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THICKENING POLYMER COMPOSITIONS FOR COTTON FABRIC FILLING

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Abstract:

This article explores the impact of sodium carboxymethyl cellulose (Na-CMC) and sericin on the rheological, physical, and mechanical properties of thickening polymer compositions used in cotton fabric printing. Thermodynamic and structural characteristics of polymer systems based on starch, Na-CMC, and sericin are investigated using analytical methods including IR spectroscopy and electron microscopy. The study emphasizes both the ecological and economic advantages of these compositions. Additionally, a cost-effective and ecologically friendly process has been developed for printing cotton textiles with active dyes, which boosts print quality, colorfastness, and declines material discomfort. The results confirm the potential of these thickening systems to replace traditional alginate-based compositions while maintaining or exceeding performance standards.

Keywords: Thickener, Sericin, Cotton Fabric, Active Dye, Textile Material, Efficiency Evaluation

1. Introduction

All over the world, active dyes and pigments are mainly used in finishing plants for printing cotton textiles. In both cases, the evaluation of the printing process efficiency largely depends on the correct choice of thickener, the role of which is manifested both in the quality of the printed pattern and in the economic and environmental aspects of the production of printed fabrics.

Today, all near the globe, a specific emphasis is dedicated to research activity targeted at developing cost-effective procedures for generating thickening polymer compositions based on water-soluble natural and synthetic polymers. Therefore, it is quite obvious that research is relevant and in demand, aimed at creating and improving technologies for obtaining thickening compositions, which are important both for reducing the cost of products and for increasing their competitiveness, expanding the range of products. In this regard, the development of energy- and resource-saving

technology using local raw materials for thickening polymer systems for printing cotton fabrics is relevant.

Purpose of the study consists of the creation of resource-saving technologies for obtaining thickening compositions based on starch, carboxymethyl cellulose and sericin, used for printing cotton fabric.

Literature review

In scientific and technical literature there is a large volume of materials on the study of the development of highly effective thickening compositions for fabric filling, which are being studied by M.A. Askerov, S.S. Negmatov, Yu.T. Toshpulatov, M.Z. Abdukarimova, O.M. Yariev, I.A. Nabieva, B.E. Geller, M.R. Amonov and others. Their works collect and comprehensively analyze existing technologies for obtaining thickening ingredients based on natural polymers of the Republic and abroad, as well as on water-soluble and synthetic polymers [1],[2],[3].

The works of foreign scientists B.J.Collier, J.L.Willet , A.V.Senayakhov , A.S.Stepanova , I.M.Lipatova , T.L.Shcheglov , F.I.Sadov , G.E.Krichevsky and others provide data on the development of a thickening composition with various polyfunctional compounds of natural and synthetic origin. Despite the large number of studies conducted to date, the problems of creating scientific foundations aimed at developing a rational technology for obtaining thickening polymer systems based on local raw materials remain unresolved [4], [5],[6],[7],[8].

2. Methods

The work used thermodynamic analysis, isothermal sorption, IR spectroscopy, electron microscopy and physicochemical methods of analysis.

3. Results

Water-soluble polymer compositions using natural and synthetic polymers—starch (4.0; 5.0; 6.0%), modifiers Na - KM C (1.0-4.0%), and sericin (0.1-0.3%)—were identified, based on the interaction patterns of the components.

The polymer systems were identified.

The formation of bonds between the functional groups of the developed synthetic polymers with the primary hydroxyl groups of cellulose was revealed, and a technology was proposed for obtaining thickening compositions with improved performance characteristics as a result of the formation of a thin hydrophilic elastic film on the surface of printed fabrics.

The impact of many influences on the physical and chemical characteristics of a starch-based composition sericin and Na- CMC was studied, and the optimal compositions of the components included in the thickener were determined. The specificity of the influence of Na- CMC and sericin on the physical and mechanical properties of thickening compositions, as well as on the main printing indicators, was established.

