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The use of sodium edate in the dyeing of cotton with reactive dyes

Nahed S.E. Ahmed*

Textile Research Division, National Research Centre, El-Behouth St. Dokki, Cairo, PO 12622, Egypt

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Abstract

The present paper was aimed at studying the possibility of using organic salt (sodium edate) in the dyeing of cotton fabrics with reactive dyes in place of inorganic salt (sodium sulphate) and in the absence of alkali. For this purpose, dyeing of cotton fabrics with reactive dyes using sodium edate and sodium sulphate was investigated and the results obtained were compared. Factors affecting dyeability such as salt concentration, alkali concentration, the use of mixed electrolyte, dyeing time and temperature were also studied. The colour strength and fastness properties of the dyed fabrics using sodium edate were comparable to those obtained with sodium sulphate. The overall results suggest that sodium edate offers the potential as an exhausting and fixing agent for reactive dyeing of cotton.

Keywords: Textile auxiliary; Sodium edate; Salt; Reactive dyes; Dyeing; Cotton

1. Introduction

The increased awareness of environmental issues has been driven much interest in eco-friendly textile wet processing techniques. The main challenge that textile industries faces is to modify production at a competitive price by using safe dyes and chemicals as well as by reducing treatment costs.

Exhaustive dyeing of cotton with direct, vat, sulphur, and, especially, reactive dyes requires the presence of electrolytes (NaCl or Na_2SO_4), which suppresses negative charge build-up at the fibre surface and promotes increased dye-uptake [1]. The quantities of electrolyte present can vary up to 100 g/l depending on the depth of colour required, the structure of the dyes or the dyeing recipe [2].

Reactive dyeing of cotton fabrics in addition to its consumption of high concentrations of potentially toxic non-biodegradable salt relies on an elevated pH (commonly over 10.5) for covalent fixation of the dyes on cotton. Under alkaline conditions reactive dyes react with hydroxyl groups of cellulose, mostly by neucleophilic substitution or addition, to form the covalent bonds. These strong bonds would be expected to lead to excellent wash fatness properties. However, the dyes can also react with hydroxyl groups of water present so that they are no longer able to react with cellulose. Thus, low reactive dye fixation and the use of high salt concentration would lead to environmental problems.

Progress has been made in reducing salt requirements for some newer reactive dyes, but salt concentrations are still too high [3]. An alternative approach for zero salt dyeing and for increasing dye-uptake and dye fixation on cotton is either by using the newly emergent reactive cationic dyes [4,5] or by using pre-treated cellulosic fibres [6–8] followed by dyeing with reactive dyes.

Recently, reduced salt by the replacement of non-biodegradable inorganic salt (sodium chloride) with biodegradable organic one (trisodium citrate) in the

* Tel.: +20 23371718; fax: +20 23370931.
E-mail address: nahedsea@hotmail.com

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exhaustive dyeing of cotton using reactive, direct and solubilised vat dyes has been reported [9]. Also, in another study [10], the use of polycarboxylic acid salts have proved the most effective class evaluated, promoting higher exhaustion and fixation of reactive dyes on cotton than sodium chloride.

Sodium edate, ethylenediaminetetraacetic acid, tetrasodium salt is a sequestering agent that works by a complexation mechanism. The resulting complex remains soluble and innocuous under the condition of processing. This phenomenon has been widely exploited in textile industries such as in dyeing to prevent precipitation of dyes by calcium and magnesium salts present in hard water and thus producing a brilliant dyed goods [11]. However, the use of sodium edate as exhausting and fixing agent in the dyeing of cotton with reactive dyes has not yet reported.

In the present work, sodium edate was used in the dyeing of cotton fabrics with reactive dyes. Exhaustion behaviour of this organic electrolyte was compared with sodium sulphate. Also, using this electrolyte for reactive dye fixation was evaluated in comparison with sodium carbonate. Different factors affecting dyeability and fastness properties were thoroughly investigated.

2. Experimental

2.1. Materials

2.1.1. Cotton fabric

Mill scoured and bleached cotton fabric of 160 g/m^2 was further treated with a solution containing 5 g/l of sodium carbonate and 3 g/l of non-ionic detergent (Hostapal CV, from Clariant-Egypt) under the boiling condition for 4 h, after which time it was thoroughly rinsed and air dried at room temperature.

