

Original Article

Reactive Dyeing of Viscose Fabric using Polyacrylamide for Absorption

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Abstract - This article describes a method for dyeing the viscose fabric with a reactive dye using polyacrylamide as an absorbent for 0.5, 1, 2, 3, and 4% shades. Similar viscose fabrics were dyed with the identical reactive dye to the like shades (%), deploying Glauber's salt as absorbent. The difference between the samples of like shades (%) unveiled that the samples colored with polyacrylamide are comparatively lighter. The tests of wash fastness of both types of samples furnish similar results with good fastness, and the tests of rubbing fastness of both types of samples purvey similar results with medium to good fastnesses.

Keywords - Viscose fabric, Reactive color, Polyacrylamide, Spectrophotometry, Wash fastness.

1. Introduction

Viscose is a regenerated cellulosic fiber manufactured from wood pulp. Due to its durability and soft touch feeling, it is used to make several kinds of clothing items, including dresses, blouses, skirts, and trousers. [1] The polymer system of viscose is rather similar to that of cotton, for which, similar to cotton fiber, viscose fiber is also mostly dyed with reactive dyes. However, like cotton fiber, cellulose of viscose fibers gains negative charges when immersed in water. The reactive dyes also form anions in the dye liquor. The negatively charged hydroxyl groups of cellulose repeal the similar negatively charged anions of reactive dye. Large amounts of electrolytes are usually used to overcome this repulsion and accelerate dye absorption. [2] These electrolytes are not absorbed in the fibers or destroyed by chemical reactions but remain in the discharged dye solution, increasing soil and water salinity and causing serious environmental problems. [3] For example, salinity influences the yielding of crops, grasses, and trees by minimizing growth and preventing their reproduction. Again, various salt ions are poisonous to plants, and with increasing ion concentration, the plant is seriously poisoned and dies. [4]

Several researchers in various places have worked to diminish or remove the usage of salt amounts in the reactive dye solution. [5-9] Adding cationic sites within the cellulose is the utmost inferred process to enhance the absorption. [10-15] Dyeing of cotton, jute, and silk fibers using polyacrylamide as the absorbent was reported in several published articles before. [16] It was reported that polyacrylamide has very little harmful effect on the environment [17] for which it has a wide range of applications

such as water treatment, oil mining, textile sizing and finishing processes, paper making, mineral processing, clay stabilizing, medicine, agriculture, and other industries. [18] Rahman et al. observed lower reactive dye absorption by cotton fabric when absorption was carried out by cationic polyacrylamide as compared to the NaCl absorption method. They concluded that larger-size polyacrylamide could not get near every hydroxyl group of cellulose in the amorphous region for which the number of bond formations with dye is comparatively low. Similarly, Rahman et al. used polyacrylamide during jute fabric dyeing by basic dye. As basic dye has a direct affinity for jute fabric, they found lower dye absorption in the case of the polyacrylamide exhaustion method. They concluded that polyacrylamide retarded basic dye to interact directly with jute cellulose. The dyeing of cotton cloth with basic dye by conventional tannic acid mordanted process and cationic polyacrylamide exhaustion process were compared in another article for 0.5, 1, 2, and 3% shades. In this article, it was stated that polyacrylamide-treated samples looked lighter for 0.5 and 1% shades. But, for 2 and 3% shades, polyacrylamide-treated samples looked deeper. It was concluded that due to the larger size of polyacrylamide, the depth of shades for 0.5 and 1% shades appeared lighter than the tannic acid-mordanted cotton. However, the reasons for deeper shades for the 2 and 3% samples were not explained clearly. The dyeing of silk fabric with reactive dye by the common salt exhaustion method and polyacrylamide exhaustion method was compared in another article. Samples dyed with the polyacrylamide exhaustion method appeared lighter than the samples of the common salt exhaustion method. The author concluded that the larger-size polyacrylamide could not form covalent bonds with all the carboxylic acid groups of silk in the amorphous region for



which the samples appeared lighter. The dyeing of silk fabric with basic dye by Glauber’s salt absorption method and polyacrylamide absorption method was also compared in a published article. The spectrophotometric evaluation of silk samples also revealed that the fabric samples colored with the polyacrylamide absorption process are slightly lighter. However, the author did not explain the reason for the lightness of polyacrylamide exhausted samples.