It has been established that the use of a polymer composition improves the physical, mechanical and coloristic properties of printed fabrics. The color intensity of fabrics printed with active dyes increases from 65% to 84% while simultaneously improving the resistance of the print to washing under various conditions [9].

The mechanical and operational properties of printed fabrics thickened with developed thickeners based on water-soluble natural and synthetic polymers were studied, and deeper penetration of printing inks into the fabric was revealed, compared to printing inks thickened with sodium alginate.

4. Discussion

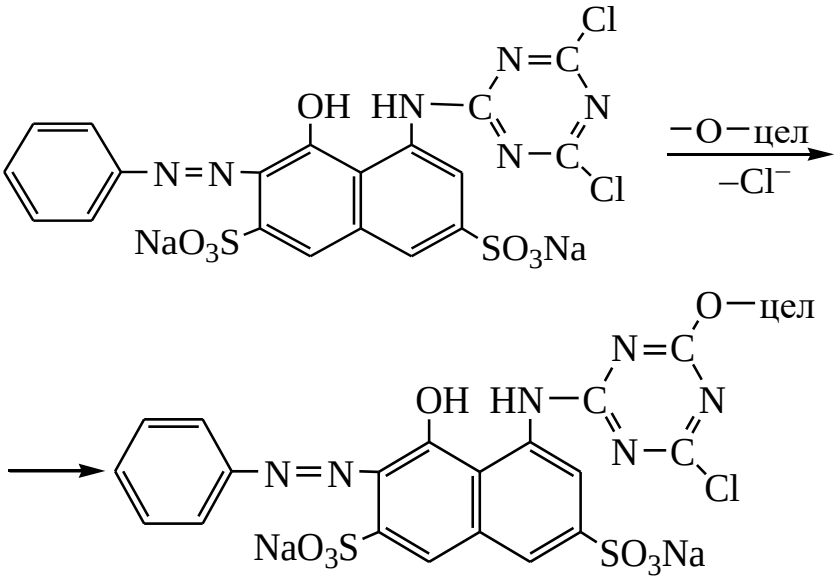
In the textile industry, starch and its derivatives are mostly used as economical thickeners in the printing process with cold dyes. Nevertheless, the use of starch as a thickening agent has some drawbacks, including its chemical interaction with active colours, which leads to substantial

overconsumption of both starch and dye, and its insufficient removal from the fabric surface. This therefore results in a rise in the cost of produced finished products. In this regard, in order to improve the printing and technical properties of starch-based thickeners, as well as to reduce the proportion of starch in the thickener, a polymer composition based on water-soluble starch, sodium carboxymethyl cellulose and sericin solution is proposed. Sericin is a protein-containing adhesive substance, which is a waste product of silk-winding enterprises. The use of natural and synthetic polymer thickeners based on starch, CMC and sericin containing carboxyl and amino groups are capable of increasing the viscosity of the thickening composition. Printing of cotton fabric with the developed composition is accessible and cost-effective and is characterized by environmental safety of use [10].

It is necessary to emphasize the content of such groups as oxy-, dicarbonic and diaminocarboxylic acids, as well as amino acids in the sericin molecule. Sericin contains hydrocarbon radicals with a complex and bulky structure, such as arginine, histidine, tyrosine. As a result, in the sericin macromolecule, the side parts of the polypeptide chain have a huge number of functional polar groups. These groups give the sericin molecule greater polarity and hydrophilicity [11].

Due to the fact that sericin contains many free carboxyl and amino groups, intermolecular interactions of molecules occur. sericin and cellulose. As is known, in sericin macromolecules there are fibrillar sections that can serve as a place of binding between cellulose fiber and sericin. The chemical makeup of sericin results in a folded β-form secondary structure with substantial side chains. During the printing process, the loose nature of the sericin layer allows for unobstructed diffusion and adsorption of the dye by the fibres. The free functional groups on the side chains of sericin facilitate the formation of chemical bonds with the fibre, hence enhancing the durability of the colouration. Also, the strength and stability of the coloring depends on the high polarity of the sericin molecule, which provides mutual reinforcement of the intermolecular interaction between the fiber and the dye.

