Austrian Journal of Technical
and Natural Sciences, 2026 No 7–8
ISSN 2310-5607

PREMIER Publishing
ppublishing.org

Section 4. Materials science

DOI:10.29013/AJT-26-7.8-80-85

AMINATION AND DYEING PROPERTIES AND OPERATIONAL PERFORMANCE OF CELLULOSE FIBER FABRICS

***Amonov Mukhtor Rahmatovich* [1], *Jumayeva Matluba Sultonovna* [2]**

[1] Professor, Department of Chemistry and Oil and Gas Technologies, Bukhara State University, Doctor of Technical Sciences (DSc), Professor

Bukhara State University, Republic of Uzbekistan

[2] Independent Researcher, Department of Chemistry and Oil and Gas Technologies

Bukhara State University, Republic of Uzbekistan

Cite: *Amonov Mukhtor R., Jumayeva M.S. (2026). Amination and Dyeing Properties and Operational Performance of Cellulose Fiber Fabrics. Austrian Journal of Technical and Natural Sciences 2026, No 7–8.* https://doi.org/10.29013/AJT-26-7.8-80-85

Abstract

This paper investigates the chemical modification of cellulose fiber fabric through amination using glutaraldehyde and ethylenediamine, together with the subsequent dyeing of the modified fabric with complex (metal-containing) dyes. The main purpose of the study is to increase the fabric's affinity for dye and to improve dyeing efficiency by introducing active functional groups into the cellulose fiber structure. The results obtained make it possible to evaluate the effect of the modification process on the dyeing properties of the fabric.

Keywords: *cellulose, cotton fiber, glutaraldehyde, ethylenediamine, amination, chemical modification, complex dye, dyeing, colorimetric indicators, color intensity, color fastness, operational properties*

Introduction

Cotton fiber is one of the natural fibers most widely used in the textile industry, particularly in garment production. Its widespread use is primarily related to the presence of a large number of hydroxyl (–OH) groups in its structure, which provide the fiber with high hydrophilicity. In addition, the low static-charging tendency of cotton fiber, its good moisture absorption, and its comfort for the human body make it an essential raw material for garment manufacturing (Kim & Choi, 2014; Dehabadi et al., 2013; Hauser & Tabba, 2001; Li et al., 1997).

Modification of cotton cellulose can substantially increase its binding capacity toward anionic dyes. This, in turn, reduces the consumption of electrolytes – particularly salts – during dyeing. As a result, not only does dyeing efficiency improve, but the environmental impact of the technological process is also reduced owing to the lower salt content of the resulting wastewater. In addition, introducing cationic functional groups into cellulose fiber can improve certain functional properties of the material (Park et al., 2014; Trask-Morrell & Choi, 1994).

Chemical modification of cellulose fibers not only improves the physico-mechanical properties of the fabric but also increases its binding capacity toward dyes. From this standpoint, introducing amine functional groups into the cellulose structure is of particular importance (Mitchell & Birnboim, 1977; Naven & Harvey, 1996; Zhao & Heindel, 1991). Ethylenediamine (EDA) is one of the highly reactive amine-functional cationic compounds. Its functional groups react rapidly with aldehydes, which is why the reagent is also used for the qualitative and quantitative determination of aldehyde groups.

Research Method

A range of modern physicochemical research methods was used to evaluate the changes in the structure and functional properties of the modified cellulose fabric. In particular, IR spectroscopy was used to determine the composition of functional groups and the changes occurring in them, while elemental analysis was used to assess the nitrogen content and other elements in the material as a result of modification. In addition, determination of the dye-binding capacity made it possible to directly assess the effect of modification on the dyeing process.

A comprehensive evaluation of the operational properties of the modified fabrics – including thermogravimetric analysis, IR spectral analysis, and optical microscopy – is of considerable importance. These methods were used to comprehensively assess the effect of the modification and dyeing processes on the morphological structure and functional activity of the fabric.

