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Dyeing of Cotton Fabric with Reactive Dye Using Egg White for Absorption

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Abstract
This article outlines a new process for dyeing cotton fabric with reactive dye utilizing egg white as an absorbent in shades of 0.5, 1, 2, 3, and 4%. Similar cotton fabrics were colored with the same reactive dye to the like shades (%), deploying sodium chloride salt as an absorbent. The percentage difference between the samples with similar shades (%) indicated that the egg white-colored samples are significantly lighter in comparison. The tests of wash fastness of both types of samples showed a comparatively inferior wash fastness in case of egg white absorption process, and the tests of rubbing fastness of both types of samples provide similar results with very good fastnesses for dry rubbing and medium fastnesses for wet rubbing.

Keywords
Cotton fabric, Egg white, Reactive color, Rubbing fastness, Spectrophotometry, Wash fastness

INTRODUCTION
Cotton is a natural cellulosic fiber comprising numerous β(1-4) D-glucose units linked in polymers (Sreekala et al., 2023). As the cellulose contains many hydroxyl groups in its structure, cotton accumulates negative charges on its surface when submerged in water, which has the opposite effect of anionic reactive dye absorption. To solve this issue, large amounts of electrolyte (30–100 g/L) are added (Bhuiyan et al., 2014). Because these electrolytes are neither depleted nor eliminated, they remain in the dye liquor that is released, raising the salinity of the soil and water and posing a serious threat to the environment (Wei et al., 2002).

Researchers from different locations have attempted to reduce or eliminate the quantity of salt used in the reactive dye solution (Burkinshaw et al., 2000; Blackburn & Burkinshaw, 2003; Zhang et al., 2007; Montazer et al., 2007; Srikulkit & Santifuengkul, 2000). It is very likely that adding cationic sites to the cellulose will improve absorption (Evans et al., 1984; Hauser & Tabba, 2001; Youssef, 2000; Lei & Lewis, 1990; Micheal et al., 2002; Wu & Chen, 1993). A number of previously published articles have described the utilization of polyacrylamide as the absorbent in the dyeing of cotton, jute, silk, and viscose fibers (Kannan & Nithyanandan, 2006; Rahman et al. 2015; Rahman & Foisal, 2016; Rahman, 2020; Rahman, 2018; Rahman, 2021; Rahman, 2023). The amide group (-CONH-), amino group ($-NH3^{+}$), and carboxylate group ($-COO^{-}$) are present in the molecular structure of egg-white protein, just like present in polyacrylamide. Due to this similarity, silk fabric samples were dyed with reactive dye deploying egg white as an absorbing reagent (Rahman et al. 2022). Excellent results were found as the silk samples gave higher color depth than the conventional sodium chloride absorption technique of dyeing silk with reactive dye.

There hasn't been a published article yet about the coloring of cotton fabric with reactive dye while using egg white as an absorbing agent. Therefore, it is necessary to investigate whether or not dyeing cotton with reactive dye using egg white as an absorbent is feasible. In this process, it's also necessary to understand the various fastness characteristics and shade depths of the colored cotton fabric. To determine if it would be possible to dye cotton cloth with a reactive dye while using egg white as an absorbent for different shade percentages, we ran a number of tests. Also, to compare the test findings achieved, we dyed cotton samples with the same reactive dye for like shades (%), deploying common salt as an absorbent.

MATERIALS AND EXPERIMENTAL METHODS

The materials used in these experiments are as follows:
100% cotton fabric, Reactive dye Novacron Red C2BL (Huntsman, USA), Caustic soda, Detergent, Hydrogen per oxide, Stabilizer, Anti-foaming agent, EDTA, Leveling agent, Wetting agent, Egg-white, Glacial acetic acid, Sodium carbonate, Common salt.

Scouring and Bleaching of Cotton fabric samples

Combined scouring and bleaching were done by the following recipe:
140 g woven cotton fabric was taken in a large stainless-steel pan containing scouring and bleaching liquor. The material liquor ratio was 1:20. The liquor was composed of caustic soda 4 g/L, detergent 2 g/L, hydrogen peroxide 5 g/L, stabilizer 1 g/L, anti-foaming agent 1 g/L, EDTA 1 g/L, leveling agent 1 g/L, wetting agent 1 g/L. The scouring and bleaching were done at boiling temperature for 50 minutes. The fabric was then washed thoroughly and neutralized. The fabric was then dried. After then 4 g cotton fabric samples were cut for dyeing with reactive color.

