Reactive Dyeing of Cationized Cotton: Effects on the Dyeing Yield and the Fastness Properties

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Received 7 January 2010; accepted 15 April 2010
DOI 10.1002/app.32648
Published online 27 July 2010 in Wiley Online Library (wileyonlinelibrary.com).

ABSTRACT: The cationization of cotton fibers is emerging as an effective tool for solving the environmental problems associated with the dyeing of cotton fabrics with anionic dyes. In this study, the dyeing performance of cationizing agents (Rucomor Bur, Kemifix REA, Optifix F, and Optifix RSL) were examined, and we found that this method had better results compared with normal or existing methods of reactive dyeing. The dye-bath exhaustion and fixation were determined by the help of an ultraviolet–visible absorbance spectrophotometer on the basis of the maximum absorbance wavelength. Better fixation values were found with the cationizing process than with salty dyeing. The washing and rubbing fastness results were as the same as those of traditional dyeing. J Appl Polym Sci 119: 500–504, 2011

Key words: cationizing; cotton fabrics; exhaustion; fixation; fastness

INTRODUCTION

Reactive dyes preferred for cotton textile applications.[1] However, the reactive dyeing process requires a huge amount of salt to exhaust and fix the dye.[2–5] These salts are neither exhausted or destroyed and, hence, remain in the dye bath after dyeing. Electrolytes are needed in the dyeing process to overcome the long-range repulsion forces occurring between the slightly negatively charged fibers and the negatively charged dye molecules. Salt in the waste dye bath is harmful to the environment.[6–9]

Increasing the dyeing yield by a cationizing process reduces the amount of waste dyestuff.[10,11] The application of a cationizing agent before dyeing to cotton fabrics lowers the surface negative charge. Decreasing the negative charge on the surface of cotton fabric increases the efficiency of dyeing with anionic dyes.[12–14] Figure 1 shows the surface charge status of cationized cotton fibers.

The purpose of this study was to analyze the influence of cationic agents on reactive dyeing. For this, cotton fabrics were pretreated with various cationic agents for reactive dyeing without salt. Instead, quaternary ammonium salts were used.

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Contract grant sponsor: Research Fund of Erciyes University; contract grant number: FBY-09-714.

EXPERIMENTAL

Materials

Throughout this study, the following materials were used.

Fabrics

The fabrics, scoured, bleached, unmercerized, and free of fluorescent whitening agents, were supplied by Çetinkaya Textile Co. (Kayseri, Turkey). The fabric was woven as plain 1/1, the weight of the fabric was 305 g/m^2, the warp and weft yarns were identical (20 tex), and the densities of these yarns were 39 and 24 threads/cm.

Chemicals and dyes

To prepare the cationized cotton fabrics, four commercial cationizing agents were used, which are shown in Table I. The cationizing agents were known as *quaternary ammonium salts*; however, because the cationizing materials were commercial, we could not determine the composition of these chemicals in detail. Thus, comparison or evaluation of the cationizing materials was carried out by the name of the products.