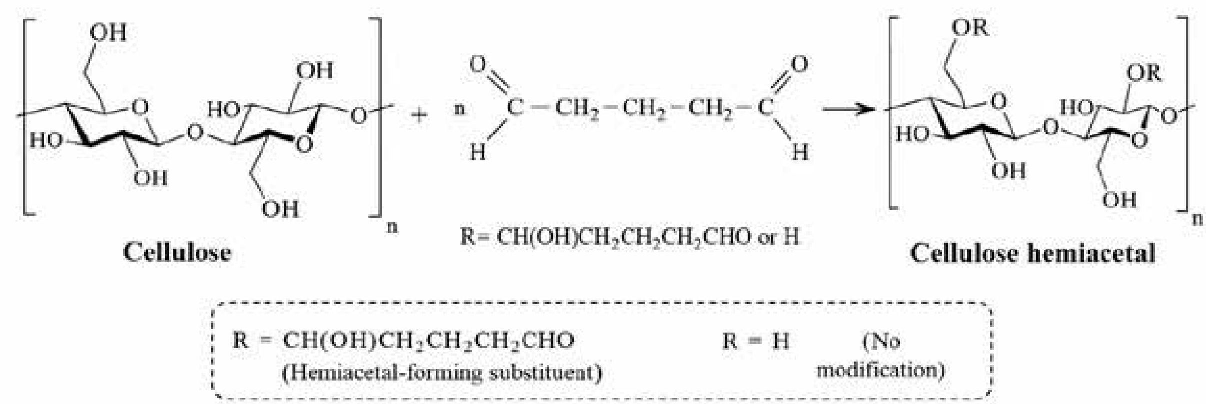
Elemental Analysis of the Modified Cotton Fiber

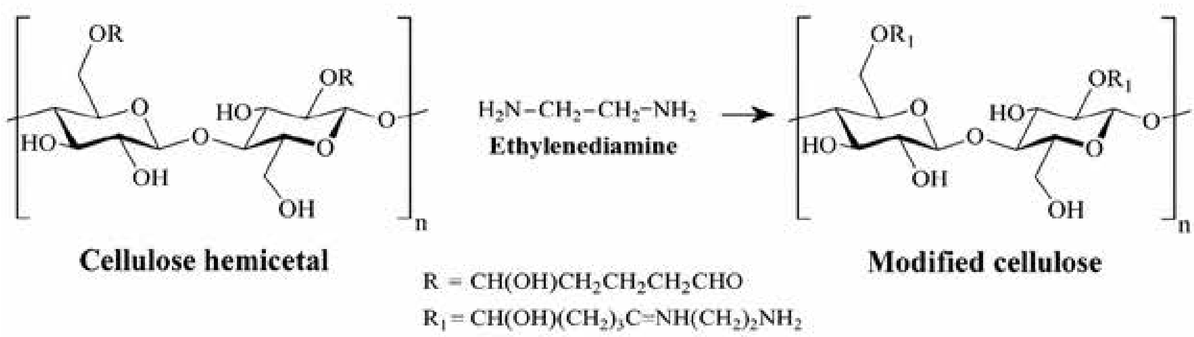
The elemental composition of unmodified cotton fiber and of cotton fiber modified with glutaraldehyde (GA) and EDA reagents was analyzed. The results presented in Table 1 show that nitrogen appeared in the fiber composition after modification. This result is one of the pieces of evidence confirming that the nitrogen-containing functional groups of EDA were incorporated into the cellulose fiber.

Table 1. *Nitrogen content in modified and unmodified cellulose fiber fabric*

Sample	**N, %**
Untreated cellulose fiber fabric	0.00
Cellulose fiber fabric modified with GA: EDA (1:1 molar ratio)	0.32 ± 0.05

These findings indicate that the process proceeds according to the following reaction mechanism:





As a result of modification, the main cellulose backbone is preserved; however, its surface and functional-group composition change, forming additional active centers for dye binding through amine groups and imine (C=N) bonds. This is a highly important outcome for the subsequent stage of dyeing with complex dyes.

Dyeing of the Modified Cellulose Fiber Fabric

To evaluate the effect of the modification processes on the dyeability of cotton fabric, both treated and untreated samples were dyed with 3d-metal complex dyes. During dyeing, the dye concentration was 3% relative to the fabric weight, and the liquor ratio of fabric to dye solution was 1:50. The pH of the dye bath was adjusted to 2–3 using acetic acid.

