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## IMPORTANCE OF MOLECULAR WEIGHT OF CHITOSAN BIOPOLYMER IN DYEING OF COTTON FABRICS AND CHANGES IN FIBER SURFACE PROPERTIES

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**Kumush Rasulova**

*Tashkent Institute of Textile and Light Industry, Tashkent, 100100, Uzbekistan.*

### **Abstract**

In the experiments, the technology of cationic dyeing with chitosan and subsequent dyeing of cotton fiber fabric with active dyes was studied. First, it was studied which of the biopolymers of chitosan with different molecular weights 1 (low), 2 (medium) and 3 (high) is suitable for dyeing processes. Then, the effect of chitosan concentration on the surface properties of cotton fabric was studied. It was found that 1% solution of chitosan has a positive effect on its capillarity and surface potential. As a result, the efficiency of the dyeing process increases dramatically.

### **Keywords**

"*Bombyx mori*", chitosan, capillarity, molecular weight, color change, zeta potential.

**Introduction.** In industrial sectors, "green" technologies, in particular, technologies that enable resource-saving, waste-free production, waste processing and transition to safer chemicals and research and implementation of renewable energy technologies is an urgent issue. For this purpose, it was isolated from the non-fibrous waste of the silk industry, that is, from the cocoon of the mulberry silkworm [1] it is necessary to study the application of biopolymer chitosan in dyeing technologies of the textile industry [2]. The natural biopolymer chitosan is one of the promising raw materials for solving environmental problems, including reduced dye consumption [3], salt-free dyeing [4] and resource-efficient [5] technologies. The purpose of this work is to study the importance of the molecular weight of chitosan in dyeing cotton fabric with reactive dyes and to study its effect on the surface properties of the fiber.

### **Methodological part.**

**Fabric:** A textile fabric made of 100% cotton fiber with a whiteness level of 86% was selected as the object of research.

**Biopolymer chitosan:** isolated by deacetylation of chitin from the silkworm cocoon "*Bombyx mori*" [2]. Molecular weights of biopolymers are (low)  $66 \times 10^3$ , (medium)  $198 \times 10^3$ , and (high)  $274 \times 10^3$ , with a degree of deacetylation of 87% at

0.5, 1.0, 1.5, and 2.0% solutions. Sample preparation: 0.5, 1.0, 1.5, and 2.0% chitosan solutions were soaked in the fabric for 10 minutes, squeezed, and dried at 70°C.

Dyeing parameters: The dyeing process was carried out in a 1:50 module on a laboratory testing machine "DLS-6000" [6] at a temperature of 60-65°C.

Determination of capillarity. The capillary effect (water absorption/ wicking) of cotton fabric is commonly determined using the ISO 9073-11 standard, which measures the absorption height of a liquid over time.

**Results and discussion.** The physicochemical parameters of chitosan biopolymers of 3 different molecular weights obtained for the experimental work are given in Table 1. The results of the dyeing process are expressed in terms of color change, i.e. color intensity and color fastness ( $\Delta E$ ).

