ISSN: 1999-1630

SEU Journal of Science and Engineering, Vol. 10, No. 2, December 2016

Dyeing of Cotton Fabric with Basic Dye in Conventional Method and Pretreated with Cationic Polyacrylamide

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Abstract

Cotton fabric is pretreated with polyacrylamide and dyed with 0.5%, 1%, 2% and 3% basic dye in the Wet Processing Laboratory of Southeast University, Dhaka, Bangladesh on 3 December 2015. Tannic acid mordanted cotton fabrics are also dyed with 0.5%, 1%, 2% and 3% basic dye in conventional process in the same laboratory on 10 December 2015. Spectrophotometric evaluation of samples was made in Clarichem Ltd, Dhaka, Bangladesh on 21 January 2016. Comparison among these samples showed that polyacrylamide pretreated dyed samples appeared lighter for 0.5 and 1 shade% but at higher shade% of 2 and 3, the polyacrylamide pretreated dyed samples appeared deeper in color. The wash and rubbing fastness tests (which were also made in Wet Processing Laboratory of Southeast University on 17 December 2015) showed that the results are almost same and quite comparable to each other.

Key words: *Basic Dye, Cotton Fabric, Tannic Acid, Cationic Polyacrylamide*

I. Introduction

Cotton is a natural cellulosic fiber. The polymer chain of cotton consists of several hundred to many thousands of β (1-4) D-glucose units (R. L. Crawford, 1981) linked to each other. It builds up negative charges on its surface when immersed in water resulting an inverse effect on exhaustion of anionic dyes (S. A. Rahman *et al.* 2015).

Cotton is generally dyed with direct and reactive dyes, both of which have anionic characters. Since the fibre assumes a negative charge on its surface in aqueous solution a large amount of salt is usually required to reduce electrostatic repulsion and enhance dye exhaustion. These salts are neither exhausted nor destroyed but remain in the discharged dye liquor which create enormous environmental problem (C. Pisuntornsug *et al.* 2002).

Basic dyes are extensively used for dyeing of jute, acrylic, wool fiber etc. It shows excellent property in case of wash and rubbing fastness. Basic dyes are known to have no affinity towards cotton fabrics. This drawback is overcome by the introduction of acidic groups into the polymer molecules via radiation grafting of cotton fabrics in acrylic acid solution (E. H. K. El-gendy 2001).

However, in conventional method, cotton fibers are treated with tannic acid anions which attract basic dye cations. The cotton is said to have been mordanted. The mordanted cotton with basic dyes results in the formation of water insoluble ionic complexes on the fiber by interaction of the tannic acid anions and the basic dye cations. The conventional method of cotton dyeing with basic dye is time consuming. Even the chemicals are harmful and hazardous to human health and environment.

Pretreatment of cotton with polyacrylamide enhances the possibility of dyeing cotton at unbiased pH with different sensitive dyes. The color capability might have been postulated because of the amide groups ($-CONH_2$) in polyacrylamide that probably enhances the reactivity of cellulose substrate. (Q. Zaman *et al.* 2015, D. Retama *et al.* 2005, S. M. Burkinshaw *et al.* 1995).

In this paper we have investigated the dyeing possibility of cationic polyacrylamide pretreated cotton fabric samples with Basic dye for different dye shade%. The results are also compared with the conventional mordant method of cotton dyeing with basic dye.

II. Materials and Methods

A. Pretreatment of cotton

Single jersey 100% cotton fabric was used for scouring and bleaching with the following recipe:

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Table 1: Pretreatment recipe.

Name of Chemicals	Amount
Sodium Hydroxide	5gm/l
Hydrogen peroxide	8gm/l
Stabilizer	1gm/l
Detergent	1gm/l
Sequestering Agent	1gm/l
Time	50 min
Temperature	100°C
M:L	1:30

The samples were then thoroughly washed and dried.

B. Dyeing of cotton fabric with Basic Dye in Conventional mordant method:

To dye cotton, it requires mordanting before dyeing. Mordants are those types of chemicals which have affinity for both fiber and dyestuff. Tannic acid was used as mordant. 4% Tannic acid solution was boiled. The cotton fabric samples were then immersed in this solution. After then the temperature was lowered to 60°C within 2 hours.