2.1.2. Dyestuffs and chemicals

The vinyl sulphone reactive dyes used were Primazin Black BN, from BASF-Egypt (CI Reactive Black 5), Primazin Brilliant Blue RL, from BASF-Egypt (CI Reactive Blue 19), Remazol Yellow 3RS, from Dystar-Egypt (CI Reactive Yellow 176), Remazol Brilliant Red 3BS, from Dystar-Egypt (CI Reactive Red 239), Remazol Navy Blue GG, from Dystar-Egypt (CI Reactive Blue 203), Remazol Brilliant Blue BB, from Dystar-Egypt (CI Reactive Blue 220) and the monochlorotriazine dye used was Ismative Orange SH 2R, from Ismadye-Egypt (CI Reactive Orange 13). All dyes were of commercial grade and were used as received. Sodium edate (SE) was purchased from Fluka (Germany). All other reagents, namely sodium carbonate and sodium sulphate (SS), were commonly used laboratory reagent grade.

2.2. Dyeing conditions

In a dyebath containing different amounts of SE (0–50 g/l) and 2% shade of CI Reactive Blue 19 or CI Reactive Black 5 with liquor ratio 40:1, cotton fabric was added at 35 °C and the temperature was raised to 60 °C or 80 °C over 20 min for vinyl sulphone or monochlorotriazine dyes, respectively. After which time the dyeing was continued at 60 °C for 30 min (migration phase). Then 20 g/l of sodium carbonate was added portionwise and the dyeing was maintained at 60 °C for further 45 min. For comparison, the same method of dyeing was applied using SS (50 g/l). The optimum amount of exhausting agent SE that produces comparable results with that of SS was selected.

To find out whether SE could also act as fixing agent for reactive dyeings, cotton fabric was dyed as described above with the selected amount of SE using variable amounts of sodium carbonate (0–15 g/l). For comparison, the same method of dyeing was applied using SS (50 g/l) in absence of sodium carbonate. To reveal the effect of adding SS (0–25 g/l) in a dyebath containing SE (40 g/l) on the dyeability of cotton fabric with reactive dyes (CI Reactive Blue 19 and CI Reactive Black 5), dyeing of the fabric was followed as described above with the selected amount of SE and without sodium carbonate.

Also, dyeing was conducted at 60 °C for different time intervals (5–135 min). The optimum time at which the fabric absorbs maximum dye was selected and used in studying the dyeability of the fabric at different temperature (50–80 °C) using constant amount of SE and without sodium carbonate. The temperature at which maximum dye was absorbed by the fabric was selected. The viability of the above dyeing method (40 g/l of SE, 2% shade, 40:1 liquor, 60 °C, for 90 min) was checked with other reactive dyes including monochlorotriazine type reactive dye (CI Reactive Orange 13). The dyed samples were rinsed with cold water, washed in a bath of liquor ratio 60:1 containing 2 g/l of non-ionic detergent (Hostapal CV, Clariant) and 2 g/l sodium carbonate under the boiling condition for 30 min, then rinsed and finally dried at ambient temperature.

2.3. Measurements and analysis

2.3.1. Colour measurements

The relative colour strength of dyed fabrics expressed as K/S was measured by the light reflectance technique using the Kubelka–Munk equation [12]. The reflectance of dyed fabrics was measured on a Reflectance Spectrophotometer Model Ics-Texicon limited.

The dye exhaustion percentage (E%) was calculated according to the following equation:

$$\%E = \left[\frac{A_0 - A_f}{A_0}\right] \times 100$$

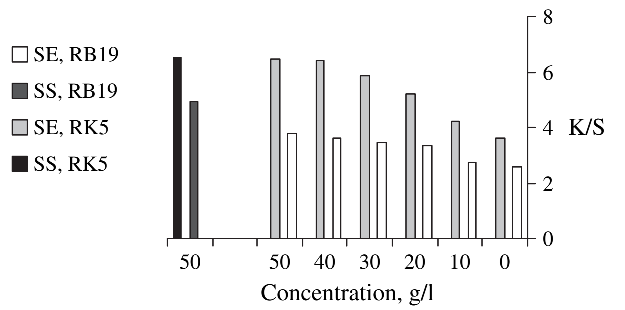

Fig. 1. Effect of salt concentration on the colour strength of the dyed cotton fabrics.

where A_0 and A_f are, respectively, the absorbance of the dyebath before and after dyeing at λ_{max} of the dye used. The absorbance was measured on a Shimadzu UV/Vis spectrophotometer at λ_{max} of the dye used.