Coloring of viscose fiber with reactive dye deploying polyacrylamide has not yet been reported in any article. Thus, it is required to examine the coloring feasibility of the viscose fiber with reactive dye deploying polyacrylamide as an absorbent. Also, it is required to know the depth of shades and different fastness properties of dyed viscose fabric in this method. Therefore, we conducted several tests to investigate the dyeing feasibility of viscose fiber with a reactive dye deploying polyacrylamide as an absorbent of various shades. To compare these obtained test results, we dyed viscose fabric samples with the same reactive dye to the same shade percentage, deploying Glauber’s salt as an absorbent.

2. Materials and Methods

100% Viscose gray fabric was collected from the local industry for experimental purposes. A sufficient amount of viscose fabric was scoured for dyeing. The chemicals for scouring were taken as follows: wetting agent 1 g/L, detergent

2 g/L, sequestrants 2 g/L, NaOH 0.8 g/L, soda ash 2 g/L. The scouring was carried out for 45 minutes at a temperature of 80 °C. Liquor was taken 20 times of fabric weight. pH was kept at 10.5. After scouring, the fabric was thoroughly washed with hot and cold water and then neutralized.

Reactive dye Dyecol Red SS (Purple color) was used for dyeing. Dyecol Red SS dyed ten viscose samples for different shades (%) (0.5, 1, 2, 3, and 4%). Five samples of 0.5, 1, 2, 3, and 4 shades (%) were dyed deploying Glauber’s salt as absorbent (one set), and five samples of the same shades (%) (another set) were dyed using polyacrylamide as absorbent. The amount of Glauber’s salt was taken as follows: 30, 40, 50, 60, and 70 g/L were used for 0.5, 1, 2, 3, and 4 shades (%) respectively. On the other hand, 0.3% (of fabric weight) polyacrylamide was used for dyeing all five shades (%). 7.5, 10, 12.5, 15, and 17.5 g/L soda ash were used for fixation of dye of 0.5, 1, 2, 3, and 4 shades (%) respectively. Sequestrants, leveling agents, and wetting agents were used (1 g/L each) during dyeing. The material and liquor ratio was kept at 1:10. Absorption was carried out at 30 °C for 30 minutes for all samples, and fixation was carried out at 70 °C for 60 minutes for all samples.

A sample dyeing machine (ECO DYER Rapid, China) was deployed for dyeing. X-Rite Spectrophotometer (USA) was deployed to measure the color depth of each sample.

Table 1. Spectrophotometric results of several shades (%)

Shade %	Illuminant	DL*	Da*	Db*	DC*	DH*	CMC DE
0.5	D65	12.03	-10.03	-5.58	-7.32	-8.83	7.52
1.0	D65	8.12	-6.8	-4.65	-5.45	-6.04	5.24
2.0	D65	8.92	-5.42	-5.03	-4.78	-5.64	5.47
3.0	D65	7.58	-2.68	-4.56	-2.34	-4.72	4.06
4.0	D65	8.81	-2.44	-6.58	-2.28	-6.64	5.89
0.5	F02	12.15	-7.3	-5.92	-3.39	-8.76	7.51
1.0	F02	8.46	-4.56	-4.43	-2.76	-5.73	5.14
2.0	F02	9.41	-3.64	-4.34	-2.61	-5.03	5.48
3.0	F02	8.18	-1.51	-3.64	-0.91	-4.03	4.76
4.0	F02	9.45	-1.23	-5.54	0.62	-5.64	6.06

3. Results and Discussion

Table 1 exhibits the Spectrophotometric outcomes of five shades (%) (0.5, 1, 2, 3, and 4) of viscose samples. Fabric samples dyed with Glauber’s salt absorption process (from now illustrated as the GSA process) are taken as the standard. We can see from the table that all lightness disparity, DL* are positive, which means that all samples colored with the polyacrylamide absorption process (from now illustrated as PA process) are lighter than the standards. The CMC overall

color disparity and CMC DE also implicate that the samples of the PA process are much lighter than the standards (also exhibited in Figure 1).

Variations of color strength K/S values with the variation of shades (%) are exhibited in Figure 2 for both the GSA process and the PA process. The purple color shows a broad pick around 550 nm wavelength. [19] Here, we also found the maximum K/S at 550 nm. For all shades, the higher K/S values are obtained in GSA process samples.

