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Dyeing of Silk Fabric with Basic Dye using Polyacrylamide as Exhausting Agent

Syed Atiqur Rahman*

Department of Textile Engineering

Southeast University, Dhaka, Bangladesh.

Abstract

Silk fabrics were successfully dyed with 0.5%, 1%, 2%, 3% and 4% basic dye using polyacrylamide as exhausting agent in the Wet Processing Laboratory of Southeast University (SEU), Dhaka, Bangladesh on 15 April, 2019. For comparison, silk fabrics were also dyed with same dye for same shade% in conventional salt addition method in the same laboratory on same day. Spectrophotometric evaluation of samples was made in the Color Matching Laboratory of Southeast University on 25 April, 2019. Comparisons showed that fabric samples dyed with polyacrylamide exhaustion method are slightly lighter. The wash fastness was measured in the Wet Processing Laboratory of SEU on 29 April 2019 and the rubbing fastness was measured in the Testing and Quality Control Laboratory of SEU on same day. The wash fastness for both type of samples are found poor but the rubbing fastness are found quite good. However the wash fastness and rubbing fastness for both types of samples are found quite comparable to each other.

Key words: *Basic Dye, Silk Fabric, Polyacrylamide, Glauber's Salt, Spectrophotometry, Color Fastness*

I. Introduction

Silk is one of the most popular protein fiber extruded from silkworm. Because of its unique properties like wearing comfort, soft handle, good air permeability & elegant appearance, this fibre becomes as one of the symbol of royalty (R. Rehman *et al.* 2015). The mature silkworms build its cocoon by extruding viscous fluid from two large glands in the body and force this fluid through openings in the head called spinneret. The viscous part (fibroin) is covered by another secretion (sericin) which flows from two other symmetrically placed glands. These two components are cemented together by emerging into the air, coagulating and producing firm continuous filament. As a consequence of this spinning process, the fibre has two main part sericin and fibroin. Sericin is called silk gum a minor component of the fibre (i. e. about 25% of the raw silk) and it also has some impurities such as waxes, fats and pigments. Sericin is yellow, brittle and inelastic substance. It encased two fibroin filaments and conceals the unique lustre of the fibroin. Sericin is dissolved by hot soap solution. The greatest sericin content is present in outer layer of cocoon whereas the least sericin is present in the innermost layer of the cocoon (M. K. Uddin *et al.* 2010). Fibroin is the principal water insoluble protein (i.e. about 75% of the weight of raw silk). Silk is estimated to be about 65-70% crystalline and correspondingly, about 35-30% amorphous (E. P. G. Gohl *et al.* 1983).

There are wide ranges of dyestuff accessible for silk dyeing. Nearly every type of dyestuff used for cotton and/or wool can be used for dyeing silk. Silk can also be dyed with basic dye using salt as an exhausting agent (M. Al-Amin *et al.* 2018). The conventional method of dyeing cotton with basic dye is the mordanting method. Cotton is mordanted with tannic acid before dyeing with basic dye. In a previous article, we showed that cotton can also be dyed with basic dye using polyacrylamide as exhausting agent (without using mordant) (S. A. Rahman *et al.* 2016). Whether silk can also be dyed with basic dye using polyacrylamide as exhausting agent, we performed a series of experiments to see dyeing possibility of silk with basic dye using polyacrylamide for different shade%. The results are also compared with conventional silk dyeing process with basic dye using Glauber's salt as exhausting agent.

* **Corresponding Author:** Dr. Syed Atiqur Rahman, Associate Professor, Department of Textile Engineering, Southeast University, Tejgaon, Dhaka, Bangladesh. E-mail: *syedatiq68@yahoo.com*

II. Materials & Methods

Degumming of required amount of Mulberry silk fabrics is done with following recipe:

Table 1: The recipe of silk fabric degumming

Chemicals	Amount
Soda ash	2 g/L
Detergent	2 g/L
Temperature	85 ^oC
pH	10.5
Time	40 min.
M:L	1:30

The fabric samples are then thoroughly washed and dried. Five samples of silk fabric were dyed with 0.5%, 1%, 2%, 3% and 4% basic dye (Basic Orange 22). 0.1% polyacrylamide was used as exhausting agent. From now this dyeing process will be illustrated as polyacrylamide exhaustion method. The dyeing recipe is shown in table 2.