2.3.2. Fastness testing

The dyed samples were tested according to ISO standard methods. The specific tests were: ISO 105-X12 (1987), colour fastness to rubbing; ISO 105-C02 (1989), colour fastness to washing; and ISO 105-E04 (1989), colour fastness to perspiration.

3. Results and discussion

The primary objective of this work is to investigate the possibility of using sodium edate (SE) as exhausting and fixing agent in the dyeing of cotton with reactive dyes and in this regard the different factors that may affect this process are investigated.

3.1. Effect of exhausting agent concentration

Based on the information available elsewhere, the use of 50 g/l of SS was considered as the standard exhausting amount necessary for reactive dyeing of cotton fabrics with 2% shade [1]. The effect of SE concentration on the dyeability of cotton fabrics with

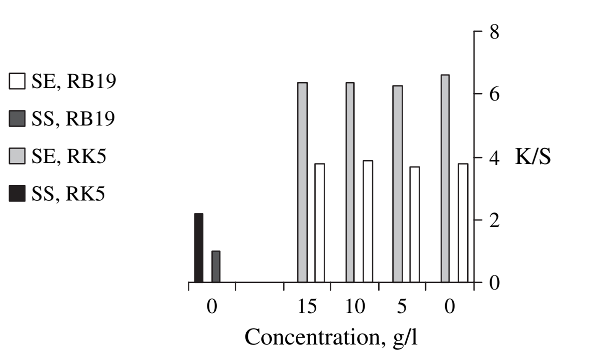

Fig. 2. Effect of sodium carbonate concentration on the colour strength of the dyed cotton fabrics.

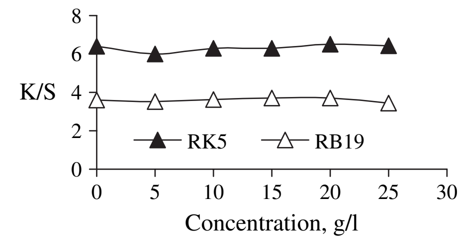

Fig. 3. Effect of sodium sulphate concentration in a dye-bath containing sodium edate on the colour strength of the dyed cotton fabrics.

Reactive Blue 19 and Reactive Black 5 was conducted at different concentrations (0–50 g/l).

As shown in Fig. 1, the colour strength of dyed fabrics increases as the concentration of SE increased up to 40 g/l after which a negligible increase in the colour strength values was observed. Also, Fig. 1 shows a comparative colour strength of dyed fabrics between those obtained using 40 g/l of SE and those obtained using 50 g/l of SS for both dyes. It is clear that SE is rather an effective exhausting agent for bifunctional vinyl sulphone reactive dye (Reactive Balck 5) than monofunctional vinyl sulphone reactive dye (Reactive Blue 19). This result reflects the fact that SE could be used as an alternative biodegradable exhausting agent and the enhanced effect in the case of Reactive Balck 5 may be attributed to its bifunctionality that would further enhance dye sorption.

3.2. Effect of alkali concentration

It is known that alkali is necessary for covalent bond fixation of reactive dye on the cotton fibre. Therefore, it was of interest to reveal whether SE would be affective as a fixing agent as well. Fig. 2 shows the effect of sodium carbonate concentration (0–15 g/l) on the colour strength of the dyed cotton fabrics using both dyes (Reactive Blue 19 and Reactive Black 5). Also, Fig. 2 shows a comparative colour strength of dyed

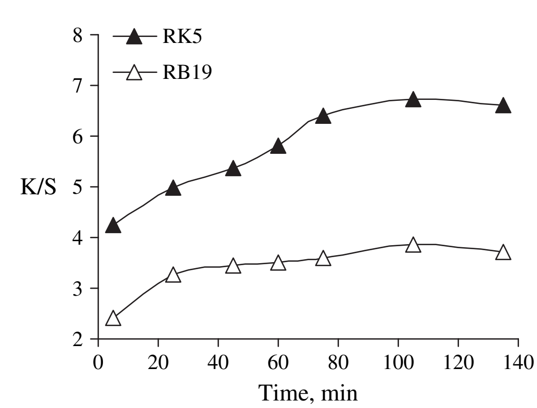

Fig. 4. Effect of dyeing time on the colour strength of the dyed cotton fabrics.

