

THE USE OF HYDROXYPROPYLMETHYLCELLULOSE FOR PRINTING TEXTILE MATERIALS

Nabiyeva I.A., Iskhakova D.Sh.
Institute of Textile and Light Industry

Annotation: This article presents the findings of a study investigating the application of hydroxypropylmethylcellulose (HPMC) as a thickening agent in textile printing processes. The primary objective of the research was to develop and optimize the formulation of an HPMC-based printing paste to achieve improved rheological properties and printing performance. The object of the study was a cotton fabric provided by the enterprise TASH TIB TEX LLC, in accordance with the Russian standard GOST 21790 - 2005. The printing process was carried out in a single-stage mode using the reactive dye BEZEMA ROT S-3B150 RED ACTIVE (X) (Switzerland), with fixation performed in a GD Mathis (Switzerland, 2011) steaming unit. The color intensity of the printed samples was analyzed spectrophotometrically according to the HYPER CHOSHOKU-SENKA TX methodology. The test results demonstrated that the viscosity of the cellulose ether at concentrations of 1%, 1,5%, and 2% varied within the range of 19563 to 400000 mPa*s. The study also established a correlation between the sharpness of the printed pattern contours and the concentration of the cellulose ether. The samples printed with HPMC-based pastes at concentrations of 1%, 1,5%, and 2% exhibited contour sharpness values of 98,2%, 97,5%, and 97,0%, respectively. A comparative analysis of the color fastness of the printed patterns to various external factors was carried out. It was found that the samples based on cellulose ether provided a high level of color fastness, rated at 4,5 - 5,0 points on a five-point scale, which is comparable to the performance of conventionally used sodium alginate. The obtained results confirm the feasibility of employing HPMC as an effective thickening agent for textile printing applications.

INTRODUCTION

In recent years, significant progress has been achieved in the artistic and coloristic design of textile materials, with printed textiles accounting for an increasingly substantial share of global production. Competition in the field of textile printing has reached a global scale. Particular attention is being paid to enhancing the environmental sustainability of the printing process, which has led to a growing interest in the application of cellulose ethers in textile printing technologies. Among them, hydroxypropyl methylcellulose (HPMC) is of special interest due to its cold-water solubility, thickening ability, film-forming properties, and capacity to control dye spreading [1]. In textile finishing enterprises, natural sodium alginate is predominantly used as a thickening agent in printing processes [3]. It should be noted that the efficiency of the printing process and the quality of the coloristic characteristics of textile materials largely depend on the properties of the thickening agent. Sodium alginate provides good color yield and contour sharpness; however, it has the disadvantage of high cost, as it is a naturally derived substance. In addition, its use requires extra time for preliminary dissolution and preparation of a viscous paste [2]. Another drawback of this thickening agent is its limited storage stability, and fabrics printed with it exhibit insufficient color fastness to wet treatments. Therefore, the use of chemical or synthetic thickeners with high viscosity at low concentrations, which allow for a reduction in preparation time, has become particularly relevant. The study [4] on the application of HPMC as a thickening agent for printing various materials demonstrates that, due to its rheological properties, this cellulose ether positively affects the hydrophilicity of fabrics. Water-soluble cellulose ether exhibits high viscosity even at low concentrations, thereby ensuring the economic

efficiency of the printing process [5]. Nevertheless, there is currently insufficient information regarding the influence of HPMC viscosity grade and the printing technology of cotton fabric with reactive dyes on the sharpness of printed patterns and color fastness under conventional printing with fixation in a steaming unit. Accordingly, the aim of this study was to develop an optimal formulation for conventional printing of cotton fabrics, to evaluate the effect of different HPMC concentrations on the sharpness of printed patterns, and to compare the color fastness of the printed samples under various physical and mechanical stresses with that of samples based on sodium alginate.

METHODS

The object of the study was bleached cotton fabric (GOST 21790 - 2005) provided by TASHTIB TEX LLC, Tashkent, Republic of Uzbekistan. Its technical specifications are presented in Table 1.

Table 1

Characteristics		Показатели
Degree of whiteness, %		76,0
Moisture content, %		7,4
SUR°		97
Shrinkage, %	By warp	8,0
	By weft	9,0
Tensile strength, N	By warp	490
	By weft	255
Tensile elongation, %	By warp	8,0
	By weft	23
Air permeability $\text{cm}^3/\text{c} \cdot \text{cm}^2$		109,8

HPMC is a white, odorless, and tasteless powder that provides optimal and stable viscosity during storage, improves the consistency, stability, and water retention of the printing paste, enhances adhesion properties, and reduces shrinkage and cracking. The main specifications of the water-soluble cellulose ether HPMC used in this study are presented in Table 2.

Table 2.