Dyeing of Cotton fabric samples

Cotton fabric samples of 4 g each were dyed with Novacron Red C2BL dye for 0.5, 1, 2, 3, 4 shade%. Novacron Red C2BL is a bi-functional reactive dye of Huntsman Corporation, USA. In a conical flask, a 30 g/L egg white solution was prepared. 5% diluted glacial acetic acid was put into the egg white solution for complete dissolving. The quantities of Egg white solutions utilized for dyeing were 7.5, 10, 12.5, 15, and 17.5 g/L for 0.5, 1, 2, 3, and 4% shades, respectively. From now on, the procedure will be referred to as the EWA process.

Coloring process

The requisite quantities of the prepared egg white solutions were put into the cells of the lab dyeing machine. The requisite amount of EDTA, leveling, and wetting reagent was put and stirred. 1% stock solution of Novacron Red C2BL was prepared. The cells were filled with the requisite amount of dye solution for each shade percentage and stirred. Then requisite quantity of water was poured in to the cells. Cotton fabric samples of 4 g each were put in the cells and soaked. The samples were Shaked at 25 ^{o}C for 35 minutes for absorption. 10% stock solution of soda ash was made. Then the requisite quantity of soda ash solution was taken to each cell. After that, the dyeing machine's temperature was raised to 60 °C and colored for 60 minutes. The samples were then soap-washed and dried.

Table 1 The recipe for woven cotton fabric dyeing with the EWA process

Novacron Red C2BL%	0.5	1.0	2.0	3.0	4.0
EDTA (g/L)	1	1	1	1	1
Leveling reagent (g/L)	1	1	1	1	1
Wetting reagent (g/L)	1	1	1	1	1
Egg-white (g/L)	7.5	10	12.5	15	17.5
Soda ash (g/L)	7.5	10	12.5	15	17.5
Fixation Temp. (^{o}C)	60	60	60	60	60
M:L	1:20	1:20	1:20	1:20	1:20
Time (min.) (Absorption + Fixation)	35+60	35+60	35+60	35+60	35+60

For comparing the color depth of cotton fabric samples of 0.5, 1, 2, 3, and 4% shades dyed by the traditional sodium chloride salt absorption process (hereafter referred to as the SCA process) with the like shades of the EWA process, five cotton samples (4 g each) were again dyed with the identical dye. The EDTA, levelling reagent, wetting reagent, M:L, absorption and fixation temperature, and duration were maintained the same as for the EWA process. The quantities of common salt taken were 30, 40, 50, 60, and 70 g/L for the 0.5, 1, 2, 3, and 4% shades.

Spectrophotometry

Datacolor Spectro 700 spectrophotometer was utilized to measure the color variations among cotton fabric samples colored with the EWA process and the SCA process.

RESULTS AND DISCUSSION

Table 2 displays the spectrophotometric data for five (0.5, 1, 2, 3, and 4) color-shade% of cotton fabric samples. The samples dyed utilizing the SCA process were taken as the standard. The table shows that every lightness difference (DL*) value is positive, meaning that fabric samples dyed using the EWA process are lighter than the standard. The CMC DE values also suggest that the samples of EWA process are significantly lighter than the samples of SCA process (also shown in Figure 1).

Table 2 The spectrophotometric results of several shade%

Shade%	Illuminant	DL*	Da*	Db*	DC*	DH*	CMC DE
0.5	D65	18.29	-17.67	-0.15	-16.36	-6.68	11.29
1.0	D65	19.92	-16.60	-3.14	-14.68	-8.35	11.83
2.0	D65	20.39	-14.34	-4.95	-12.52	-8.57	12.09
3.0	D65	21.90	-13.76	-7.25	-11.91	-10.00	13.85
4.0	D65	23.53	-14.72	-7.58	-12.45	-10.91	14.51
0.5	TL83	10.39	-15.50	-2.89	-13.84	-7.56	10.39
1.0	TL83	18.06	-13.27	-5.70	-11.41	-8.85	10.76
2.0	TL83	19.06	-9.79	-6.69	-8.35	-8.42	10.83
3.0	TL83	20.76	-845	-98.68	-7.12	-9.79	12.54
4.0	TL83	22.33	-9.06	-9.11	-7.37	-10.52	13.14

