Improved Reactive Dye-fixation in Pad-Steam Process of Dyeing Cotton Fabric Using Tetrasodium N, N-Biscarboxylatomethyl- L-Glutamate

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ABSTRACT

Pad steam process of dyeing cotton with reactive dyes is known to give lower levels of dye-fixation on the fiber because of excessive dye-hydrolysis. This research presents improved reactive dye-fixation in pad-steam process of dyeing cotton found in an effort of using biodegradable organic salts to improve the effluent quality. The CI Reactive Blue 250, a *bis*sulphatoethylsulphone dye and the Tetrasodium N, N-biscarboxylatomethyl-L-Glutamate, a biodegradable organic salt, were used. The new dye-bath formulation using the organic salt gave more than 90% dye-fixation.

Traditional pad-steam process of dyeing cotton with reactive dyes requires the use of inorganic electrolyte, sodium-chloride, and alkali, sodium-carbonate, to ensure effective dye consumption and fixation. These inorganic chemicals when drained generate heavy contents of dissolved solids and oxygen demand in the effluent leading to environmental pollution. Thus, Tetrasodium N, N-biscarboxylatomethyl-L-Glutamate was used in place of inorganic electrolyte and alkali to improve effluent quality. A significant increase in dye-fixation and ultimate color-yield was obtained with same colorfastness properties of the dyed fabric comparing to the traditional pad-steam dye-bath formulation.

Key Words: **Pad-Steam Dyeing, Cotton, Reactive Dye-Fixation, Biodegradable Organic Salt.**

1. INTRODUCTION

Reactive-dye-cotton is a predominant dye-fiber combination for apparels [1]. This is mainly due to the natural comfort and performance properties of cotton fiber and the covalent bond formation between the cotton cellulose and the dye molecules leading to very good washing fastness. Nevertheless, the reactive dyeing process consumes high volume of water and causes the heavy discharge of inorganic electrolytes, alkalis and unfixed dyes. This creates heavy contents of dissolved solids and oxygen demand leading to environmental pollution [2-6]. The reactive dye-fixation efficiency is typically in the range of 50-80% [6]. The relatively lower dye-fixation efficiency is mainly due to possible dye-bath hydrolysis. This problem is more evident in continuous pad-steam dyeing [4]. The hot and humid treatment of wet fabric during steaming tends to cause excessive hydrolysis and thus lowers the ultimate color-yield.

Developments in dye structures, dyeing processes and machinery have been proved to be effective for reducing

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the concentrations of inorganic electrolyte and improving dye-fixation [2, 7-12]. Chemical cotton modification prior to dyeing has been proved to eliminate the requirement of inorganic electrolyte, and also alkali as in some cases [13-17]. Organic chemicals have also been proved to be possible alternative to inorganic electrolytes in batch dyeing processes [18-21]. Tetrasodium-EDTA, a biodegradable alkaline organic salt, has been proved as an alternative to inorganic electrolyte and alkali in batch process of dyeing cotton with reactive dyes [22]. Another alkaline organic salt, trisodium nitrilo triacetate, has recently been proved as an alternative in pad-steam process of dyeing cotton with reactive dyes [23]. This effort was extended to the use of Tetrasodium N, N-biscarboxylatomethyl-L-Glutamate (Tetrasodium-GLDA, Fig. 1), a biodegradable alkaline organic salt, in pad-steam process of dyeing cotton with reactive dyes and the findings are presented in this paper. The presentation of this paper focuses mainly on the improvements in fixation efficiency of a *bis*sulphatoethylsulphone dye by using the tetrasodium-GLDA.

2. MATERIAL S AND METHOD

2.1 Fabric, Dyes and Chemicals

The mill scoured and bleached cotton woven fabric (282g/m^2) and the CI Reactive Blue 250, a *bis*sulphatoethylsulphone dye, were used. The Felosan-RGN-S (a non-ionic detergent) was used for soaping during washing-off after dyeing. The tetrasodium-GLDA, sodium-chloride and sodium-carbonate were laboratory grade.