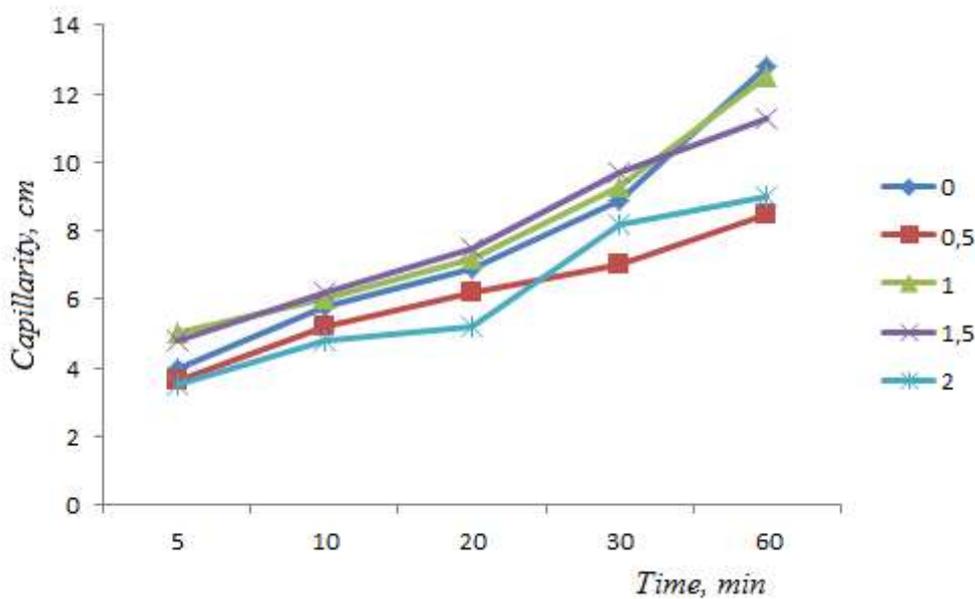
Table 1.

**Physicochemical parameters of chitosans with different molecular weights and results of the dyeing process**

No	Name	Molecular weight (MW) M <sub>r</sub> , kDa	Total nitrogen content, %	Viscosity, Pa*s	Degree of deacetylation (DDA)	Color intensity, K/S	Color change, $\Delta E$
1	Low	(66) <sub>n</sub>	7,97	3.9	86	3,54	0.45
2	Medium	(198) <sub>n</sub>	8,31	5.2	87	6.21	0.5
3	High	(274) <sub>n</sub>	8,15	7.4	86	6.74	1.2

The smaller the color change  $\Delta E$  in the dyed samples, the lower the color change. This means that the fixation is high and the resistance to washing is high. If  $\Delta E < 1.5$ , this means that the dye has a strong fixation and almost no change after washing. This value indicates high color fastness and color fastness of the dyed fabric. After dyeing with a medium molecular weight biopolymer, the color change was 0.5, which means that the dye is evenly distributed across the fabric surface. The color intensity was also higher in the sample treated with medium molecular weight chitosan, while the high molecular weight sample also achieved high color intensity but uneven staining. It can be concluded that the medium molecular weight biopolymer, i.e. 198\*103 kDa, is suitable for the staining process.

In the next stage of the experimental work, the surface properties of the selected chitosan were studied. The surface properties of the fiber depend primarily on the topography of its outer surface. This property, in turn, depends on the morphology of natural fibers and the cross-sectional geometry of chemical fibers, as well as the electrical properties of the interfacial area. Different chemical fibers have different cross-sections. The diffusion and adsorption of the dye into the fiber depends on its outer surface, that is, the initial stage of dye absorption (sorption) is determined by the properties of the outer surface of the fiber. [7].

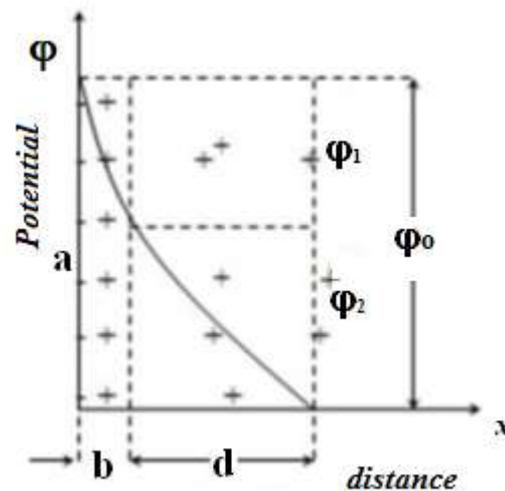


**Figure 1.** Dependence of chitosan concentration on capillarity.

The experimental work shows that at a concentration of 1% chitosan, high capillarity is observed. This is due to the inner surface of the fiber. The inner surface consists of a surface collection of pores, voids, and cracks of various sizes. When a fiber is immersed in an aqueous solution, a surface charge is generated as a result of the dissociation of active groups on the outer and inner surfaces or the adsorption of various ions from the solution onto the surface. As a result, an electric double layer is formed, and an electric potential is created. The surface charge of the fiber and the charge of the dye are the same, and the higher its amount, the higher the potential barrier that the dye overcomes for absorption (sorption).