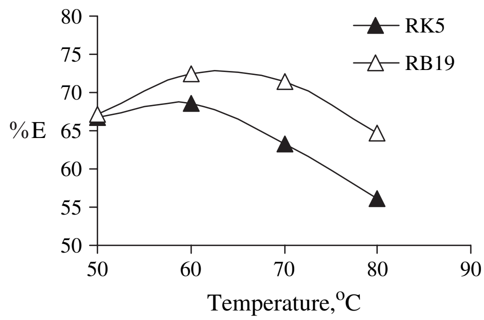

Fig. 5. Effect of dyeing temperature on the exhaustion of Reactive Black 5 and Reactive Blue 19 on cotton fabrics.

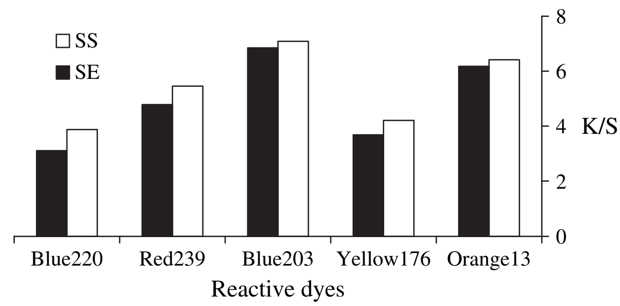

Fig. 6. Comparative colour strength of the dyed cotton fabrics with sodium edate (SE) and sodium sulphate (SS) using different reactive dyes.

samples with both dyes without sodium carbonate (0 g/l) using SS and SE.

As shown in Fig. 2, the colour strength values obtained using SE were independent on sodium carbonate concentration. On the other hand, the colour strength values of dyed samples using SE were significantly higher than those obtained using SS in the absence of sodium carbonate (0 g/l), which were lowered about 79 and 66% using Reactive Blue 19 and Reactive Black 5 (compare with Fig. 1), respectively. This result emphasizes the fact that alkali is necessary for covalent bond fixation using SS as this salt is neutral electrolyte. Whereas SE is alkaline polycarboxylic sodium salt (pH ∼11) and in addition to be as exhausting agent would also act as fixing agent.

3.3. Effect of using sodium sulphate together with sodium edate

Having the information that SE could act as exhausting agent and fixing agent, it was desirable to study the effect of adding SS to the selected amount of SE in the dyebath. Fig. 3 shows that the colour strength values for dyed samples of both dyes are independent of the concentration of SS added. It is known that SS as a neutral electrolyte is an effective exhausting agent (using optimum amount of salt) in the dyeing of cellulosics with anionic dyes.

The major effect of the electrolyte on such dyes, in addition to its extinguishing effect on the negative charge on cotton fibres, is to increase the degree of aggregation of the dye molecules in solution by the common-ion effect. The electrolyte suppresses the ionisation of the dye molecule in solution, thereby effectively reducing its solubility in the dyebath and modifying the equilibrium in favour of movement of dye molecules from the solution to the fibre [1,11]. On the other hand the alkalinity effect of SE in the dyebath seems to have suppressed the effect of the amount used of SS in such alkaline medium, which favours more dye ionisation.