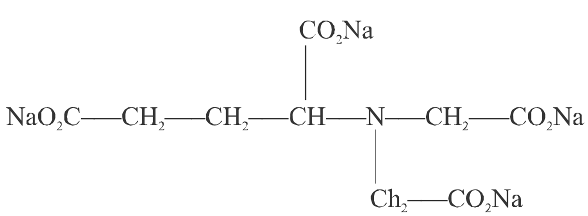


FIG. 1. TETRASODIUM N,N-BISCARBOXYLATOMETHYL-L-GLUTAMATE

2.2 Pad-Steam Dyeing

Fabric samples were padded in aqueous dye-bath containing 20g/l dye and the pertinent quantities of sodium-chloride and sodium-carbonate or tetrasodium-GLDA with 70% liquor-pick-up on a Benz padding mangle. The fabrics were then steamed at 101-102^{o}C and 100% moisture on a Mathis steamer for 60, 90 and 120 sec.

2.2.1 Washing-Off

The dyed samples were washed with cold water then warm water, soaped with 2g/l detergent under the boiling condition for 15 min, and then washed with hot water until no further color desorbed. Finally, the samples were washed with cold water and oven dried.

2.3 Color-Yield, Dye-Fixation and Colorfastness Testing

Datacolor 600 spectrophotometer was used for measuring the color-strength values at the maximum absorption. The color-strength after washing off (*K/S*) was obtained as the final color-yield. The extent of dye-fixation on the fabric was measured as, $\%F=[(K/S)/(K/S\text{before washing})]\text{x}100$ [24-26]. The dyed and washed-off samples were tested for colorfastness properties (rubbing: AS 2001.4.3 - 1995, washing: AS 2001.4.15C - 2006, and light: AS 2001.4.21 - 2006).

3. RESULTS AND DISCUSSION

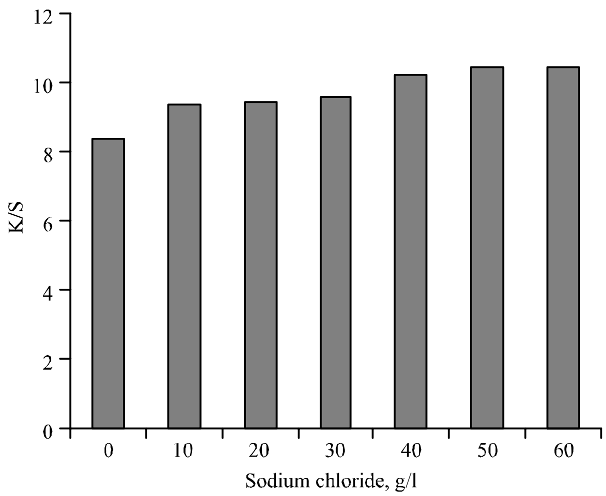
3.1 Optimum Inorganic Electrolyte and Alkali

In pad-steam process of dyeing, an electrolyte promotes dye levelness in the fiber and the ultimate color-yield [4, 27,28]. Fig. 2(a) shows that the optimum color-yield was achieved with 50g/l sodium-chloride for 20g/l CI Reactive Blue 250 at steaming time of 60sec. Under alkaline pH conditions, reactive dye react with the hydroxyl-groups of the cotton cellulose and can also react with the hydroxide-ions of water molecules in aqueous dye-bath

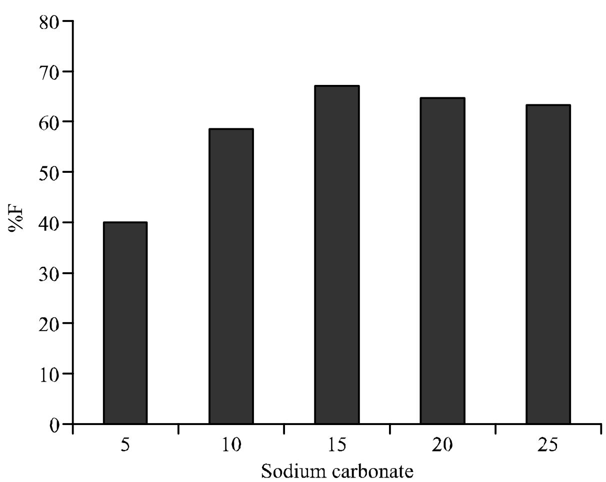
[3, 4, 27]. Thus, an excess in the concentration of alkali can increase dye-hydrolysis at the expense of dye-fiber reaction. Fig. 2(b) shows that 15g/l was the optimum alkali (sodium-carbonate) concentration for dye-fixation efficiency.

3.2 Effect of Tetrasodium-GLDA Concentration

Fig. 3(a-b) shows the effect of tetrasodium-GLDA concentration on dye-fixation and ultimate color-yield.