The experimental results show that at a concentration of 1% chitosan, the capillary strength is high. This is due to the inner surface of the fiber. The inner surface consists of a surface collection of pores, voids, and cracks of various sizes. When a fiber is immersed in an aqueous solution, a surface charge is generated as a result of the dissociation of active groups on the outer and inner surfaces or the adsorption of various ions from the solution onto the surface. As a result, an electric

double layer is formed, and an electric potential is created. The surface charge of the fiber and the charge of the dye are the same, and the higher its amount, the higher the potential barrier that the dye overcomes for absorption (sorption).



**Figure 2.** Surface electric potential:

**A** - negatively charged fiber surface, **b** - stationary adsorption layer, **d**- mobile diffuse layer.  $\varphi_0$ - full potential,  $\varphi_1$ - stationary adsorption layer potential,  $\varphi_2$ - electrokinetic potential.

$$\varphi_0 = \varphi_1 + \varphi_2$$

Since it is difficult to determine the full potential of a surface (Fig. 2), its mobile part, called the electrokinetic or zeta  $\xi$ -potential, is usually determined.

Various physical and chemical influences affect the  $\xi$ -potential. Its sign and magnitude of charge depend on the environment (pH), temperature, electrolyte and the nature of the liquid medium. The influence of external factors is very wide, they can also change the surface charge density and the charge distribution in the diffuse part.

An increase in the amount of chitosan in tissues is associated with an increase in the height of the rise and the volume of absorbed fluid, which is associated with an increase in surface potential.

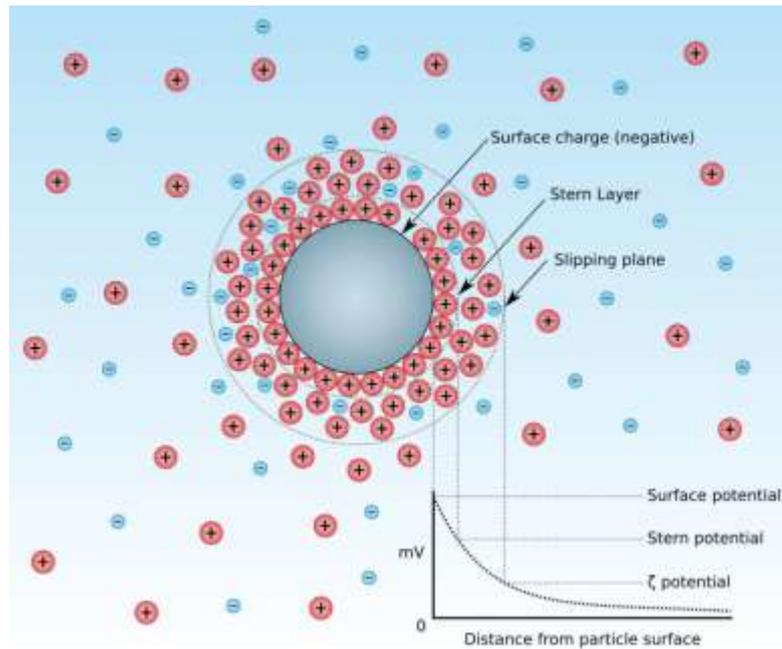


Figure 3. Surface charge of textile fabrics

Zeta potential ( $\zeta$ -potential) is a key indicator of the surface charge of textile fabrics, which affects their dyeability. It is a measure of the electrical potential at the interface between a fabric and a liquid, often water, and is a very important indicator for understanding the interaction of a fabric with the environment and other substances.

Different fibers have different surface chemistry and exhibit different zeta potential values. For example, cellulosic fibers such as cotton have a negative zeta potential [8].