Table 2: Recipe for dyeing in mordant method.

Recipe for mordanting	
Tannic acid	4 %
M:L	1:40
Temperature	100°C 60°C
Time	2 hours
Recipe for Fixing	
Tartar emetic acid	2 %
M:L	1:20
Temperature	Room Temperature
Time	30 minuets
Recipe for dyeing	
Basic dye (Red)	0.5%, 1%, 2%, 3%
Acetic acid	1 g/L
M:L	1:40
Wetting Agent	1gm/l
Sequestering Agent	1gm/l
Leveling Agent	1gm/l
pH	4
Temperature	70°C
Time	90 minutes

Then the samples were withdrawn from the bath and squeezed. After 2 minutes the mordanted samples were dipped into 2% tartar emetic solution where they were soaked for 30 minutes at room temperature. As a result the tannic acid was fixed on the cotton fiber. Four samples of mordanted cotton fabrics were dyed with basic dye of shade% 0.5, 1, 2, 3. The dyeing recipe is shown in table 2. The dyeing process was as follows: Required amount of water was taken in the dyeing pots. Then required amount of sequestering agent and leveling agent were taken and stirred. 5 g mordanted cotton fabric samples were taken in each pot. 1% stock solution of basic dye was made with acetic acid and hot water in a conical flask. Required amounts of stock solution for each shade% were taken in the pots. The samples were agitated at 70°C for 90 minutes. The dyed samples were then rinsed, squeezed and dried.

C. Dyeing of cationic polyacrylamide pretreated cotton fabric with Basic dye:

Necessary amount of scoured and bleached 100% cotton single jersey fabric samples were pretreated with 0.5% polyacrylamide solution for 1 hour. The samples were then squeezed and dried. The fabric samples were then cured at 120°C for 7 minutes in laboratory drier. Four samples of polyacrylamide pretreated fabrics were dyed with basic dye (Red) of shade 0.5%, 1.0%, 2.0%, 3.0%. The dyeing recipe is shown in table 3.

Table 3: Recipe for dyeing in polyacrylamide pretreated cotton fabric.

Recipe for pretreatment	
Cationic polyacrylamide	0.5%
M:L	1:20
Temperature	Room Temperature
Time	1 hour
Recipe for dyeing	
Basic dye (Red)	0.5, 1, 2, 3%
Acetic acid	1g/L
M:L	1:40
Wetting Agent	1gm/l
Sequestering Agent	1gm/l
Leveling Agent	1gm/l
pH	4
Temperature	70°C
Time	90 minutes

The dyeing process was as follows: Required amount of water was taken into a dyeing pot. Then required amount of wetting agent, sequestering agent and leveling agent were taken and stirred. Required amount of fabric was taken into each pot. 5 g polyacrylamide pretreated cotton fabric samples were taken in each pot. 1% stock solution of basic dye was made with acetic acid and hot water in a conical flask. Required amounts of stock solution for each shade% were taken in the pots. The samples were agitated at 70°C for 90 minutes. The dyed fabrics were then thoroughly washed, squeezed and dried. It should be mentioned here that the fabric quality remains the same even after polymer treatment.

D. Comparison on shade variation

The shade differences of the samples were evaluated by Verivide light box.

E. Color fastness to wash

Color fastness to wash was measured by the ISO 105 C03 method. The sample size was 10 cm × 4 cm and washes with 4 g/L ECE (European Color fastness Establishment) reference detergent & 1 g/L sodium perborate solution at 40° C. The samples dyed with 3.0% shade were evaluated for wash fastness test.

F. Colour fastness to Rubbing

This test was performed to determine the degree of color transferred from the surface of the colored fabric to the specific test cloth for rubbing (dry and wet). Machine Name: Crock master, ISO 105× 12:1993 method was followed to measure the rubbing fastness. The sample size was 14cm×5cm. The samples dyed with 3.0% shade were evaluated for rubbing fastness test.