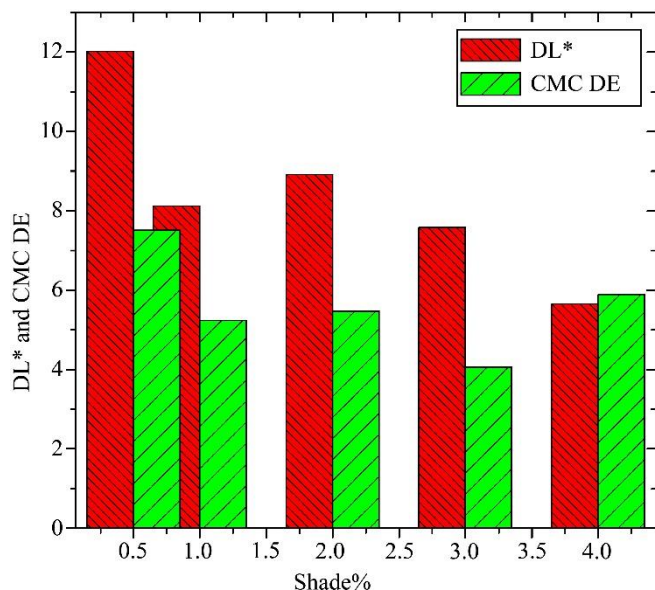


Fig. 1 Variation of DL* and CMC DE with the raise of shades (%)

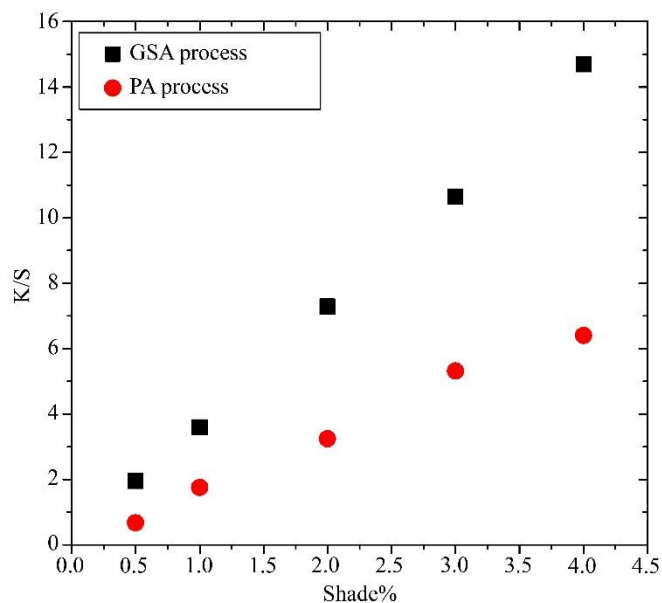


Fig. 2 Variation of K/S with the raise of shades (%)

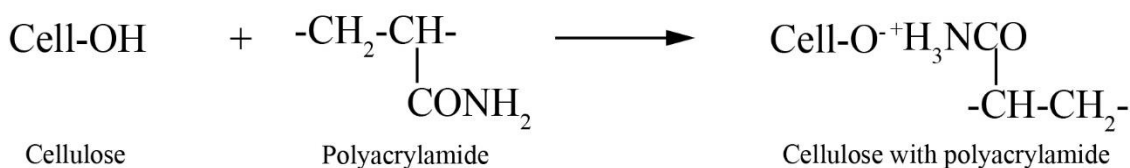


Fig. 3 Reaction between viscose cellulose and polyacrylamide

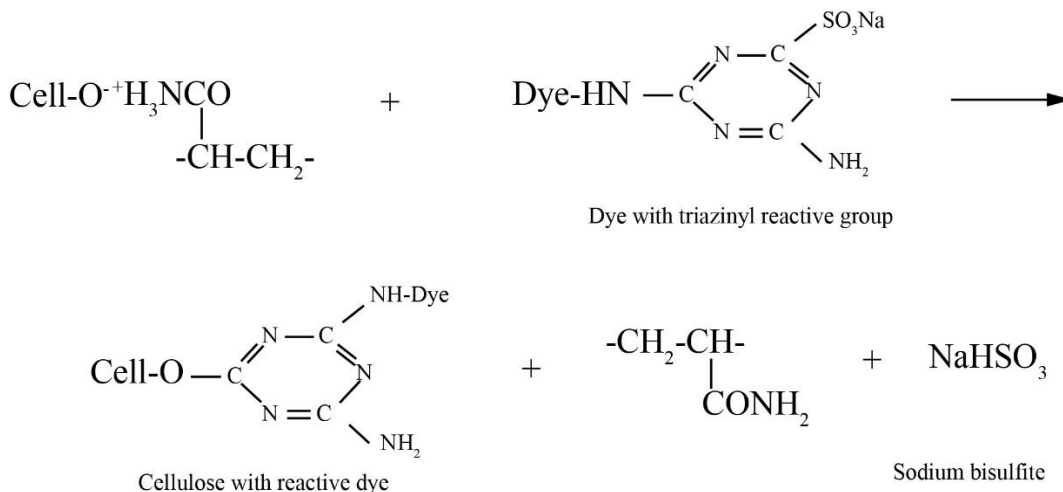


Fig. 4 Reaction possibilities between polyacrylamide modified viscose cellulose and triazinyl reactive dye

The amine group ($-\text{NH}_2$) of polyacrylamides can form a protonated amino group when in touch with the hydroxyl group of viscose cellulose in watery media, as exhibited in Figure 3, which reduces the ‘-’ve charge formed by cellulose in water. These protonated amino groups also drag the ‘-’ve ions of the dye molecules and form a covalent link with cellulose in an alkaline environment at 60°C (exhibited in Figure 4).

