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# THE EFFECT OF CHITOSAN TREATMENT ON COTTON FABRICS

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**Abstract**

Within the framework of this research, it has been demonstrated that introducing a preliminary chitosan treatment into the dyeing technology of cotton fiber knitted fabric with reactive dyes increases the utilization efficiency of the dye. The experiments propose a new technology for dyeing cotton fiber knitted fabric with reactive dyes after treatment with the chitosan biopolymer. Cotton fiber knitted fabrics were impregnated with chitosan solutions of various concentrations (0.5%, 1%, 1.5%, and 2.0%) and then dyed with reactive dyes. The color quality indicators of the dyed fabric were analyzed by comparing them with undyed fabric samples (conventionally dyed). The K/S values of the dyed samples (at λmax = 600 nm) were 6.44, 6.72, 7.43, 8.90 and 4.95 for the 0.5%, 1%, 1.5%, 2.0% chitosan-treated fabrics and the untreated fabric, respectively. The color fastness of the dyed samples to washing and rubbing was tested.

**Keywords**

cotton, chitosan, water absorption capacity, washing fastness, rubbing fastness, color intensity.

**Introduction.** The sericulture industry is well developed in the Republic of Uzbekistan. This figure illustrates that the volume of cocoon production in the industry has been increasing annually.

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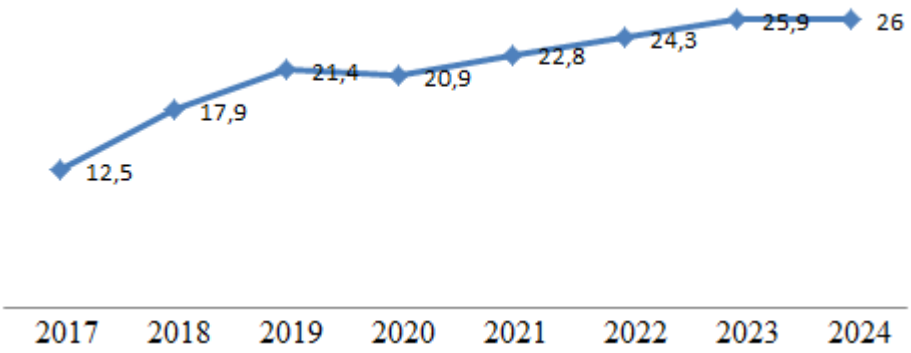


**Figure 1.** The volume of cocoon production in the Republic of Uzbekistan by year, in thousand tons.

Considering that the silkworm cocoon is a complete waste product, obtaining targeted raw materials from this waste for other sectors of industry provides a positive solution to the issues of creating a waste-free technology. The cocoon waste, considered as the pupa, accounts for about 60% of the total mass. Assuming that 26.000 tons of cocoons are produced annually in the Republic, it can be estimated that 26.000 tons × 0.6 = 15.600 tons of pupae are generated as by-products. Thus, in Uzbekistan, approximately 15.600 tons of pupae may have been generated in 2024. The extraction of chitin from this pupal waste and its subsequent deacetylation to obtain chitosan represents a pressing and relevant issue [1]. Rational utilization of natural resources, addressing environmental challenges, and, in particular, the expansion of the use of biodegradable polymers containing chitin have created wide opportunities for obtaining materials with diverse structures and properties from the chemical derivatives of chitin. These factors have made such polymers one of the most promising and attractive raw materials for various fields of application.

**Methodological part.**

**Materials: To carry out this research work, fabric, reactive dye, chitosan, basic, and auxiliary chemicals will be required. The properties of these materials are given below:**

**Fabric:** As the object of the study, cotton fiber knitted fabric with a surface density of 120 g/m² was used. The whiteness degree was 86%.

**Biopolymer**: In the form of 0.5%, 1%, 1.5%, and 2.0% solutions dissolved in chitosan and acetic acid with a molecular weight of 198 × $10^3$ and a deacetylation degree of 86%, obtained from the cocoons of the mulberry silkworm *Bombyx mori* [2].

**Sample preparation:** Cotton fabric was pretreated with a chitosan concentration of 1.0, which was employed for the treatment weight by volume method. Chitosan solution was prepared by dissolving the required amount of

chitosan powder in 0,5%, 1%, 1,5% and 2,0% (v/v) acetic acid at room temperature. The fabric was treated in the solutions for 30 min at 60°C. Excess solution was squeezed, and the samples were dried at 70°C.

**Dyeing parameters:** The dyeing process was carried out in a 1:50 module on the equipment of laboratory testing machines "DLS-6000" [3] at a temperature of 60-65$^0$C.

**Dye:** Setazol Yellow (Reactive Yellow) dye was used for dyeing.

**Chemicals:** Sodium carbonate (GOST ISO 5100-85), sodium chloride (GOST ISO 6353-2-83), and the nonionic surfactant Cottoclarin OK produced by the "Pulcra" company were used.