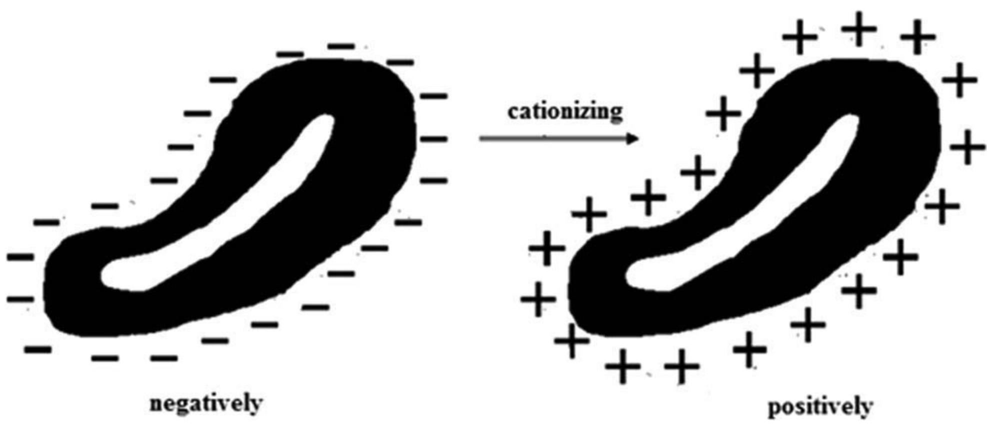

Figure 1 Negative and positive surface charges of cotton fibers.

In experiments, Everzol Yellow 3RS H/C (CI Reactive Yellow 145) was used as a reactive dyestuff; the dyestuff structure is shown in Figure 2.[15] During the experiments on industrial purity, $CaCO_3$, Na_2SO_4, and softened water were used.

Cationization

The cotton fabrics were treated with various commercial cationic agents at different concentrations (20, 30, and 40 g/L) with the padding method at 80% pickup. All of the cationized fabrics were dried in an oven at 50°C.

Dyeing

All of the dyeing processes were carried out in a laboratory dyeing machine (Termal-Turkey) at a liquor ratio of 20 : 1 according to the exhaustion technique in the presence of 1 g/L wetting agent and 20 g/L soda. Dyeing was carried out at various concentrations (0.1, 0.5, 1, and 2% owf, on the basis of the weight of the fiber) Dyeing was started at 25°C, the temperature was then raised to 70°C (2°C/min), and dyeing continued at the same temperature for a further 45 min.[16] For comparison, untreated cotton was dyed under the same conditions but in the presence of 50 g/L salt.[17] After dyeing, the washing of the dyed cotton fabrics was carried out according to the manufacturer's washing recipe (cold, boiled, boiled with nonionic detergents, and cold rinsing). The dyeing graphs are given in Figure 3.

TABLE I
Chemicals Used as Cationizing Agents

Number	Commercial name	Supplier
1	Rucomor BUR	Rodolf Duraner (Turkey)
2	Kemifix REA	Kemiteks (Turkey)
3	Optifix F	Clariant (Switzerland)
4	Optifix REA	Clariant (Switzerland)

Assessments of the characteristic parameters of dyeing

First, we prepared dye solutions at different determined concentrations, and their absorbance values were read by an ultraviolet–visible spectrophotometer. The results were then graphed to make a calibration curve, from which the unknown concentrations could be determined by their absorbance values. The uptakes of the reactive dyes by cotton were measured before and after dyeing. The absorbance of the unknown dye solution was measured on an PG T80 (Leicester-England) spectrophotometer on the basis of the maximum wavelength of absorbency of the dye (417 nm). On the basis of the spectrophotometric values, the individual dye exhaustion and fixation values were calculated as follows:[18]

$$\text{Dye exhaustion}(\%) = [(D_1 - D_2)/D_1] \times 100 \quad (1)$$

$$\text{Fixation}(\%) = [(D_1 - D_2 - D_3)/D_1] \times 100 \quad (2)$$

where D_2 is the amount of dye in the dye bath after t minutes of dyeing, D_1 is the initial dye amount in the dye bath before dyeing, and D_3 is the amount of dye in the soap bath at t minutes.

Washing and rubbing fastness testing

To examine the performance of the reactive dyed cotton fabric, the colorfastness to washing with monofiber adjacent fabrics and rubbing tests were carried out according to ISO 105-CO6:1997 C2S and ISO 105-X12, respectively. The impact of the cationizing process was identified by the fastness results.

