues SBF SP, Yellow S3R) and fixation with four types of fixing agents with concentration levels from 0.5 % to 1.5%. The color bleeding from dyed fabrics is also a major

consideration of the wash color fastness. The color bleeding value was 4.5 in most of the cases but it was 5 for 0.5% of Albafix FRD and 1% of Optifix RSL and Albafix FRD The figure is showing that after using fixing agents the color fastness to wash is increased. In most of the cases, it is seen that the color fastness properties of dyed fabric treated with two groups of fixing agents did not show a significant difference. Most improvements in wash fastness are at fixatives concentration up to or lower than 1%. Further increase of the fixatives concentrations could not improve the wash fastness with the same proportion as it did at a concentration below 1%. A possible explanation is that at a concentration below 1%, there are already enough fixative molecules on the fabric to neutralize most of the dyes

3.4.1 Color fastness to perspiration

Fig. 4 presents the perspiration fastness results of the fabrics dyed with reactive dye and fixation with all four fixing agents at various concentration levels from 0.5%, 1.0%, and 1.5%. The figure is showing that after using fixing agents the color fastness to perspiration is increased in between grayscale ratings from 4/5 to 5.

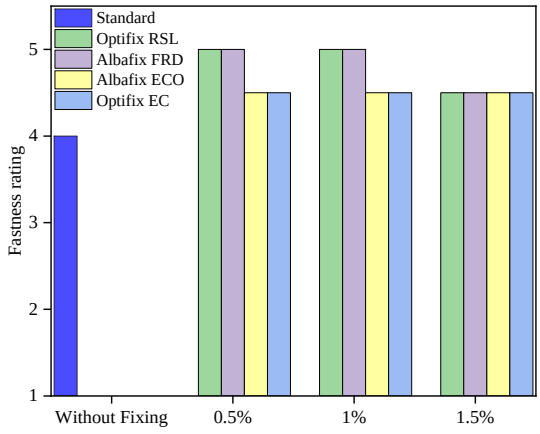

Fig. 4: Perspiration Fastness for Color Change (Grey Scale Rating)

However, no significant difference of the fastness properties among four types of fixing agents but from the above figure it is clear that Quaternary ammonium compound fixing agents (Optifix RSL and Albafix FRD) gave better perspiration fastness results than aliphatic derivatives fixing agents (Optifix EC and Albafix ECO).

3.4.1 Color fastness to rubbing

Table 7: Color fastness to rubbing

Without Fixing agents	**Dry**			**Wet**		
	4/5			3/5		
Fixing agents	**0.5%**		**1.0%**		**1.5%**	
	Dry	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
Optifix RSL	5	4/5	5	4	5	4
Albafix FRD	5	4/5	5	4	5	4
Optifix EC	5	4/5	5	4	5	4
Albafix ECO	5	4	5	4	5	4

Table 7 shows that after using different fixing agents with different concentrations, the color fastness to rubbing is increased but no significant improvement in both dry & wet crock fastness was encountered for red dyestuff examined with the four fixatives. As shown in the figures the maximum improvement was only 0.5 classes

4. CONCLUSIONS

In this study, the fastness properties of reactive dyed cotton fabric were compared after using different fixing agents with different concentrations. Different fastness properties such as rubbing fastness, perspiration fastness, wash fastness, CMC value, and also the K/S value of reactive dyed cotton fabric were investigated. Upon the completion of this investigation, it had been observed that the color fastness of reactive dyed cotton fabric was increased due to the presence of fixing agents. The following conclusions were drawn. Color fastness to wash and perspiration rating of reactive dyed cotton fabric was good to excellent for quaternary ammonium compound fixing agents up to concentration 1% and also good for aliphatic derivatives fixing agents up to concentration

1%. Colorfastness to rubbing of reactive dyed cotton fabrics was good for quaternary ammonium compound fixing agents up to concentration 1% and good for aliphatic derivatives fixing agents up to concentration 1%. CMC or ΔE & K/S value decrease for aliphatic derivatives fixing agents and also shade change (slightly red color reduction).

To conclude, the quaternary ammonium compound fixing agents gave better performance than aliphatic derivatives fixing agents. It was concluded that formaldehyde-free shade unchangeable fixing agents (quaternary ammonium compound) better performed for less dye bleeding and shade change of fabric than that formaldehyde-free shade changeable fixing agents (aliphatic derivatives).

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CONFLICT OF INTEREST

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

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