**Textiles —** Determination of water absorption time and water absorption capacity of textile fabrics. The international standard for determining the water absorption time and capacity of textile fabrics is ISO 20158:2018. This standard outlines the methods to assess a fabric's ability to quickly absorb water (time) and the total amount of water it can hold (capacity), which is crucial for products like cleaning cloths and mops. The test involves applying a water drop to the fabric to measure wetting time and immersing a weighed fabric sample in water to determine its water absorption capacity by re-weighing it after it's been allowed to dry.

The color quality indicators of the dyed samples were measured using an X-Rite Ci7800 (Korea) spectrophotometer [4]. The wash fastness of the color samples was determined according to GOST 9733.4-83, and the rubbing fastness was evaluated according to GOST ISO 105-X12-2014.

**Washing fastness.** GOST 9733.4-83 tests a textile's ability to resist color change (fade) or color transfer (staining) during laundering. These tests involve mechanically agitating a textile specimen with a reference detergent and water at defined temperatures and times, and then assessing any changes in color on the specimen and adjacent fabrics using a grey scale. Specific tests like ISO 105-C06 are used for domestic and commercial laundering, while others cover industrial procedures or specific components.

**Rubbing fastness.** "Rubbing fastness ISO" refers to ISO 105-X12, DL – 2007A on a laboratory device, a standard for determining the color fastness of textiles to rubbing (crocking). This international standard specifies a method using a crockmeter to rub a dry or wet standardized cotton fabric against a textile sample under controlled conditions. The test assesses how much color from the textile transfers to the rubbing cloth, with results rated using a gray scale to evaluate potential staining on other materials.

**Results and discussion.**

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In the process of dyeing cotton fiber fabric with reactive dyes, the application possibilities of a preliminary chitosan treatment were investigated to develop a resource-efficient technology through the use of chitosan as a secondary biopolymer. Chitosan treatment of cotton has been widely developed in textile chemistry, as such treatment improves the physicochemical properties of the fabric. Various application methods have been used for the preliminary chitosan treatment of cotton fiber textile fabrics. It has been used by scientists worldwide as an agent for modifying the surface of fabrics [5]. The results were evaluated based on the color intensity of the samples dyed with the reactive dye. In this process, the cotton fiber is modified, and the introduction of positively charged functional groups imparts favorable properties to it [6]. Such modifications, commonly referred to as cationization, are achieved by treating cotton with low-molecular-weight chemicals or polymers containing positively charged functional groups. Most of the positively charged functional groups are quaternary, tertiary, or secondary amines. In such modifications, the surface properties of the fiber primarily depend on the topography of its outer surface. This property, in turn, depends on the morphology of natural fibers, the cross-sectional geometry of chemical fibers, and the interfacial surface electrical characteristics. Different chemical fibers have various cross-sectional shapes. The diffusion and adsorption of the dye toward the fiber depend on its outer surface, meaning that the initial stage of dye uptake (sorption) is determined by the surface properties of the fiber [7].

Chitosan forms an amorphous film on the surface of textile materials, improving their physical, mechanical, and hygienic properties [8].

For the modification of linen, cotton, and wool fabrics, a chitosan concentration in the range of 0.5–2.0% is recommended, and a correlation between the chitosan concentration and the capillarity of the modified fibrous materials has been established [9].

At the initial stage of the research, fabrics were impregnated with chitosan at concentrations of 0.5, 1.0, 1.5, and 2.0%, dried, and their capillarity was examined. The results are presented in graphical form in Figure 1.

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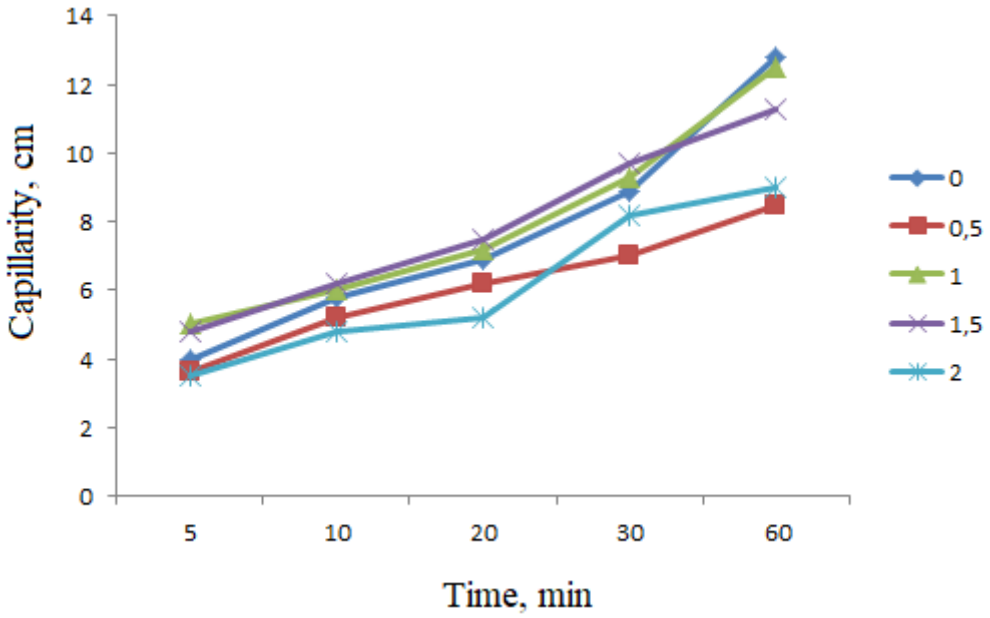