G. Spectrophotometric evaluation:

The spectro photometric evaluation of the samples was done by Data color 650^{TM}.

III. Result and Discussions

A. Spectrophotometric evaluation:

Table 4 shows the spectrophotometric results of 0.5%, 1%, 2%, 3% shade of fabric samples. For all shade%, the conventionally dyed samples were taken as standard. The DL* values calculated from CIE 1976 L*a*b* (CIELAB) coordinates (CIE for Commission International de l'Eclairage or International Commission on Illumination, L* the lightness coordinate, a* the red/green coordinate, b* the yellow/blue coordinate) indicate that for 0.5 and 1 shade% the cationic polyacrylamide pretreated dyed fabric samples are lighter than their respective standard and for 2 and 3 shade% the cationic polyacrylamide pretreated dyed fabric samples are deeper than their respective standard. The DL* value (lightness difference) are decreasing (from 4.59 to -6.39 at D65 illuminant) with the increase of color shade% as shown in Figure 3. The CMC (Color Measurement Committee of the Society of Dyers and Colorists, Great Britain) overall color difference, CMC DE values indicate that the color difference have decreased with the increase of shade% (also shown in Figure 3).

Table 4: Spectrophotometric results of cationic polyacrylamidepretreated and dyed samples of different shade%.

Shade%	Illuminant	Lightness difference, DL*	Red/green difference, Da*	Yellow/blue difference, Db*	CMC overall color difference, DE
0.5	D65	4.59	4.47	-5.83	7.20
1	D65	1.52	7.64	-2.08	5.4
2	D65	-4.56	0.83	5.18	4.42
3	D65	-6.39	-0.73	2.25	3.05
0.5	F11	4.6	4.2	-6.6	7.89
1	F11	1.81	7.6	-2.00	5.37
2	F11	-4.44	1.12	5.76	4.80
3	F11	-6.32	-0.62	2.67	3.21

As the cationic polyacrylamide molecules are much larger in size which cannot reach close to all hydroxyl groups in amorphous region of cotton (like the tannic acid used in conventional dyeing), the attached dye molecules with cellulose are lower in number, thus the cationic polyacrylamide pretreated dyed samples appeared lighter for 0.5 and 1 shade%. With the increase of dye shade%, the depth of the shade of both conventionally and cationic polyacrylamide pretreated dyed samples increased but the rate of increase of color depth of cationic polyacrylamide pretreated dyed samples are faster than the conventionally dyed samples because at lower dye shade%, number of attached dye molecules with cellulose are lower but with increasing dye shade%, more and more dye molecules have attached with cellulose molecules and color depth became high.

Reaction involved in Polyacrylamide treatment method

The amine ($-NH_2$) group of polyacrylamide may be formed protonated amino group whencome contact with the hydroxyl group of cellulose in aqueous medium as shown in Figure 4, thus attract the chlorine anionclose to it and at the same time dye cation come close to cellulose anion and anchor the dye molecule with cellulosic fabric at higher temperature (up to 70° C) (as shown in Figure 5).

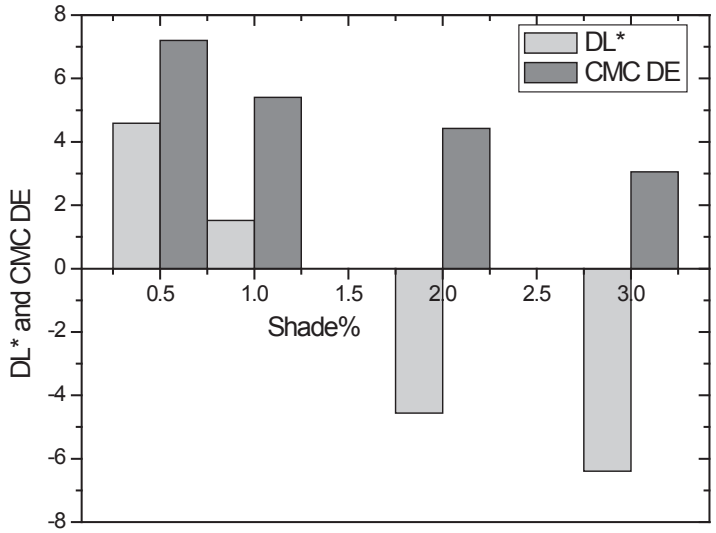

Figure 3: Decrease of DL* and CMC DE with the increase of shade%.