Table 1
Fastness properties of the dyed cotton fabrics with sodium edate (SE) and sodium sulphate (SS)

Salt	Reactive dye[a]	Washing[b]			Rubbing		Perspiration[b]					
							Acidic			Alkaline		
		A	C	W	Wet	Dry	A	C	W	A	C	W
SE	**1** (λ_{max} 591 nm)	4	4–5	2–3	4	4–5	4–5	4–5	4–5	4–5	4–5	4–5
SS		4	4–5	2–3	3–4	3–4	4–5	4–5	4–5	4–5	4	4–5
SE	**2** (λ_{max} 595 nm)	4	4–5	4–5	3–4	4–5	4–5	4–5	4–5	4–5	4	4–5
SS		4	4–5	4–5	3	3–4	4–5	4–5	4–5	4–5	4–5	4–5
SE	**3** (λ_{max} 609 nm)	4–5	4–5	4–5	4	4–5	4–5	4–5	4–5	4–5	4–5	4–5
SS		4–5	4–5	4–5	3–4	4–5	4–5	4–5	4–5	4–5	4–5	4–5
SE	**4** (λ_{max} 422 nm)	4–5	4–5	4–5	3–4	4	4–5	4	4–5	4–5	4	4–5
SS		4–5	4–5	4–5	3	3–4	4–5	4	4–5	4–5	4	4–5
SE	**5** (λ_{max} 488 nm)	4–5	4	4–5	3	3	4–5	4	4–5	4–5	4	4–5
SS		4–5	4	4–5	3	3	4–5	4	4–5	4–5	4	4–5
SE	**6** (λ_{max} 520 nm)	4–5	4–5	4	3	3–4	4–5	4	4–5	4–5	4	4–5
SS		4–5	4–5	3–4	2–3	3	4–5	4–5	4–5	4–5	2–3	4–5
SE	**7** (λ_{max} 600 nm)	4–5	4–5	4–5	4	4–5	4–5	4–5	4–5	4–5	4–5	4–5
SS		4–5	4–5	4–5	3–4	4–5	4–5	4	4–5	4–5	4	4–5

[a] Molar extinction coefficients are 0.0101 and 0.0219 $mg^{-1}\ l\ cm^{-1}$ for dye **1** and dye **2**, respectively.
[b] A, change in colour; C, staining on cotton; W, staining on wool.

3.4. Effect of dyeing time

Figs. 1 and 2 have concluded that SE edate can be used as exhausting and fixing agent at the same time. Therefore, the dyeing process has become rather simple and relies on SE and dye solution without the need of sodium carbonate dosing. In this regard, once the dyeing temperature has reached 60 °C migration and fixation take place simultaneously within certain time. Fig. 4 shows the effect of dyeing time on the colour strength obtained of dyed fabrics using Reactive Blue 19 and Reactive Black 5. It is clear that the colour strength increases with increasing the dyeing time up to 90 min after which time a marginal increases in the colour strength of samples dyed with both dyes were observed.

3.5. Effect of dyeing temperature

Fig. 5 shows the effect of dyeing temperatures (50, 60, 70, 80 °C) on exhaustion of dyes on the fibres. An increase in the exhaustion of dyes on cotton fibres is observed as the dyeing temperature increased from 50 to 60 °C. However, increasing the temperature from 60 to 80 °C was accompanied by a successive decrease in the exhaustion values for both dyes. It is known that increasing the temperature allows for the swelling of the cotton fibres, which leads to a higher dye-uptake. The result indicates that 60 °C is a suitable temperature for vinyl sulphone dyes above which temperature the hydrolysis of the dyes takes place, which results in a decrease in the dye-uptake.

3.6. Application on different dyes

The viability of using SE alone in comparison with using SS together with sodium carbonate (conventional method) in the dyeing of cotton fibres with different reactive dyes is shown in Fig. 6. It is clear that SE method have comparable results with all reactive dyes used (vinyl sulphone and monochlorotriazine).

3.7. Fastness properties

As shown in Table 1, the fastness tests of washing, rubbing and perspiration of samples that had been dyed with reactive dyes are generally higher using SE compared with SS conventional method. The fastness improvement may be as a result of better dye penetration and thus good covalent fixation with cotton fabrics.

4. Conclusion

This study explores the viability of replacing the inorganic exhausting (sodium sulphate) and fixing (sodium carbonate) agents, which are widely used in the dyeing of cotton with reactive dyes causing some environmental concerns, with organic sodium edate that functions as exhausting and fixing agent. The fastness properties of dyed samples using SE were better than those obtained using SS conventional method.

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