Table 2: The recipe of dyeing of silk fabric with polyacrylamide method

Shade%	0.5	1.0	2.0	3.0	4.0
Polyacrylamide (%)	0.1	0.1	0.1	0.1	0.1
Sequestering Agent (g/L)	1	1	1	1	1
Leveling Agent (g/L)	1	1	1	1	1
Wetting Agent (g/L)	1	1	1	1	1
M:L	1:30	1:30	1:30	1:30	1:30
Temperature (^oC)	80	80	80	80	80
Time (min.)	30	30	30	30	30

The dyeing process was as follows: Required amount of water was taken in the dye pots of Laboratory dyeing machine (ECO DYER Rapid, China). 1% stock solution of polyacrylamide in water was made in a conical flask. Required amount of polyacrylamide solution was taken in the dye pots. 1 g silk fabric samples were taken in each dye pots and soaked the samples for 30 minutes. Then required amount of sequestering agent, leveling agent and wetting agent were taken and stirred. 1% stock solution of basic dye was made in a conical flask. Required amounts of stock solution for each shade% were taken in the dye pots. The samples were agitated at room temperature. Then the temperature was raised to 80^{o}C and dyed for 30 minutes. After dyeing, the samples were thoroughly washed and dried.

To compare the shade variation of fabric samples dyed with polyacrylamide exhaustion method with conventionally dyed fabric samples using Glauber's salts (from now illustrated as conventional salt addition method), five samples were again dyed with same basic dye of shade% 0.5, 1, 2, 3 and 4. The dyeing recipe is shown in Table 3.

Table 3: The recipe of dyeing silk fabrics in conventional method using salt.

Shade%	0.5	1.0	2.0	3.0	4.0
Salt (g/L)	6	8	10	12	14
Sequestering Agent (g/L)	1	1	1	1	1
Leveling Agent (g/L)	1	1	1	1	1
Wetting Agent (g/L)	1	1	1	1	1
M:L	1: 30	1: 30	1: 30	1: 30	1: 30
Temperature (^oC)	80	80	80	80	80
Time (min.)	30	30	30	30	30

X-Rite Spectrophotometer (USA) was used to compare the color difference between the fabric samples dyed with polyacrylamide exhaustion method and conventional salt addition method.

III. Results and Discussions

Table 4 shows the spectrophotometric results of 0.5%, 1%, 2%, 3% and 4% shade of fabric samples. For all shade%, the fabric samples dyed with conventional salt addition method are taken as standard.

Table 4: Spectrophotometric results of different shade%.

ade%	Illuminant	Lightness difference, DL*	Red/green difference, Da*	Yellow/blue difference, Db*	Chroma difference, DC*	Hue difference, DH*	CMC overall color difference, DE
0.5	D65	1.07	-2.43	-3.57	-4.31	-0.20	1.70
1.0	D65	0.72	-0.49	-1.91	-1.84	-0.72	0.98
2.0	D65	1.67	-1.99	-4.16	-4.55	-0.76	1.72
3.0	D65	2.10	-3.51	-4.14	-5.41	0.51	1.93
4.0	D65	0.22	-2.70	-1.53	-2.80	1.34	1.43
0.5	F02	0.75	-1.68	-4.04	-4.37	0.16	1.67
1.0	F02	0.61	-0.34	-2.13	-2.11	-0.43	0.82
2.0	F02	1.57	-1.64	-4.40	-4.69	-0.10	1.60
3.0	F02	2.16	-3.18	-4.36	-5.23	-1.30	2.02
4.0	F02	0.33	-2.35	-1.60	-2.38	1.55	1.30

The positive DL* values calculated from CIE 1976 L*a*b* (CIELAB) coordinates (CIE for Commission International de I'Eclairage or International Commission on Illumination, L* the lightness coordinate, a* the red/green coordinate, b* the yellow/blue coordinate) indicate that all fabric samples dyed with polyacrylamide exhaustion method are slightly lighter than their respective standard. The CMC (Color Measurement Committee of The Society of Dyers and Colorists, Great Britain) overall color difference, CMC DE values between salt exhaustion method and polyacrylamide exhaustion method indicate that the color of fabric samples dyed with both exhaustion methods are close to each other. (shown in Figure 1).

The amine ($-NH_2$) group of poly acrylamide may be formed protonated amino group when come contact with the carboxylic acid group of silk in aqueous medium as shown in Figure 2, thus attract the chlorine anion close to it and at the same time dye cation come close to carboxylate group of silk and anchor the dye molecule with silk fabric at higher temperature (up to 80 ^oC) (as shown in Figure 3).

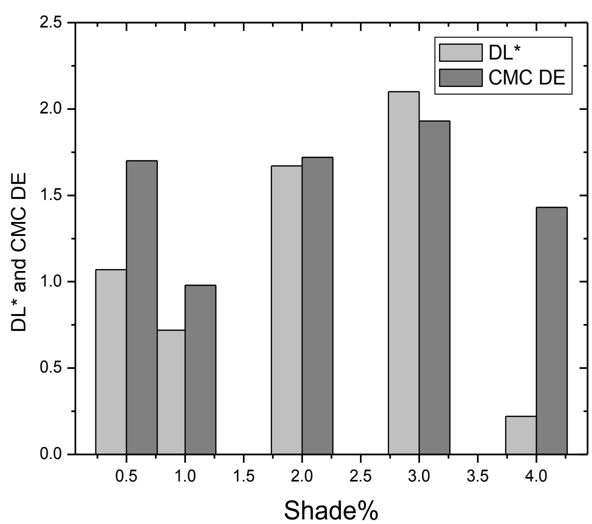

Figure 1: Variation of DL* and CMC DE values with the increase of shade%.