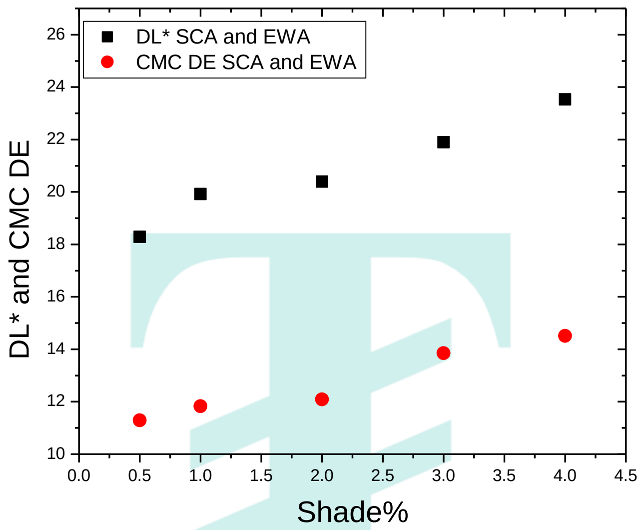

Fig. 1 Alteration of DL* and CMC DE values with the raise of shade%

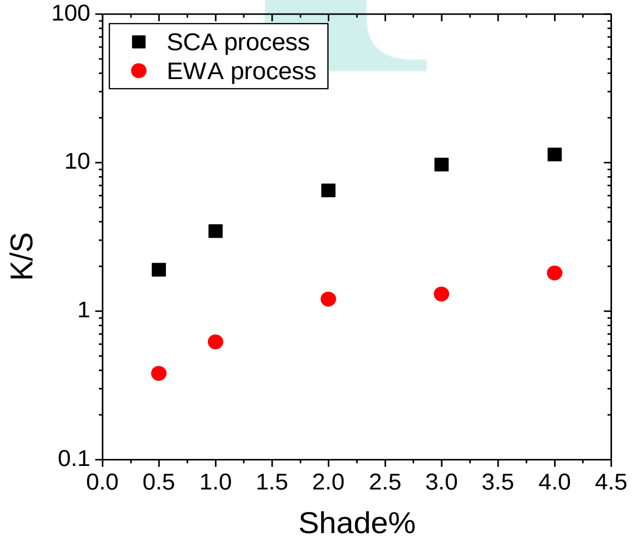

Fig. 2 Alteration of K/S with the raise of shade%

Figure 2 displays the alteration of the highest K/S values with the raise of shade% for both the SCA and the EWA processes. Here, the highest K/S values are taken from 530 nm peak as the Novacron Red C2BL showed broad peak at 530 nm. Higher K/S are found for the SCA process with every shade.

The egg white's protonated amino (-NH_3^+) groups form ionic bonds when they approach cotton's hydroxyl groups (-OH) in the watery medium (Figure 3). This attracts the negative ions from dye molecules and forms a covalent bond with cellulose in a basic medium at 60°C (Figures 4 and 5). Again, the cations of several amino acids within the protein of egg white may also react with the anions of dye molecules for which dye loss occurs. This might be one of the reasons for the lower shade% obtained in the samples of the EWA process.

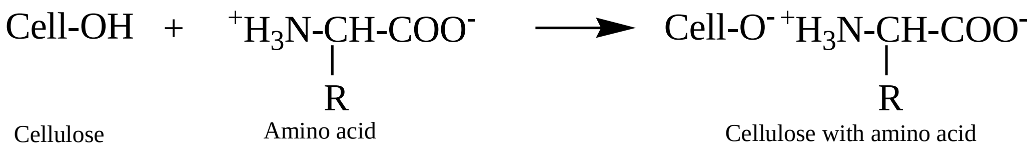

Fig. 3 Interaction between Cotton cellulose and amino acids

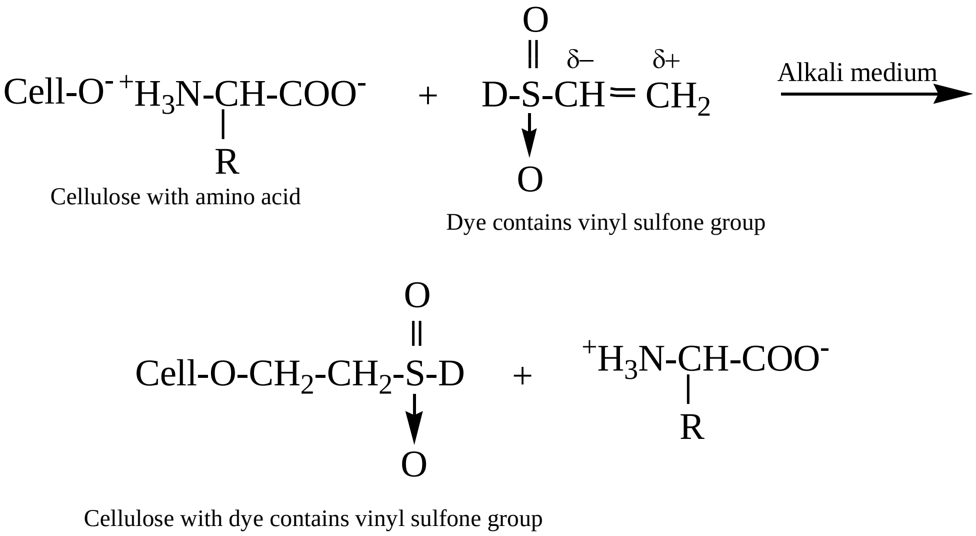

Fig. 4 Reaction possibility between amino acids added Cotton cellulose and vinyl sulfone group of reactive dye