Results Analysis

Optical Microscopic Analysis of the Modified Cellulose Fiber Fabric

Within the scope of the study, the cellulose fiber was modified, and the modified fabric was examined under an optical microscope at 5000× magnification (Figure 1).

Figure 1 shows the sample surface at 5000× magnification after completion of the activation and amination stages. The surface of the sample is golden-yellow in color, and the structural integrity of the main and transverse threads of the cotton fiber is clearly preserved. This indicates that the chemiacylation reaction between glutaraldehyde and the cellulose hydroxyl groups, as well as the nucleophilic substitution reaction with ethylenediamine, did not negatively affect the macrostructure of the fabric or the mechanical strength of the fiber.

The surface color became noticeably darker, indicating a change in the light-absorbing properties of the fiber owing to the attachment of new functional groups to the macromolecule. Thus, figure 1 provides preliminary morphological data confirming the successful implementation of the two-stage modification.

Figure 1. *Micrograph of cellulose fiber aminated with ethylenediamine after activation with glutaraldehyde*

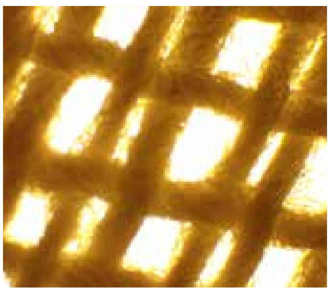


Figure 2. *Micrograph of fabric dyed with Fe^{3+} ion complex dyes of modified cellulose*

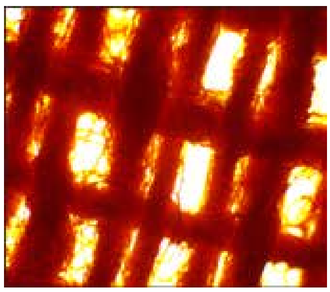
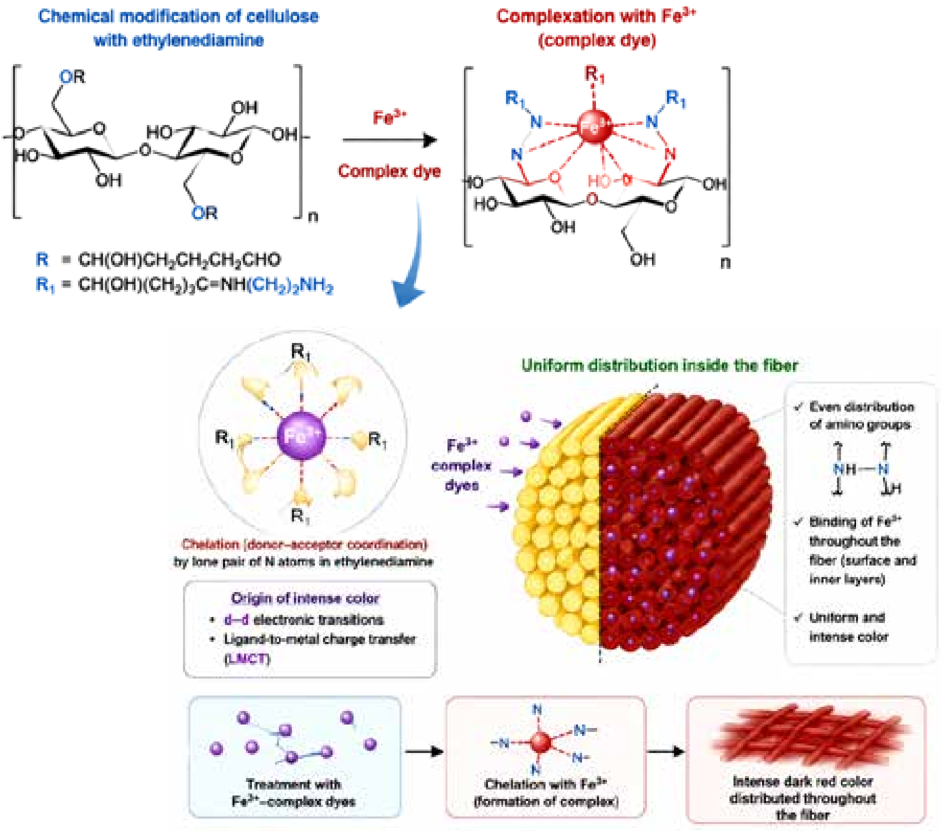