Name	Спецификация	Результаты тестирования
Appearance	Белый порошок	Белый порошок
Hydroxypropyl groups, %	4-12	11,6
Methoxy groups, %	19-24	23,8
Moisture content, %	$\leq 5,0$	3,9
Ash, %	$\leq 5,0$	3,1
Ph	4,0-8,0	6,8
Transmittance, %	≥ 70	82
Whiteness, %	≥ 75	77
Gel formation, °C	65-75	68-72
Water retention factor	65-95	92

The chemical reagents included in the printing paste were used as received and were supplied by TASHTIB TEX LLC.

Sodium alginate - a brown powder ($\text{C}_6\text{H}_7\text{O}_6\text{Na}$)_n M = (198)_n SC/T 3401-2006

Urea (carbamide) - a colorless crystalline powder. H_2NCONH_2 M=60,0 ISO 4500:2018

Sodium bicarbonate - a white crystalline powder, NaHCO_3 M=84,0 ISO 22000

Ludigol - a light gray, odorless powder $\text{C}_7\text{H}_6\text{N}_2\text{Na}_2\text{O}_5$ ISO 827-95-2

Nonionic surfactant (NIS) - ISO 1065-91

Reactive dye - BEZEMA ROT S-3B150 RED ACTIVE (X) with a chromophore system Na_2SO_3 -Kp-T-X, and active DHTA group, Switzerland, ISO 2846-1-2017

Experimental Methods:

Preparation and composition of conventional sodium alginate-based printing paste. In practice, specifically at TASHTIB TEX LLC, an 8% sodium alginate solution is used for preparing the printing paste. Sodium alginate was gradually added to water heated to 30 - 35 °C under constant stirring and then cooked at 80 - 88 °C for 20 - 25 minutes until a homogeneous mass was obtained. The resulting thickener was cooled with continuous stirring and subsequently filtered through a sieve. Next, all dry components of the printing paste formulation were completely dissolved in warm water and then mixed with the thickener to obtain a homogeneous paste (master thickener). The dye powder was gradually added to the thickener containing all other paste components under continuous stirring, and the mixture was stirred until the dye was fully dissolved, forming a uniform viscous mass [6].

Composition of sodium alginate-based printing paste (g/kg): dye - 40; urea - 150; ludigol - 10; sodium bicarbonate - 15; water (50 - 70°C) - 285; thickener - 500.

Preparation and composition of cellulose ether-based printing paste. Due to the good water solubility of the simple cellulose ether, no additional effort is required for its mixing or preliminary preparation. During the preparation of the printing paste based on the investigated cellulose ether, all dry components, together with the weighed thickener powder and reactive dye, were added to water (50 - 70 °C) and thoroughly mixed until gelatinization occurred, resulting in a uniform viscous mass.

Composition of water-soluble cellulose ether-based printing paste (g/kg) [7]: dye - 40; urea - 150; ludigol - 10; sodium bicarbonate - 15; water (50 - 70 °C) - 285; thickener - 500 (for a 1,5% cellulose ether solution: cellulose ether - 7,5; water - 492,5).

Printing and washing of cotton fabric with reactive dye using sodium alginate. The primary method for printing fabrics with reactive dyes is direct printing, which can be performed using either single-stage or two-stage techniques. In this study, printing was carried out under laboratory conditions using the conventional single-stage method, with dye fixation in a steamer (GD Mathis, Switzerland, 2011).

The printing was carried out in the following sequence: application of the printing paste onto the fabric; drying of the fabric in a printing dryer; fixation of the reactive dyes on the fabric by steaming – treatment in a saturated steam environment at 102 - 105°C for 4-5 minutes; fabric washing in a washing apparatus:

1st chamber - cold running water;

2nd and 3rd chambers - hot water at 85 - 95°C;

4th and 5th chambers - detergent solution at a concentration of 1,5 g/l and temperature of 90 - 95°C;

6th and 7th chambers - hot water at 85 - 90°C;

8th and 9th chambers - warm water at 60°C.

Printing and washing of cotton fabric with reactive dye using cellulose ether. The printing technology for samples based on cellulose ether does not differ from the conventional method using sodium alginate, and the dye fixation process was carried out under laboratory conditions on a GD Mathis (Switzerland, 2011) unit. The washing process of the samples after dye fixation was carried out in a washing apparatus:

1st and 2nd chambers - cold running water;

3rd chamber - detergent solution at a concentration of 1,5 g/l and a temperature of 90 - 95°C;
4th and 5th chambers - cold running water.

Analytical Methods

Methods for assessing the printed samples’ resistance to physical and technical impacts:

Colorfastness to soap solution at 40°C was determined according to ISO 105-E04-2014.

Colorfastness to perspiration was determined according to ISO 105-E04-2014.