RESULTS AND DISCUSSION

Dyeing yield

The treated and untreated cotton fabrics were dyed with reactive dyes at various concentrations (0.1, 0.5, 1, and 2% owf). In Table II, the reactive dyeing

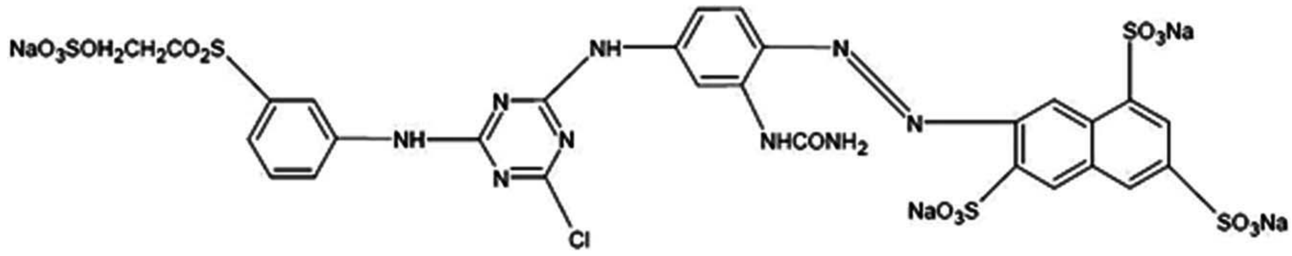

Figure 2 Chemical structure of Everzol Yellow 3RS H/C.

exhaustion and fixation results are presented according to the various dyeing conditions. In general, the dyeing yield of the cationized cotton dyed without salt was higher than that of the noncationized cotton.

The exhaustion (%) results were examined after traditional reactive dyeing with salt, and the traditional dyeing exhaustion range was 78–83%. In the pretreated cotton, the results were as follows: Rucomor BUR, 86–94%; Kemifix REA, 88–96%; Optifix F, 77–97%; and Optifix RSL, 84–98%. From these results, we determined that the exhaustion values of cationized cotton were higher than those of the untreated fabrics.

The fixation (%) results were examined after washing, and the traditional dyeing fixation range was 70–74%. In the pretreated cotton, the results were as follows: Rucomor BUR, 78–92%; Kemifix REA, 85–95%; Optifix F, 72–91%; and Optifix RSL, 78–95%. We determined that the fixation values of the cationized cotton were higher than those of the untreated cotton fabrics.

The ratio of the fixation value to the exhaustion value is called the *relative fixation rate*. A higher relative fixation rate means that a high proportion of dyes is connected to the fibers. Given the results of the experimental studies, the relative fixation rates of the cationized cotton fabrics were higher than those of the untreated cotton fabrics. In addition, the cationizing agents increased the fixation ability of the reactive dyestuff to the fiber.

Figure 4 shows the relative fixation percentages for each cationizing agent: salty, 87–89%; Rucomor BUR, 87–99%; Kemifix REA, 92–97%; Optifix F, 89–95%; and Optifix RSL, 87–98%. In this case, the best results were obtained with the Kemifix REA cationizing agent.

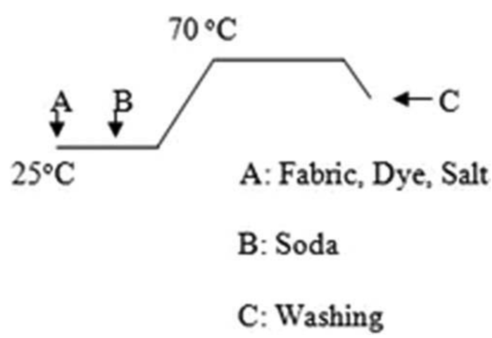

Figure 3 Reactive dyeing graph of cotton fabrics.

Fastness properties

The fastness properties of the cotton fabrics dyed at various concentrations were evaluated and are given in Table II. The results show that the colorfastness to rubbing and washing for both of the dyeing processes were more or less the same, depending on the dye fixation rate. The dry and wet rubbing fastness of all of the dyeings seem to be high. This high fastness was probably due to the fact that the dyes were reactive and penetrated the cotton fiber well.