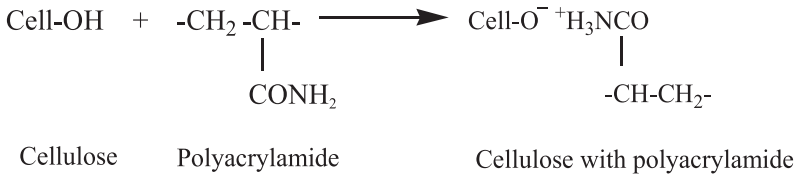

Figure 4: Cellulose treated with polyacrylamide.

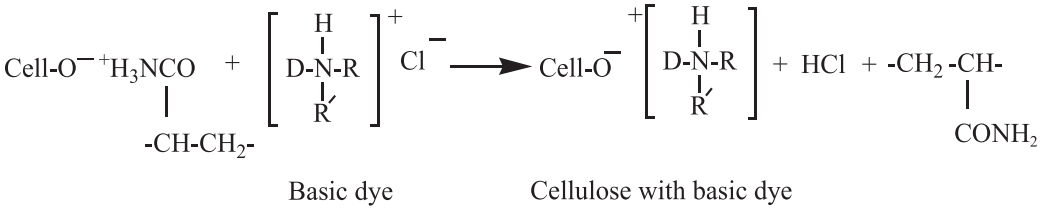

Figure 5: Reaction possibilities between polyacrylamide modified cellulose and basic dye.

Figure 6 shows the reaction of mordanting cellulose with tannic acid and

Figure 7 shows how the mordanted cotton makes bridges with basic dye.