The formation of a covalent bond, assumed to happen between the fibre of cellulose and the active bright red 8X, can be described by the formula as follows:



(1)

The printing and technical characteristics of printed cotton textiles, using the prescribed polymer composition, are crucial; hence, the efficacy of the technology's adoption in manufacturing is reliant upon these elements. As a consequence of the laboratory and pilot-industrial experiment, comparative data has been generated that characterise the quality of printing on cotton textiles while using the suggested and factory thickener. Findings indicated that considering colour fastness to wet processing, friction resistance, and stiffness of the printed fabric, the results generated with the proposed composition are very similar to those of alginate thickener, although they surpass starch-

based thickeners in directly every way [12]. In addition, the analysis of the data in Table 1.1 shows that cotton fabric printed with active dyes based on starch thickener does not sufficiently ensure the stability of the colors to dry friction (3 points) and imparts increased rigidity to the printed fabric (6.7 times). In order to solve this problem, in addition to starch and CMC, a sericin solution was added to the recommended printing composition, while the rigidity index (2.7 times) is practically reduced to the level of alginate thickeners (1.8 times), (changes in the range of 0.2-1.1).

To assess the effectiveness of the developed printing technology, comparative tests were conducted using factory and recommended thickeners. The results regarding color fastness, friction resistance, and fabric stiffness are presented in Table 1.

Table 1. Performance of fabrics printed with reactive dyes.

Quality indicators	Thickener composition			
	Factory		Recommended composition	
	alginate based	based on modified starch	based on starch and CMC	based on starch, CMC and sericin
Colour fastness to dry rubbing, points	5	3	4	4-5
Colour fastness to wet rubbing, points	4	3	4	4
Colour fastness to washing, points	5/5	4/3	5/4	5/5
Color intensity F (R)	18.6	13.8	17.4	18.5
Increase in rigidity, times	1.6	6.7	2.7	1.8

To ensure the optimal selection of printing with active dyes, the components of the polymer composite thickener were selected. At the same time, attention was paid to the composition of the thickening compositions, the variation of the original polymers was in a wide range from the point of view of evaluating the experiments of rheological properties and the quality of printing of cotton fabric. Regarding all of these thickeners, it is recommended to use printing inks due to the interaction between the chromophore anions of the dye and the functional groups of the polymers. In this instance,

The alkaline ingredient in the recipe establishes a covalent link between the dye and the fibre by creating an optimal environment, while also serving as a thickening activator.

The thickener we recommend changes the rheological characteristics of the printed composition in its presence, which leads to a pronounced tendency to increase fluidity. We have made calculations that show that the composite thickener based on sericin, Na -CMC and starch has high indicators of structuring and the degree of thixotropic restoration of the structure (more than 96%). This, in turn, makes it possible to form clear contours of the pattern of the required quality on the fabric with a relatively low resting viscosity [13]. The calculation indicators are presented in Table 2.

Upon analysing the information obtained, it is evident that sustaining the quantitative proportions in the starch system is crucial, specifically within the ranges of 5.0-5.5% for starch, 2.0-3.0% for Na-CMC, and 0.1-0.3% for sericin. This yields vibrant and long-lasting colours with no noticeable paint.

The pattern goes beyond its outline with complete fabric printing, resulting in reduced fabric stiffness. A fixing rate of active dyes is reported at a high level (95-96%) after the washing of the printed samples.

The interpretation of these effects can be linked to the fact that, unlike the film of a natural thickener on cotton fabric, a film of the corresponding composition is formed, which is firmly held on the substrate removed during washing, and the active dye is also fixed. The ground patterns obtained when covering a large part of the fabric area are combined during the printing and permanent finishing process.

Since the main parameter for manufactured products is good consumer qualities of textiles, the proposed polymer thickening compositions allow to improve and expand the properties of printed fabric.