Figure 2 presents the optical microscopic image (5000× magnification) of a sample of modified cellulose fiber fabric treated with complex dyes containing Fe^{3+} ions. The sample's color clearly changed from an initial yellow shade to a dark red shade. This color change is explained by the fact that the lone electron pair of the nitrogen atom in the ethylenediamine structure forms a donor–acceptor coordination bond (chelate) with the Fe^{3+} cation.

Figure 3. *Fe^{3+} chelation by amino-functionalized cellulose through donor–acceptor coordination of nitrogen lone pairs, resulting in an intense dark-red color*

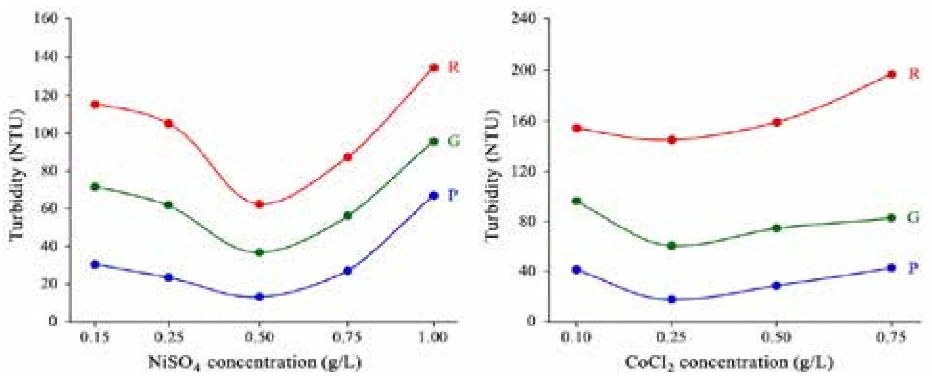


The intensely colored appearance of the resulting complex indicates the occurrence of d–d electronic transitions and ligand-to-metal charge-transfer transitions. The micrograph shows a relatively uniform distribution of color across the entire fiber surface, indicating that the amino groups are evenly distributed within the fiber and have bound Fe^{3+} ions not only in the surface layer but also in the inner layers.

Determination of Colorimetric Indicators

To evaluate the color characteristics of the dyed fabrics, color brightness and intensity were determined photometrically using the RGB color-model coordinates with a Shimadzu UV-1800 (Japan) spectrophotometer. A Canon EOS 600D camera was additionally used to digitally record the color characteristics, and the resulting images were processed by digital color analysis in Adobe Photoshop CS6.

Figure 4. *Changes in the R, G, and B components during dyeing of cotton fabric in the presence of nickel sulfate (A) and cobalt chloride (B) metal complexes in the complex-forming solution*



A B

Figure 4 (a, b) shows the optimal values for the formation of metal complexes in the cotton fiber structure as a function of nickel chloride and cobalt chloride concentration. The optimal value for nickel chloride was 0.5 g/L, and for cobalt chloride 0.25 g/L; the process is extremal in character and passes through a minimum.

On the basis of the above findings, optimal compositions and organo-mineral ingredient ratios were developed that ensure the maximum formation of metal complexes in the structure of cotton fabric, thereby enabling high-quality dyeing of cotton fabrics.

Discussion

Evaluation of the Fabric's Operational Properties

As one of the operational properties of the dyed samples, a study was conducted on the resistance of the metal complexes formed in the fabric structure to various hydrothermal treatments. The tests were carried out in accordance with GOST 9733–83 and were assessed on the basis of the ability of the fabrics containing the metal complexes to retain their original color after various external effects, as well as the degree of staining of the accompanying white materials used in the combined test.