Since the size of polyacrylamide molecules is comparatively bigger and cannot get in touch with all the hydroxyl groups in the amorphous part of the viscose fiber (like the Na^+ cation of the Na_2SO_4 molecules when the absorption is done with Glauber’s salts), there are fewer dye molecules bound to the cellulose. Hence, the samples dyed by the PA process appeared lighter. A similar size constraint of polyacrylamide was attributed to lower dye absorption by cotton and silk fibers, as reported by Rahman et al. in their

published articles. As the color shade% increases, the depth of the samples dyed by both the GSA process and the PA process increases, but the growth rate of the color strength of the samples dyed by the PA process is slower than that of the GSA process because, at a lower shade%, the formation of bonds with cellulose is less and many hydroxyl groups did not form bonds with the dye molecules. With increasing dye shades

(%), many dye molecules are gradually associated with cellulose and form bonds with them. In the case of samples dyed with the PA process, the number of bonds formed is always less in number than the corresponding shades (%) of samples dyed with the GSA process, for which K/S increased rapidly in the case of the GSA process with the increment of dye shades (%).

Table 2. Color fastness to wash

	Samples colored with GSA process		Samples colored with PA process	
	3%	4%	3%	4%
Color depth%	3%	4%	3%	4%
Color change	5	5	5	5
Stain: Di-Acetate	4-5	4-5	4-5	4-5
Stain: Cotton	4	4	4	4
Stain: Polyamide	5	5	5	5
Stain: Polyester	5	4-5	5	4-5
Stain: Acrylic	4-5	5	4-5	5
Stain: Wool	4	4	4	4

3.1. Color Fastness to Wash

A comparison of the fastness of washing of the samples colored using the PA process and the GSA process is exhibited in Table 2. Samples of 3 and 4 shades (%) were assessed for this test. The size of the samples was 10 cm x 4 cm, and were cleansed with the standard method.

The grayscale shows the same result, with a score of 5 for both samples after washing. The migration of colors from the dyed samples to the multifiber was also assessed. The grayscale score results are almost identical for both samples; for example, diacetate staining is 4-5, cotton 4, polyamide 5, polyester 4-5, acrylic 4-5, and wool 4.

In Table 3. This experiment was performed to see the dye migration from the colored samples to the crock meter test cloth for abrasion. Dry and wet fastness are measured here. Samples dyed with 3 and 4 shades (%) were assessed in this test. The size of the sample was 14 cm x 5 cm. Dry abrasion fastness is estimated to be very good, with a grayscale rating of 5 for the PA process and 4-5 for the GSA process. Wet abrasion fastness is relatively poor, with a grayscale rating of 3-4 for the PA and 3 for the GSA processes.

4. Conclusion

Viscose fabric samples have been effectively dyed with a reactive dye, deploying polyacrylamide as an absorbing agent. However, viscose fabric dyed by the PA process is comparatively lighter than viscose samples dyed by the GSA process. Since electrolytes, including Glauber’s salt, are very detrimental to the environment, viscose fabric can readily be dyed with the described PA process instead of conventional salt absorbing process.

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Table 3. Color fastness to abrasion

Color depth%	Samples colored with GSA process		Samples colored with PA process	
	Dry	Wet	Dry	Wet
3	4-5	3	5	3-4
4	4-5	3	5	3-4

3.2. Color Fastness to Abrasion

A comparison of the abrasion fastness of the samples dyed using the PA process and the GSA process is exhibited

References

- [1] 7 Things you need to Know about Viscose, ISPO.com, 2023. [Online]. Available: <https://www.ispo.com/en/trends/7-things-you-need-know-about-viscose>
- [2] M.A. Rahman Bhuiyan, Abu Shaid, and M.A. Khan, “Cationization of Cotton Fiber by Chitosan and Its Dyeing with Reactive Dye without Salt,” *Chemical and Materials Engineering*, vol. 2, no. 4, pp. 96-100, 2014. [CrossRef] [Google Scholar] [Publisher Link]
- [3] M.A. Wei, Zhang Shu-fen, and Yang Jin-zong, “Development of Functional Polymers in Modification of Cotton for Improving Dyeability of Reactive Dyes,” *The Proceedings of the 3rd International Conference on Functional Molecules*, pp. 1-7, 2002. [Google Scholar] [Publisher Link]