Хитозан таркибли ишлов янги кимёвий гуруҳларни киритиш ёки сирт зарядини ўзгартириш орқали зета потенциалини ўзгартиради. Shu maqsadda xitozan shimdirilgan mato namunalarining zeta potentsiali o'lchandi va quyidagi rasmda sirt zaryadining ortishi grafikda ifodalangan.

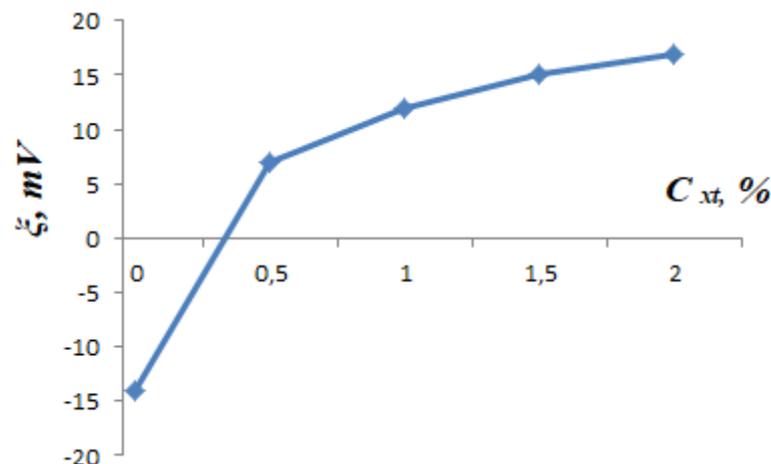


Figure 4. Zeta potential of chitosan with different concentrations effect.

The figure shows that in cellulose fabrics with negative  $\xi$ -potential values, a change in charge to positive was observed after treatment with chitosan. The  $\xi$ -potential of fabric samples impregnated with 0.5, 1.0, 1.5 and 2.0 chitosan increased sharply. This can be explained by the presence of a positive charge in chitosan.

The zeta potential of a fabric plays a crucial role in dyeing processes, especially with ionic dyes. The electrostatic attraction or repulsion between the dye and the fabric surface affects the dye uptake and color fastness. A 1% chitosan solution is recommended for further research.

Zeta potential provides information about the surface charge of a fabric and can be used to evaluate its behavior in various environments, such as dyeing or finishing processes. Finishing processes can further increase the negative charge of cotton fiber fabrics [9].

During dyeing processes, the negative charge of cellulose affects its attraction to dyes. Many common dyes, especially reactive dyes, also have a negative charge. This can lead to repulsion between the dye and the fiber, which reduces dye uptake. Various physical and chemical effects affect the  $\xi$ -potential. Its charge sign and magnitude depend on the environment (pH), temperature, electrolyte and the nature of the liquid medium. When studying the electrokinetic properties of fibrous materials, it is necessary to be able to distinguish the influence of internal and external factors on its magnitude. Internal factors are related to the properties of the fibrous material: its chemical composition, the nature and distribution of active groups on the surface, structural properties, polarization, etc. These have a significant impact on the amount of surface charge. External factors include the nature of the liquid phase, temperature, electrolyte concentration and type, surfactant, pH of the environment, time, etc., which are not related to the nature of the fiber. The influence of external factors is very wide and can also change the surface charge density and the charge distribution in the diffuse part [10].

**Conclusion.** The color intensity was also higher in the sample treated with medium molecular weight chitosan, while the high molecular weight sample also achieved high color intensity but uneven staining. It can be concluded that the medium molecular weight biopolymer, i.e. 198\*103 kDa, is suitable for the staining process. Based on the results of the experiment, a study of the effect of chitosan treatment on the capillary properties of cotton fiber fabric showed that an increase in the concentration of chitosan in the impregnation solution and, accordingly, in the fabrics leads to a decrease in the rate of liquid rise in cellulose fabrics. With increasing chitosan concentration, an increase in the total capillary volume is observed, which is explained by the formation of additional capillary space by

chitosan and, as a result, additional sorption of liquid due to the swelling of the chitosan film.

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