Table 2. *Fastness of the metal complexes to hydrothermal treatments*

Fabric color	Water, t=90 °C	Water, t=60 °C	Soap, 5 g/L, t=30 °C	Dry ironing	Steam ironing
Brown	5/5/4	5/5/4	5/5/4	5/5/4	5/5/4
Yellow	5/5/4	5/5/4	5/5/4	5/5/4	5/5/4
Green	5/5/5	5/5/5	5/5/4	5/5/3	5/5/3
Blue	5/5/4	5/5/5	5/5/4	5/5/4	5/5/4

The fastness of the dye to soap treatment was determined in accordance with GOST 9733.4–83 using a "Dyed Color Fastness Testing Laundering Machine LM-12." The test was carried out in a 5 g/L soap solution for 30 minutes with a liquor ratio of 50 at 40 °C. After the test, the samples were squeezed, trimmed along the double-stitched edges, and air-dried at room temperature; a grey-scale reference was used to evaluate color fastness. Fastness to perspiration was determined using a "Color Fastness to Perspiration Model – CF-5" instrument in accordance with GOST 9733.6–83, and fastness to rubbing was determined in accordance with GOST 9733.0–83. The test results are presented in Table 3.

Table 3. *Fastness properties of cotton fabric dyed with composite dyes*

Cotton fabric containing metal complex salts	Color	Soap fastness, points	Perspiration fastness, points	Rubbing fastness, dry	Rubbing fastness, wet
Composition based on iron sulfate	Brown	5/5/4	5/4/3	4	4
Composition based on cobalt chloride	Yellow	5/4/4	5/4/5	4	5
Composition based on nickel sulfate	Green	5/5/4	5/4/4	5	4

Conclusion

The results of the study confirmed that amination of cotton cellulose significantly improves its physicochemical and sorption properties. As a result of amination, active centers for metal-complex formation appear, and dye affinity increases. The introduction of amino groups into the cellulose matrix increases its ability to interact with polyvalent metal ions through the free electron pairs of the nitrogen atoms and facilitates the formation of coordination bonds. Such modification changes the polarity of the cellulose surface and increases its hydrophilicity, ensuring good dispersion in aqueous systems and increasing the degree of dye uptake.

Rheological analysis of the prepared dye compositions showed that the degree of thixotropic recovery depends on the composition and on the presence of modifiers. The three-component system developed on the basis of cellulose, glutaraldehyde, and ethylenediamine exhibited a higher degree of thixotropic recovery (up to 94–95%) than conventional industrial binders. This indicates its higher structural stability and its greater suitability for technological processes.

References

Dehabadi, V. A., Buschmann, H. J., & Gutmann, J. S. (2013). Durable press finishing of cotton fabrics: An overview. *Textile Research Journal,* – 83(18). – P. 1974–1995. URL: https://doi.org/10.1177/0040517513483857

Hauser, P. J., & Tabba, A. H. (2001). Improving the environmental and economic aspects of cotton dyeing using a cationised cotton. *Coloration Technology,* – 117(5). – P. 282–288. URL: https://doi.org/10.1111/j.1478–4408.2001.tb00076.x

Kim, J. Y., & Choi, H. M. (2014). *Cellulose Chemistry and Technology,* – 48(1–2). – P. 25–32.

Li, S. D., Gatewood, B. M., & Choi, H. M. (1997). *American Dyestuff Reporter,* – 86(3). – P. 36–50.

Mitchell, R. E. J., & Birnboim, H. C. (1977). *Analytical Biochemistry,* – 8*1*(1). – P. 47–56.

Naven, T. J. P., & Harvey, D. J. (1996). *Rapid Communications in Mass Spectrometry,* – 10. – P. 829–834.

Park, J. H., Choi, H. M., & Oh, K. W. (2014). Simultaneous crosslinking and cationization of cotton cellulose by using dialdehyde and choline chloride: Comparison between the pad-dry-cure and microwave irradiation process. *Cellulose,* – 21(4). – P. 3107–3119. URL: https://doi.org/10.1007/s10570–014–0326-z

Trask-Morrell, B. J., & Choi, H. M. (1994). *Journal of Applied Polymer Science,* – 51. – P. 769–779.

Zhao, H., & Heindel, N. D. (1991). *Pharmaceutical Research,* – 8(3). – P. 400–402.

submitted 03.08.2026;
accepted for publication 17.08.2026;
published 31.08.2026

Contact: sharipovms1981@gmail.com