**Figure 1.** Capillarity of fabric samples impregnated with different concentrations of chitosan.

The analysis of the capillarity of fabric samples impregnated with different concentrations of chitosan showed that the samples treated with 1.0% and 1.5% chitosan exhibited higher liquid absorption capacity compared to the others. For subsequent research, the impregnation technology with a 1.0% chitosan solution was selected.

The water absorption capacity (WAC) of fabric samples impregnated with different concentrations of chitosan was studied. Chitosan treatment leads to an increase in the amount of liquid absorbed by the cotton fabric per unit of time, indicating an improvement in its wettability. With the increase in chitosan concentration, an enhancement in the sorption capacity of the fabric is observed, which can be explained by the swelling of the chitosan polymer film. At the same time, the volume of absorbed liquid increases with the rise in chitosan concentration, which can be explained by the initial interaction of the solution with the chitosan film, leading to its swelling.

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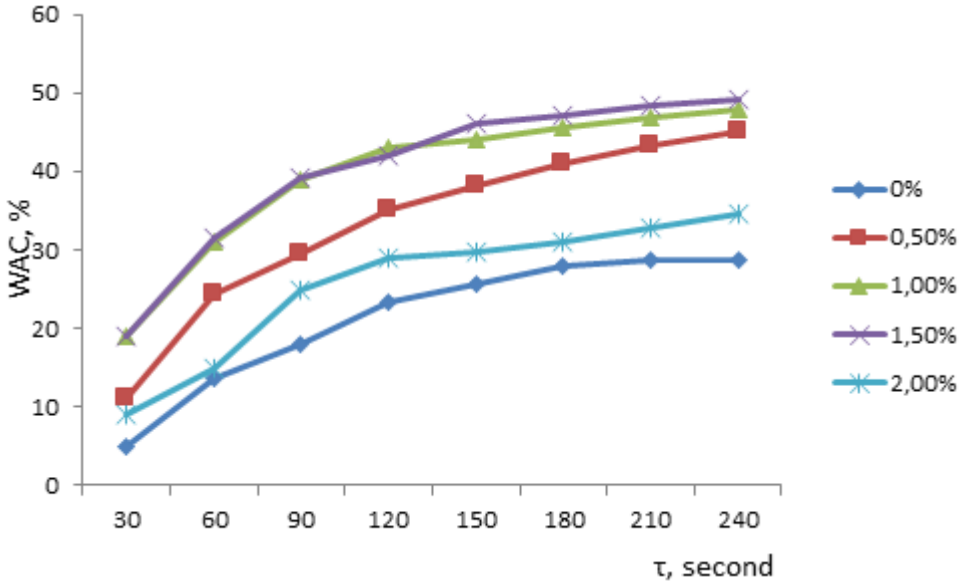


**Figure 2.** Water absorption capacity (WAC, %) of bleached cotton fabric samples impregnated with chitosan solutions of different concentrations (0.5%, 1%, 1.5%, and 2.0%) and untreated samples.

The water absorption capacity of samples impregnated with 1.0% and 1.5% chitosan solutions shows little difference. In contrast, the absorption capacity of samples treated with 0.5% and 2.0% chitosan solutions, as well as untreated samples, is comparatively lower. The relatively lower water absorption capacity of the sample impregnated with a 2% solution is likely due to the fabric reaching full saturation at 1.5%, which may depend on the fabric structure, solution concentration, and the configuration of the two polymers.

The water absorption capacity can be attributed to the hydrophilic properties of the functional groups of chitosan, which attract water, leading to its uptake and swelling. As a result, it was found that water penetrates the treated fabric more slowly compared to the untreated one. The presence of chitosan can create a network of interconnected voids within the fabric structure, allowing greater water penetration and retention. The water absorption capacity of chitosan is associated with its three main functional groups: the hydroxyl group, the amino group, and the polymer chain ends, which can accommodate additional water molecules. Based on the high water absorption capacity of samples impregnated with a 1.0% chitosan solution, this concentration was selected for treatment.