Colorfastness to dry and wet rubbing was determined according to ISO 105-X12-2014

Method for assessing the clarity of printed patterns: the dimensions of the printed figure are measured using a ruler to determine the printed area. The area of the corresponding figure on the template is also measured. The percentage of the printed pattern area relative to the template area is then calculated mathematically. The closer the obtained value is to 100% (± 2), the higher the printing quality.

Method for assessing the colorimetric properties of printed samples:

The color strength (K/S) was measured using a X-rite CIA-26 spectrophotometer (USA, 2022) based on the HYPER CHOSHOKU-SENKA TX methodology, in accordance with the established protocol, with the aim of determining the K/S function – the color intensity.

Determination of the viscosity of thickeners was performed using a NDJ-8S rotational viscometer (Brookfield, China, 2008) at a temperature of 20–22 °C and a stirring speed of 300 rpm.

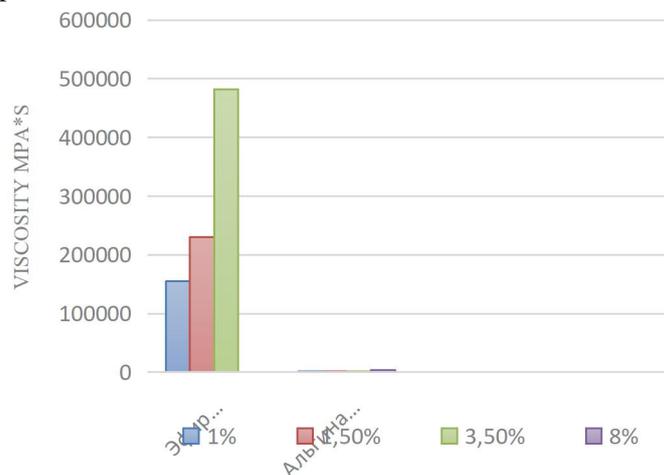
RESULTS AND DISCUSSION

This section presents the results of the study on the influence of printing parameters on the physico-mechanical and colorimetric properties of textile materials. The viscosity characteristics of the conventional thickening agent were compared with those of the studied cellulose ether. The obtained data are discussed in terms of optimizing the technological process of printing cotton fabrics with reactive dyes using a single-stage steaming method for dye fixation.

With the development of the textile industry, there is an increasing demand for higher-viscosity thickeners, and enterprises use various concentrations of sodium alginate to enhance economic efficiency. In this study, the viscosity characteristics of cellulose ether and sodium alginate were compared to better illustrate the economic advantages of using cellulose ether. The results of the viscometric analysis of the viscosity characteristics of the compared thickeners are presented in Figure 1.

Figure 1

Viscosity profiles of various concentrations of cellulose ether and sodium alginate.



The presented graph illustrates the changes in the viscosity of sodium alginate and HPMC solutions at concentrations of 1%, 1.5%, 3.5%, and 8%. At a concentration of 1%, the viscosity of sodium alginate is 500 mPa·s, whereas the viscosity of HPMC reaches 19,658 mPa·s. The exceptionally high viscosity of the studied cellulose ether is attributed to the presence of hydroxypropyl groups in its structure, which promote gelation of the ether solution at temperatures of 50–80 °C. Consequently, at a concentration of 8%, the ether achieves a viscosity of 400,000 mPa·s. The obtained data indicate a significantly higher structural stability and thickening efficiency of the ether compared to conventional sodium alginate.

The clarity of printed design contours is one of the key indicators for assessing the feasibility of using the studied ether. The contour clarity of samples printed with sodium alginate and cellulose ether was determined using the method described in the Materials and Methods section. Figure 2 shows the printed samples for visual assessment of contour clarity retention.

Figure 2

Comparison of samples printed with sodium alginate and HPMC.

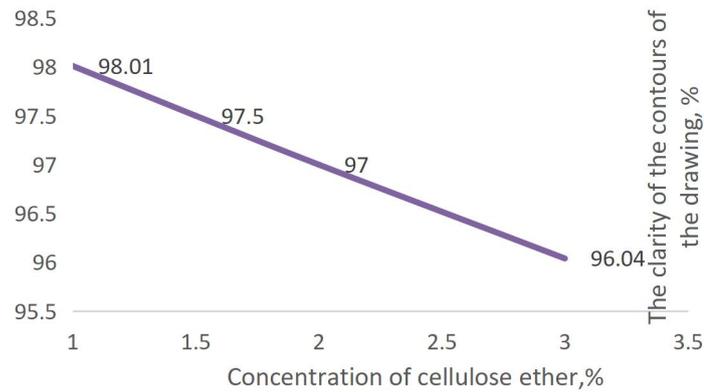


The samples shown in Figure 2 were printed using sodium alginate at concentrations of 1.5%, 2.5%, and 3.5%. At these concentrations, contour spreading and reduced clarity were observed, which can be attributed to the insufficient viscosity of sodium alginate and the inadequate film formation on the fabric surface. At these concentrations, cellulose ether exhibited contour clarity ranging from 97% to 98.5%, due to the predominance of propylene groups in its structure, which, in combination with hydroxyl radicals, form a stable gel film that retains the dissolved dye on the fabric surface and promotes improved adhesion. These results are consistent with findings reported in [8, 9].