The washing fastness was examined in terms of color changing. We found that the washing fastness of the cotton dyed with the cationized dye was better than that of the cotton dyed traditionally. However, the best washing fastness value was obtained with the Rucomor BUR cationizing agents.

Washing fastness was examined in terms of staining. We found that the washing fastnesses of the cotton dyed with cationized dye and traditional dye were approximately the same. However, the best washing fastness to staining was obtained with the Optifix F cationizing agent.

CONCLUSIONS

In this study, cotton fabrics were pretreated by cationizing agents to positively charge the sites by cationic modification before dyeing, Our aim was to decrease the surface negative charges of the cotton fibers. As a result of this process, the dyeing yield of the anionic dyes increased for the cotton fabrics. In present study, four different cationizing agents were applied to cotton fabrics at three different concentrations. Treated and untreated cotton fabrics were dyed with reactive dyes by an exhaustion method. After dyeing, exhaustion, and fixation, the rubbing and washing fastness values were evaluated to clarify how the cationizing agents impacted the reactive dyeing.

The optical density of the dye solution were measured before and after dyeing by ultraviolet–visible spectrophotometry on the basis of the maximum

TABLE II
Dyeing Performances of the Untreated and Treated Cotton Fabrics

Auxiliary chemical	Auxiliary chemical concentration (g/L)	Dyeing depth (%)	Dyeing yield (%)		Rubbing fastness		Washing fastness	
			Exhaustion	Fixation	Dry	Wet	Changing	Staining
Salty	50	0.1	78.75	70.00	5	5	5	5
		0.5	87.30	75.45	5	5	4–5	5
		1	84.24	74.11	5	4–5	4	4–5
		2	83.13	74.17	5	4–5	3–4	4
Rucomor BUR	20	0.1	86.60	78.58	5	4–5	5	4–5
		0.5	93.92	85.35	5	4–5	5	4–5
		1	92.21	83.66	4–5	4	5	4
		2	87.71	82.64	4–5	4	5	4
	30	0.1	88.75	88.32	5	4–5	5	5
		0.5	94.70	90.30	5	4–5	5	5
		1	93.66	90.35	5	4	5	4–5
		2	89.85	82.64	5	4	5	4–5
	40	0.1	93.99	90.91	5	5	5	4–5
		0.5	95.58	92.11	5	5	5	4–5
		1	93.12	90.64	5	4–5	4–5	4
		2	89.62	78.81	5	4–5	4–5	4
Kemifix REA	20	0.1	88.31	84.82	5	5	5	5
		0.5	94.97	92.50	5	5	5	4–5
		1	92.52	85.72	5	4–5	4–5	4–5
		2	84.00	80.66	5	4–5	4–5	4
	30	0.1	89.64	85.17	5	5	5	4–5
		0.5	96.71	93.88	5	5	5	4–5
		1	94.27	88.04	5	4–5	5	4
		2	93.56	90.74	5	4–5	5	4
	40	0.1	93.54	87.48	5	4–5	5	4–5
		0.5	97.65	95.54	5	4–5	5	4–5
		1	95.95	89.48	5	4	4–5	4
		2	96.91	91.79	5	4	4–5	4
Optifix F	20	0.1	88.33	82.80	5	5	5	5
		0.5	94.27	87.71	5	5	5	5
		1	85.64	80.07	5	4–5	5	4–5
		2	77.66	72.61	5	4–5	5	4–5
	30	0.1	91.81	83.34	5	4–5	5	5
		0.5	95.58	89.75	5	4–5	5	5
		1	89.03	84.78	5	4	4–5	4–5
		2	79.30	75.72	5	4	4–5	4–5
	40	0.1	97.89	87.34	5	5	5	5
		0.5	97.40	91.27	5	5	5	5
		1	95.04	91.16	5	4–5	5	4–5
		2	85.50	81.90	5	4–5	5	4–5
Optifix RSL	20	0.1	84.41	78.76	5	5	5	5
		0.5	97.49	85.44	5	5	5	4–5
		1	94.04	89.87	5	4–5	4–5	4–5
		2	87.62	81.90	5	4–5	4–5	4
	30	0.1	93.56	85.78	5	4–5	5	4–5
		0.5	97.33	93.99	5	4–5	5	4–5
		1	94.78	89.30	5	4	4–5	4
		2	89.33	84.03	5	4	4–5	4
	40	0.1	98.33	85.66	5	5	5	4–5
		0.5	95.66	94.23	5	5	4–5	4–5
		1	96.74	95.13	5	4–5	4	4
		2	92.08	88.80	5	4–5	4	3–4