After the preliminary chitosan treatment, the dyeing process was carried out. The dyeing process was analyzed using colorimetric analysis, and the results are presented in Table 1.

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**Table 1.** Dependence of color characteristics on chitosan treatment at different concentrations.

| № | Chitosan entration | Color characteristics | | | | |
|---|---|---|---|---|---|---|
| | | L* | a* | b* | C* | h° |
| 1 | Conventional reated) | 58,12 | -7,95 | -26,30 | 27,47 | 253,14 |
| 2 | *0.5* | 50,48 | -7,74 | -28,86 | 29,87 | 254,95 |
| 3 | *1.0* | 50,08 | -7,10 | -29,78 | 30,61 | 256,57 |
| 4 | *1.5* | 49,21 | -7,01 | -29,85 | 30,65 | 256,78 |
| 5 | *2.0* | 47,32 | -6,94 | -30,20 | 30,98 | 257,05 |

The spectrocolorimetric analysis results show that in chitosan-treated samples, compared to the sample dyed by the conventional method, the saturation of the colors (C*) increased by 1.35–1.54%, while the hue (h°) increased by 11.43–12.78%.

The results of spectrocolorimetric analysis show that chitosan-treated samples produced 1.35-1.54% more saturated (C*) colors, and the hue (h°) increased by 11.43-12.78% compared to samples dyed using the traditional method.

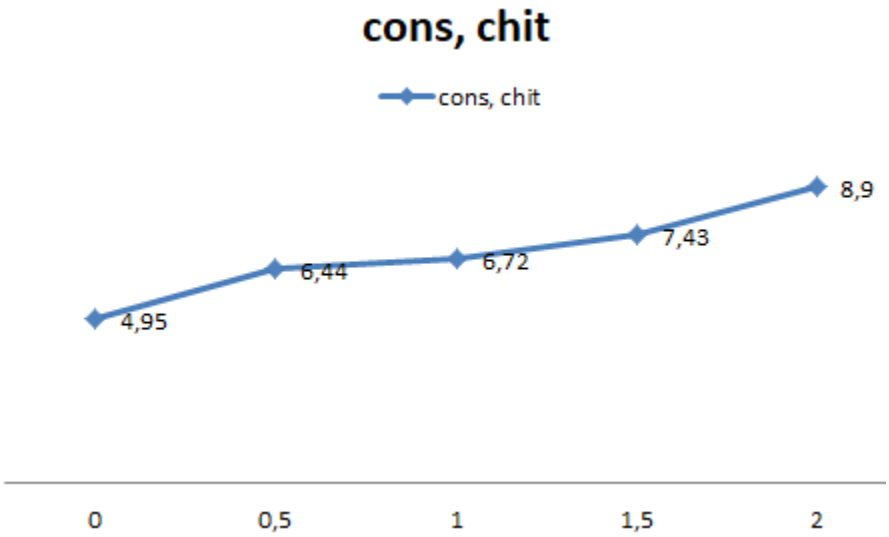


**Figure 3.** Color intensities of dyed fabric samples that were impregnated and non-impregnated with chitosan solutions of different concentrations.

In the dyed samples, it was found that the color intensity increased by 35.7% to 50.1% in samples treated with 1.0% and 1.5% chitosan. This indicates that the consumption of dye can be reduced by 35.7% to 50.1% when using chitosan. The color fastness properties were studied and are presented in Table 2.

**Table 2.** Dependence of color fastness on chitosan treatment at different concentrations.

| № | Chitosan | Color fastness |
|---|---|---|

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| | entration | Washing | Rubbing fastness | |
|---|---|---|---|---|
| | | | Dry | Wet |
| 1 | Conventional reated) | 4.5/4.5/5 | 4-5 | 3-4 |
| 2 | *0.5* | 5/5/5 | 5 | 4-5 |
| 3 | *1.0* | 5/5/5 | 5 | 5 |
| 4 | *1.5* | 5/5/5 | 5 | 5 |
| 5 | *2.0* | 4.5/5/5 | 5 | 4-5 |

The color Fastness properties also showed somewhat higher values compared to the conventional method.

**Conslution.** The research work carried out showed that using chitosan from *Bombyx mori* chitosan, which is a natural waste product of silkworm cocoons, accelerates the dyeing process of cotton textiles with active dyes. Before dyeing, fabric samples were soaked in chitosan solutions of various concentrations, and changes in the sorption properties of the fiber were analyzed. Spectrocolorimetric analysis of the samples showed that it was possible to obtain saturated, intensive colors. Color fastness indicators also showed somewhat higher results.

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