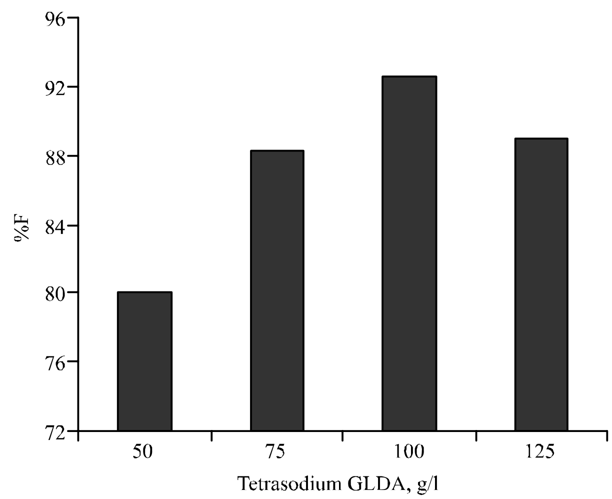
(a) SODIUM-CHLORIDE CONCENTRATION VERSUS COLOR-YIELD (CONSTANT SODIUM-CARBONATE, 15g/l)



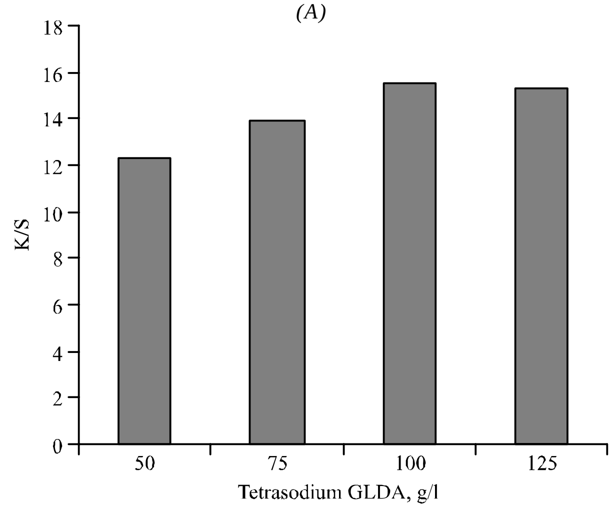
(b) SODIUM-CARBONATE CONCENTRATION VERSUS DYE-FIXATION (CONSTANT SODIUM-CHLORIDE, 50g/l)

FIG. 2. OPTIMUM CONCENTRATIONS OF SODIUM-CHLORIDE AND SODIUM-CARBONATE (20g/l CI REACTIVE BLUE 250, 60sec STEAMING)

The fixation and yield passed through maximum values with increasing concentration of tetrasodium-GLDA at steaming time of 60 sec. The optimum value was obtained with 100g/l of tetrasodium-GLDA for 20g/l CI Reactive Blue 250. More than 90% dye-fixation was achieved, which is remarkably a significant increase compared to traditionally achievable lower fixation-levels because of excessive dye-hydrolysis in pad-steam process of dyeing cotton with reactive dyes [4]. This may be attributed to the higher aqueous ionic-strength and better pH stability of tetrasodium-GLDA for the reaction of a *bis*sulphatoethylsulphone dye with the cotton cellulose.



(A)



(B)

FIG. 3. EFFECT OF TETRASODIUM-GLDA CONCENTRATION ON COLOR FIXATION AND YIELD OF CI REACTIVE BLUE 250 (20g/l) AT 60sec STEAMING

3.3 Comparison: Tetrasodium-GLDA Dyeing and Traditional Dyeing

3.3.1 Effect of Steaming Time

The steaming time range of 60-120 sec was selected. This is because industrial dyeing machines for pad-steam process are designed to operate within this time range. The effect of steaming time on color-yield and dye-fixation using the optimum tetrasodium-GLDA and inorganic chemicals concentrations is shown in Fig. 4(a-b). The figure does not show any considerable change in dye-fixation and color-yield with steaming time in both cases, i.e. tetrasodium-GLDA and traditional dyeings. The effect of longer steaming time was not studied because the time exceeds industrial possibility.

3.3.2 Comparative Color-Yield, Dye-Fixation and Colorfastness

The comparative fixation and yield results for the tetrasodium-GLDA and traditional dyeings can also be analysed from Fig. 4(a-b). It was observed that the tetrasodium-GLDA gave notably higher dye-fixation with CI Reactive Blue 250, as discussed in the Section 3.2 for Fig. 3(a-b). The ultimate color-yield obtained was also significantly higher than that obtained using inorganic electrolyte and alkali. These results obtained with tetrasodium-GLDA for the *bis*sulphatoethylsulphone dye are worthy of industrial application.