wavelength of absorbency. Before we measured the absorbency, the wavelength of maximum absorbency was determined for each dye with standard calibration solutions.

According to the experimental results of this study, the exhaustion and fixation values of the cationized cotton fabrics were better than those of the cotton dyed by traditional reactive dyeing. The fixation percentages were found as follows: salty, 70–74%; Rucomor BUR, 78–92%; Kemifix REA, 85–95%; Optifix F, 72–91%; and Optifix RSL, 78–95%. The maximum fixation percentage was obtained with the Kemifix REA cationizing agent.

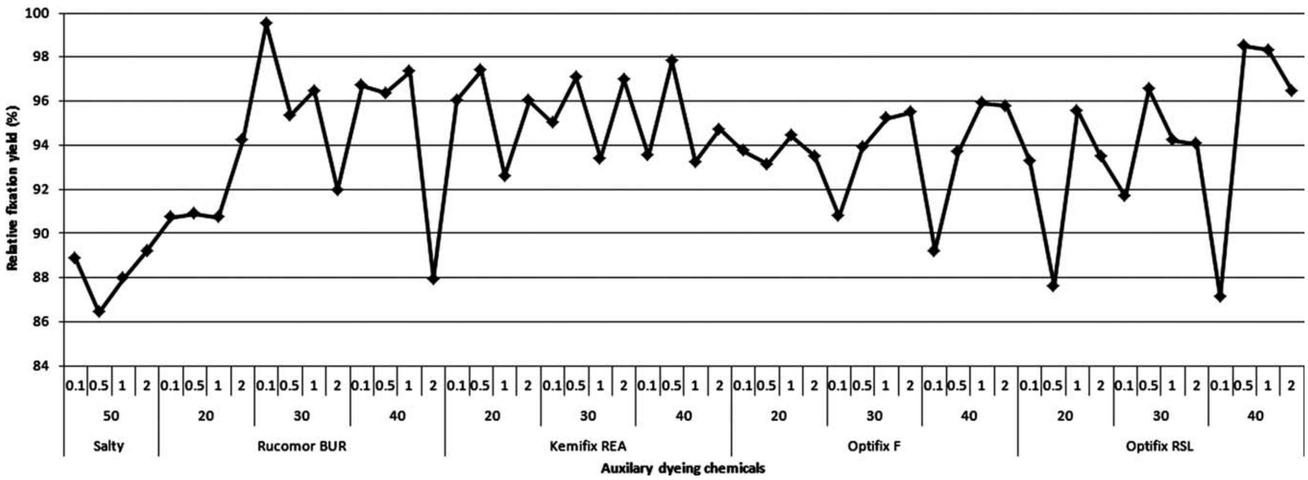

Figure 4 Relative fixation yield.

Given the evaluation of the experimental results on rubbing fastness, for both dry and wet rubbing fastness, the cationized cotton showed similar performance as the cotton dyed with the normal dyeing process. The washing fastness of cationized cotton was slightly better than that of the untreated cotton fabric. According to the experimental results, it appeared that the cationic agents increased the dyeing yield of the anionic reactive dyes. When cationizing agents were used in the reactive dyeing, we obtained a higher yield than when we used traditional reactive dyeing with salt.

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