B. Reaction involved in conventional dyeing:

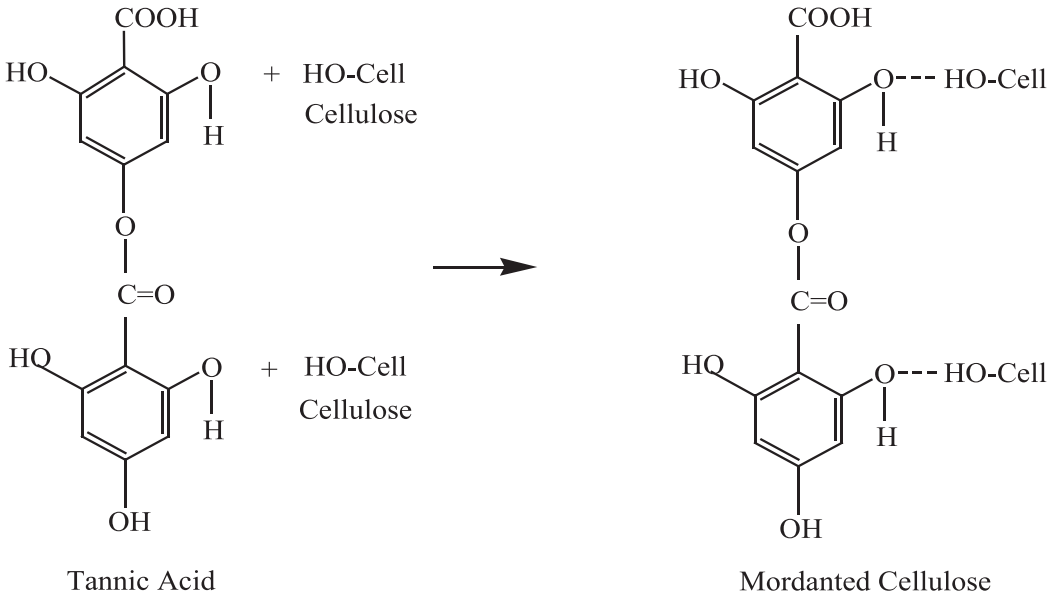

Figure 6 : Mordanting of cellulose with Tannic acid

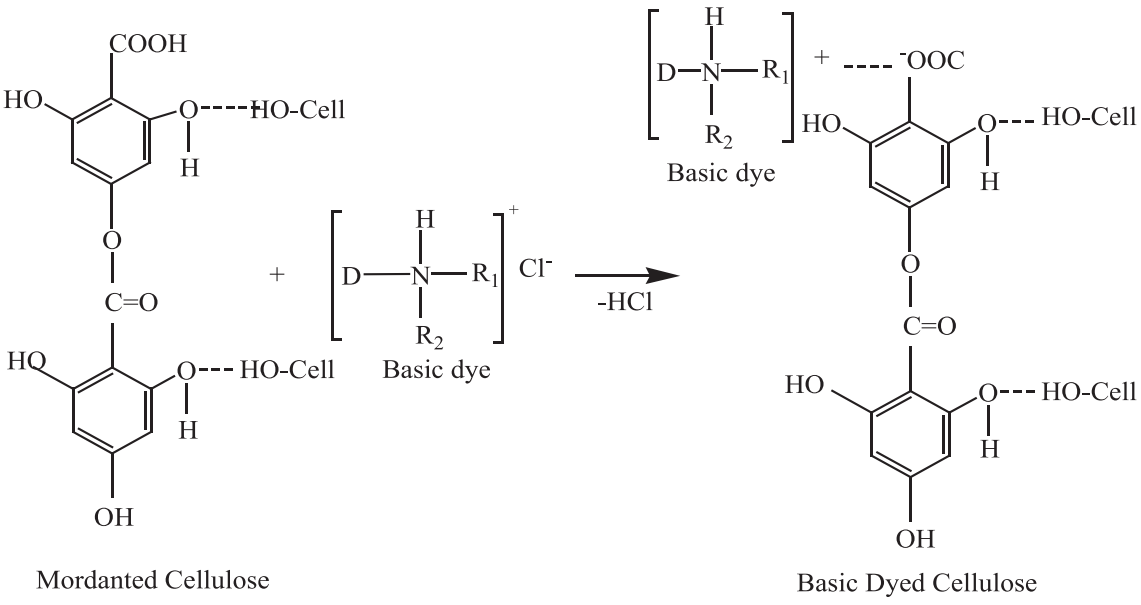

Figure 7 : Dyeing of mordanted cellulose with Basic dye

C. Color fastness to wash:

Table 5 shows the comparison of color fastness to wash between conventional and cationic polyacrylamide pretreated method. ISO 105 C01:1989 method was followed to evaluate the wash fastness. The grey scale rating for both samples in color change was found 2/3 and the staining result on bleached cotton was found 3/4 and 4/5. The staining of other fibers in multifiber fabric showed good results.

Table 5: Color Fastness to Wash.

Change in color and staining	Conventional method	Cationic Polyacrylamide pretreated method
Change in Color	2/3	2/3
Di- Acetate	4/5	4
Bleached cotton	3/4	4/5
Polyamide	4	4
Polyester	4/5	4/5
Acrylic	4	4
Wool	4	4

D. Color fastness to Rubbing

Table 5 shows the comparison of colorfastness to rubbing between conventional and cationic polyacrylamide pretreated method. Here dry and wet rubbing fastness is compared. The grey scale rating of rubbing fastness showed 4/5 to 4 which indicate that the measured fastness is quite good and comparable to each other.

Table 6: Color fastness to Rubbing

Conventional method		Cationic Polyacrylamide treated method	
Dry	Wet	Dry	Wet
4/5	4/5	4/5	4

IV. Conclusions

Cationic Polyacrylamide pretreated cotton fabric can be effectively dyed with basic dye. Comparison with tannic acid mordanted dyed cotton fabric samples showed that polyacrylamide pretreated dyed samples appeared lighter for 0.5 and 1 shade% but became deeper at shade% 2 and 3. The wash and rubbing fastness test showed that the results are almost same and quite comparable to each other.

Acknowledgements

The authors thank to Mr. Md. Mehedi Hasan and Mr. Md. Salauddin Khan for their help in experiments.

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