The contour clarity of printed designs using water-soluble cellulose ether at various concentrations was determined under laboratory conditions by a mathematical analysis method, with the results presented in Figure 3.

Figure 3

Dependence of contour clarity of samples printed with cellulose ether on concentration



From the results shown in the graph, it can be concluded that cellulose ether at low concentrations exhibits contour clarity closest to 100%.

Tests for color fastness to washing, perspiration, and rubbing demonstrated that the inclusion of hydroxypropyl methylcellulose (HPMC) in the printing paste ensures stability due to its high hydrophilicity and enhanced fiber swelling, which facilitates deeper dye penetration. The test results are presented in Table 3.

Table 3

Color fastness to physicochemical and mechanical effects

Sample based on	Soap resistance, score	Sweat resistance, score	Resistance to friction (wet/dry), point
Sodium alginate	4/4/4,5	4/4,5/5	4/4,5 4/4,5
Cellulose ether	4,5/4/4,5	4,5/4,5/5	4,5/4 4,5/5

A comparative analysis of color fastness to washing, rubbing, and perspiration demonstrated that samples printed with cellulose ether exhibited a high level of color retention, reaching 4.5–5 points on the five-point scale, comparable to traditionally used sodium alginate. Thus, cellulose ether shows potential as an effective thickener for textile printing, simultaneously providing high viscosity and excellent color fastness.

CONCLUSION

The study demonstrated that hydroxypropyl methylcellulose (HPMC) can be effectively utilized as a printing thickener for textile materials. Experimental results showed that even at low concentrations, HPMC exhibits high viscosity and excellent print outline definition, which cannot be achieved using sodium alginate. The investigated cellulose ether forms a stable polymeric network, contributing to printing consistency and enhanced resistance to physicochemical and mechanical effects. These findings confirm the potential of HPMC as an effective thickener for textile printing applications.

References:

1. LiangFeng Wang, ChengCheng Wang, YuanDa Huang, Lan Shen, YanLong Hong, LiJie Zhao, Xiao Lin. Research on the influences of binders on high shear wet granulation and tablet quality. *Journal of Drug Delivery Science and Technology*, 107, May 2025, 106832.
2. Nurutdinova F.M., Ikhtiyarova G.A. Use of a thickener based on pchelozan and acrylic polymers for printing cotton-silk fabrics. *Universum: Technical Sciences*, 2020, No. 2(71).
3. Irmatova, Mukharram, Iroda Nabieva, and Nilufar Sharipova. "A study of the process of printing patterns on mixed fabric." *E3S Web of Conferences*. Vol. 401. EDP Sciences, 2023.

4. Yan Liang, Ni Wang, Qing Li, Huiyu Jiang. Surface modification of silk fabric by polysaccharide derivatives towards high-quality printing performance using bio-based Gardenia Blue ink. *Materials (MDPI)*, 2024, 17(14), 3611. <https://doi.org/10.3390/ma17143611>
5. Nabieva I.A., Khamidova V.D., Iskhakova D.Sh. Development of resource- and energy-saving compositions for textile printing. In: *Prospects and Problems of Development of Cotton, Textile, Light Industry and Printing Technologies in the Context of New Economic Reforms in Uzbekistan*, 2nd part. Tashkent, 2024, pp. 45–47.
6. Kiselev A.M., Tikhomirova N.A., Kovaleva T.V. *Textile Printing: Textbook*. Saint Petersburg: SPbGUPTD, 2024. 716 p. ISBN 978-5-7937-2559-0.
7. UZ IAP 7665, 20.12.2022.
8. Shaban H., Kafafy H., Shahin A.A., Mashaly H.M., Zaher A., Helmy H.M. Surface functionalization of printed natural textiles for medical applications. *Egyptian Journal of Chemistry*, 67(4), April 2024, pp. 153–164. <https://doi.org/10.21608/ejchem.2023.227828.8386>
9. An F., Fang K., Liu X., Li C., Liang Y., Liu H. Rheological properties of carboxymethyl hydroxypropyl cellulose and its application in high-quality reactive dye inkjet printing on wool fabrics. *International Journal of Biological Macromolecules*, 164, 1 December 2020, pp. 4173–4182. <https://doi.org/10.1016/j.ijbiomac.2020.08.216>