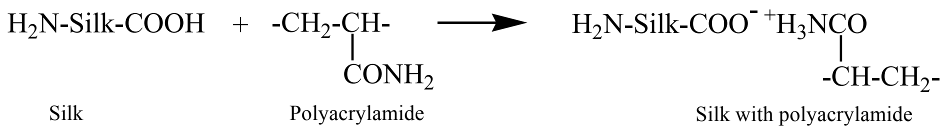

Figure 2: Reaction between silk and polyacrylamide.

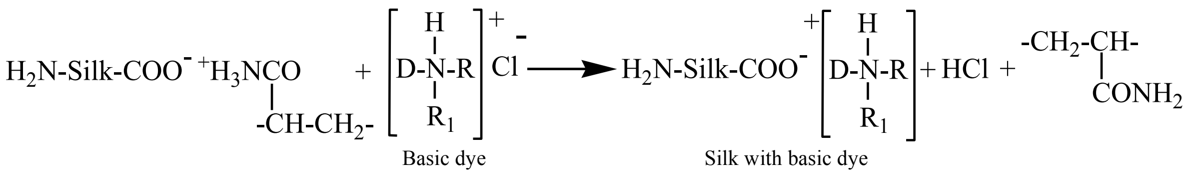

Figure 3: Reaction possibilities between polyacrylamide added silk and basic dye.

Color Fastness to Wash

Table 5 shows the comparison of color fastness to wash between the samples dyed with polyacrylamide exhaustion method and conventional salt addition method. ISO 105 C60:1994 method is followed to evaluate the wash fastness. This test (C2S) is designed to determine the color which may be transferred from the surface of a colored textile material to multifiber test cloth for washing at 60^o C for 30 minutes. The sample dyed with 3% shade has been evaluated for wash fastness test. The sample size is 10cm x 4cm and washed with 4 g/L ECE (European color fastness establishment) reference detergent and 1 g/L sodium per borate solution. The grey scale shows the same result with rating 1 for both types of samples after wash.

Table 5: Color fastness to wash.

	For sample dyed with conventional salt addition method	For sample dyed with polyacrylamide exhaustion method
Change in Color	1	1
Di-Acetate (Stain)	2	2
Cotton (Stain)	5	4
Polyamide (Stain)	5	5
Polyester (Stain)	3	3
Acrylic (Stain)	3/4	3/4
Wool (Stain)	3/4	3/4

The multifiber fabric consists of different types of fibers such as di-acetate, cotton, polyamide, polyester, acrylic and wool. The staining of colors on the fibers from the dyed samples has also been evaluated. The results of grey scale rating is almost same for both type of samples such as the staining for di-acetate is 2, cotton 5, polyamide 5, polyester 3, acrylic 3/4 and wool 3/4.

Color Fastness to Rubbing

Table 6 shows the comparison of color fastness to rubbing between the fabric samples dyed with polyacrylamide exhaustion method and conventional salt addition method. This test is designed to determine the transfer of color from the dyed samples to the crock meter test cloth for rubbing. Here dry and wet rubbing fastness has been compared. ISO 105x12:1993 method has been followed to measure the rubbing fastness. The sample dyed with 3% shade has been evaluated for rubbing fastness test. The sample size is 14cm x 5cm. The dry rubbing fastness is very good with the grey scale rating 5 for the sample of conventional salt addition method and 4/5 for the sample of polyacrylamide exhaustion method. The wet rubbing fastness is found comparatively poorer with grey scale rating 4 for both types of samples.

Table 6: Color fastness to rubbing

For samples dyed with conventional salt addition method		For samples dyed with polyacrylamide exhaustion method	
Dry Rubbing Fastness	Wet Rubbing Fastness	Dry Rubbing Fastness	Wet Rubbing Fastness
5	4	4/5	4

IV. Conclusions

Silk fabric samples were successfully dyed with basic dye using polyacrylamide as exhausting agent. Comparison among fabric samples dyed with polyacrylamide exhaustion method and conventional salt addition method showed that fabric samples dyed with polyacrylamide exhaustion method are slightly lighter in color. The wash fastness for both type of samples are poor but the rubbing fastness are found quite good. However the wash fastness and rubbing fastness for both types of samples are found almost same and quite comparable to each other.

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