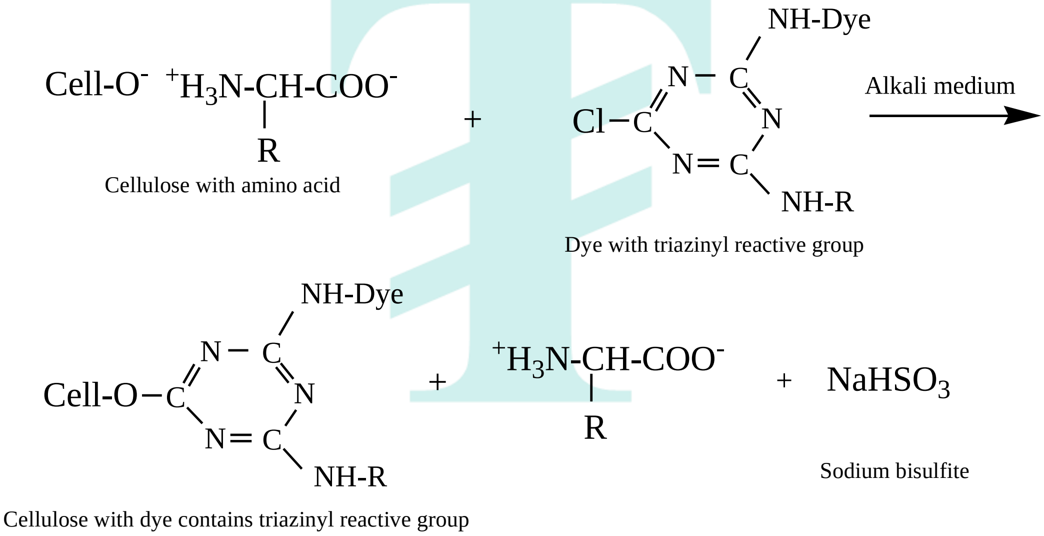

Fig. 5 Reaction possibility between amino acids added Cotton cellulose and triazinyl group of reactive dye

Wash Fastness Test

Table 3 The results of wash fastness tests

	Samples colored with EWA process		**Samples colored with SCA process**	
Color depth%	**3%**	**4%**	**3%**	**4%**
Color change	3-4	3	4	4
Stain: Di-acetate	4-5	4-5	4-5	4-5
Stain: Cotton	2-3	2-3	3	3
Stain: Polyamide	4-5	4-5	4	4
Stain: Polyester	5	5	5	5
Stain: Acrylic	4-5	4-5	4-5	4-5
Stain: Wool	4-5	4-5	4-5	4-5

The results of the wash fastness tests of the cotton samples dyed with SCA process and EWA process are shown in Table 3 for comparison. The ISO 105 C60:1994 procedure was used to assess the cotton samples colored in 3% and 4% shades for the wash fastness test. The test was done using a sodium perborate (1 g/L) solution and an ECE (4 g/L) reference detergent. For samples colored using the SCA process, the grey scale ratings for both the 3% and 4% shades are 4.

Samples dyed using the EWA process are rated 3–4 on the grey scale for 3% shade and 3 for 4% shade. These implicate that the wash fastness of samples dyed with EWA process are slightly inferior than the samples of SCA process. The color staining of multifiber cloths has also been evaluated. For both types of samples, the grey scale ratings are found to be almost equal (Table 3).

Rubbing Fastness Test

Table 4 The results of rubbing fastness tests

Color depth%	Samples colored with EWA process		Samples colored with SCA process	
	Dry	*Wet*	*Dry*	*Wet*
3	5	3	5	3
4	4-5	3	5	3

The results of the rubbing fastness tests of the cotton samples colored with the SCA process and the EWA process are shown in Table 4. Both wet and dry fastness of rubbing were evaluated. Samples of 3% and 4% shades were assessed here. The dry rubbing test showed very good results for both shades (%). However, the wet rubbing fastness is not so good (grey scale rating of 3) for these shades.

CONCLUSION

The cotton fabric samples were effectively dyed with the reactive dye utilizing egg white as the absorbing reagent. However, the color depth of the samples was much lighter than the sodium chloride absorption process. As the egg white is a natural biodegradable material, this novel process of dyeing cotton fabrics may be used for special purposes where inorganic salts or other organic absorbing materials are not suitable for dyeing of cotton fabrics.

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DECLARATION OF CONFLICT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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