- [4] Impacts of Salinity, Environment, Land and Water, Queensland Government, 2013. [Online]. Available: <https://www.qld.gov.au/environment/land/management/soil/salinity/impacts>
- [5] S.M. Burkinshaw et al., "The Use of Dendrimers to Modify the Dyeing Behavior of Reactive Dyes on Cotton," *Dyes and Pigments*, vol. 47, no. 3, pp. 259-267, 2000. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [6] Richard S. Blackburn, and Stephen M. Burkinshaw, "Treatment of Cellulose with Cationic, Nucleophilic Polymers to Enable Reactive Dyeing at Neutral pH without Electrolyte Addition," *Journal of Applied Polymer Science*, vol. 89, no. 4, pp. 1026-1031, 2003. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [7] Feng Zhang et al., "Synthesis of an Amino Terminated Hyperbranched Polymer and its Application in Reactive Dyeing on Cotton as a Salt Free Dyeing Auxiliary," *Coloration Technology*, vol. 123, no. 6, pp. 351-357, 2007. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [8] Majid Montazer, R.M.A. Malek, and A. Rahimi, "Salt Free Reactive Dyeing of Cationized Cotton," *Fibers and Polymers*, vol. 8, pp. 608-612, 2007. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [9] Kawee Srikulkit, and Pornchai Santifuengkul, "Salt Free Dyeing of Cotton Cellulose with a Model Cationic Reactive Dye," *Coloration Technology*, vol. 116, no. 12, pp. 398-402, 2000. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [10] G.E. Evans, J. Shore, and C.V. Stead, "Dyeing Behavior of Cotton after Pretreatment with Reactive Quaternary Compounds," *Journal of the Society of Dyers and Colourists*, vol. 100, pp. 304-315, 1984. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [11] Peter J. Hauser, and Adham H. Tappa, "Improving the Environmental and Economic Aspects of Cotton Dyeing using a Cationised Cotton," *Coloration Technology*, vol. 117, pp. 282-288, 2001. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [12] Y.A. Youssef, "Direct Dyeing of Cotton Fabrics Pre-Treated with Cationising Agents," *Coloration Technology*, vol. 116, no. 10, pp. 316-322, 2006. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [13] X.P. Lei, and D.M. Lewis, "Modification of Cotton to Improve its Dyeability, Part3 - Polyamide-Epichlorohydrin Resins and their Ethylenediamine Reaction Products," *Journal of the Society of Dyers and Colourists*, vol. 106, pp. 352-356, 1990. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [14] M.N. Micheal, F.M. Tera, and S.F. Ibrahim, "Effect of Chemical Modification of Cotton Fabrics on Dyeing Properties," *Journal of Applied Polymer Science*, vol. 85, no. 9, pp. 1897-1903, 2002. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [15] T.S. Wu, and K.M. Chen, "New Cationic Agents for Improving the Dyeability of Cellulose Fibres, Part 2-Pretreating Cotton with Polyepichlorohydrin-Amine Polymers for Improving Dyeability with Reactive Dyes," *Journal of the Society of Dyers and Colourists*, vol. 109, no. 4, pp. 153-158, 1993. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [16] R. Nithyanandan, and M.S.S. Kannan, "Salt and Alkali free Reactive Dyeing on Cotton," *Fibre2fashion.com*, 2007. [[Google Scholar](#)] [[Publisher Link](#)]
- [17] C.A. Seybold, "Polyacrylamide Review: Soil Conditioning and Environmental Fate," *Communications in Soil Science and Plant Analysis*, vol. 25, no. 11-12, pp. 2171-2185, 1994. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [18] The Uses of Polyacrylamide, Anhui Jucheng Fine Chemicals Co Ltd, 2023. [Online]. Available: https://www.linkedin.com/pulse/uses-polyacrylamide-anhui-jucheng-fine-chemicals-co-lt?trk=organization_guest_main-feed-card_feed-article-content
- [19] P.B. Tayade, and R.V. Adivarekar, "Extraction of Indigo dye from *Couroupita Guianensis* and its Application on Cotton fabric," *Fashion and Textiles*, vol. 1, no. 16, pp. 1-16, 2014. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]