Table 1 shows that the colorfastness properties of the tetrasodium-GLDA dyeing are same as those of the traditional dyeing using inorganic electrolyte and alkali. Such identical colorfastness results are encouraging. The rubbing and washing fastness results are generally very good. The low light fastness values of CI Reactive Blue 250 are the same as those reported by dye manufacturer's on the pattern card. The concentration of tetrasodium-GLDA, for colorfastness testing, used was 40g/l (which was not optimum) in order to have the color-yield matching to traditional dyeing.

4. CONCLUSIONS

This study shows that the tetrasodium-GLDA, a biodegradable alkaline organic salt, can successfully be used for pad-steam process of dyeing cotton with reactive dyes to replace inorganic electrolyte and alkali. Interestingly, increased dye-fixation and ultimate color-yield of a *bis*sulphatoethylsulphone dye was achieved using tetrasodium-GLDA. This increase was remarkably higher than traditionally achievable dye-fixation levels with no change in the colorfastness of dyed fabrics. The improved dye-fixation and ultimate color-yield results are worthy of industrial application.

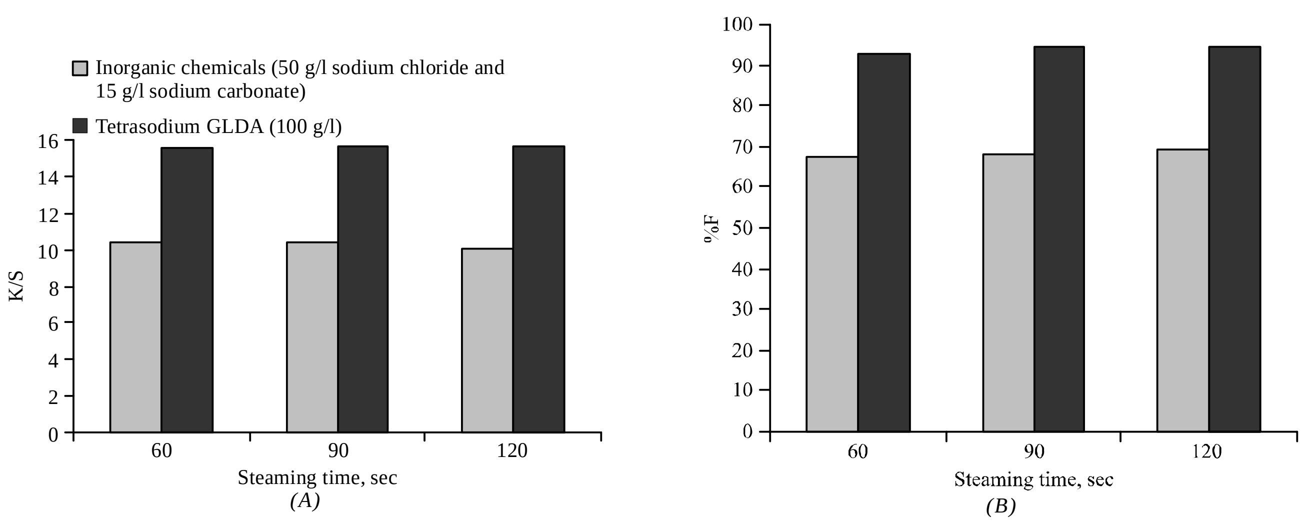


FIG. 4. EFFECT OF STEAMING TIME ON COLOR-YIELD AND DYE-FIXATION (20g/l CI REACTIVE BLUE 250, OPTIMUM TETRASODIUM-GLDA AND INORGANIC CHEMICALS CONCENTRATIONS)

TABLE 1. COLORFASTNESS OF COTTON FABRICS (20g/l CI REACTIVE BLUE 250, 60 SECONDS STEAMING)

Pad Steam Dyeings	Color Yield (K/S)	Rubbing Fastness		Washing Fastness		Light Fastness
		Dry	Weight	Change in Color	Staining on White*	Blue Wool Reference
Traditional 50g/l Sodium-Chloride 15g/l Sodium-Carbonate	10.42	4-5	4	4-5	4-5	3-4
Tetrasodium-GLDA (40g/l)	10.82	4-5	4	4-5	4-5	3-4
*Secondary Cellulose-Acetate, Cotton, Polyacrylonitrile, Polyester, Polyamide, Wool						

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