The coloristic and mechanical properties of cotton fabrics printed with alginate and sericin-Na-CMC-starch-based thickeners were evaluated. The detailed comparative data are summarized in Table 2.

Table 2. Coloristic characteristics of cotton fabric printed with reactive dyes thickened with compositions

Print quality indicators	thickener based on alginate, 4.5%	Thickener based on starch, Na -CMC and sericin
Colour fastness to dry rubbing, points	5	5
Colour fastness to wet rubbing, points	5	4
Colour fastness to washing, points	5/5	5/4
Colour intensity, %	10.6	11.9
Fabric stiffness, $\mu N \cdot cm^2$	1300	1430
Degree of fixation, active dye, %	96.5	95.2
Color gamut, %	-	5.2
Degree of penetration, %	94.3	92.5

The obtained positive effects of the developed compositions are confirmed in an experiment conducted to identify them when printing with active dyes.

When analyzing microphotographs obtained after printing cellulose fiber, polymer films can be seen around it. At the same time, color hardening is observed and the effect of final finishing also appears.

During the experiment we have proved that during intensive washing the amount of desorbed active dye in the printed fabric decreases. At the same time, we observed an inverse relationship with the amount of Na -CMC and sericin in the composite thickener, ie. this amount is smaller, the greater the proportion of Na -CMC and sericin.

The recipe for the dye composition and the step-by-step parameters used in the printing and post-treatment processes are outlined in Table 3.

Table 3. Composition and processing parameters used in printing with active dyes

Dye according to recipe	Printing
Urea - 100	Drying – 70-90 ^{o} C
Ludigol - 10	Heat treatment at 140 ^{o} C – 3 minutes
Thickener – 55	Flushing:
Water – up to 1000	1. With cold water
	2. With warm water

	3. Soap wash at 90 ^{o} C – 2 minutes
	4. With warm water
	5. Cold water
	Drying – 110-120 ^{o} C

Coloristic characteristics of cotton fabric printed with reactive dyes thickened with compositions The resulting composition, when used in printing shops of textile finishing enterprises, allows for an increase in the quality of artistic and coloristic design of textile materials and products in the process of printing with active dyes, and also improves such consumer properties as reduced costs, the cost of chemical materials, and allows for a reduction in the discharge of water pollution and the emission of waste water and polluted air.

Moreover, based on the study undertaken, we have devised a technique for printing cotton textile materials with active dyes using novel and efficient thickening processes. Starch, carboxymethyl cellulose (CMC), and sericin were used as thickening agents. In the context of finishing enterprises, the application of our developed thickening compositions during the printing of cotton fabric resulted in enhanced quality of patterned colouring, lower consumption and cost of chemical materials, and improved environmental safety of production. [14],[15],[16].

For printing cotton fabrics with active dyes, we have determined the following parameters as the optimal composition of composite thickeners based on natural (starch) and synthetic (CMC and sericin) polymers. The possibility of obtaining clear contours of the pattern with high intensity and durability of coloring has been proven.

5. Conclusion

A research on the surface tension of a starch-based system including Na-CMC and sericin shown that the addition of up to 0.3% Na-CMC effectively decreases the system's surface tension. As the concentration of Na-CMC rises, the surface tension increases.

The rheological properties of polymer compositions have been studied in relation to the concentration and characteristics of the constituent components. The dye binding capacity of the composition including starch, Na-CMC, and sericin is about 1.6 times lower than that of native starch. The stability of modified starch was shown to be up to 4 times longer than that of starch, which is stable for up to 1.5 days. The use of starch and polymers such as Na-CMC and sericin into the formulation of printing ink thickeners results in the development of a film exhibiting enhanced elasticity and fluidity. The analysis revealed that concerning colouring resistance to wet processing, intensity, friction resistance, and stiffness of the printed fabric, the outcomes achieved with the proposed composition are almost equivalent to those obtained with alginate thickening.

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