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STUDY OF THE PROCESS OF COLD DYEING OF WOOL FIBER USING DIAZONIUM NANO-SALTS

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Abstract

The article discusses a method of cold dyeing of wool fiber with insoluble azo dyes using diazonium salt nanoparticles. The azo component used is a nanodispersed diazonium salt, in combination with the reactivity of the side radical of the tyrosine amino acid of the keratin macromolecule, which ensures the effective occurrence of the azo coupling reaction directly in the fiber structure. Dyeing is carried out at a temperature of 20–25°C for 15–20 minutes with a bath module of 1:50. The effect of pH in the range of 4–8 on the physical, mechanical, and coloristic properties of wool was studied. It has been established that the proposed method ensures the production of stable and intense coloration while maintaining the fiber structure and reducing the energy and labor costs of the process.

Key words

cold dyeing, wool fiber, diazo compounds, nanoparticles, azo coupling.

Introduction

At the heart of wool fiber is a protein - keratin. It is a very complex fiber, and amino groups are the basis of keratin. All layers of fiber are mainly composed of keratin, which varies in composition, shape and cell size. Wool fibers contain protein and non-protein substances, which are random waste, cellulosic substances, protein wax and salt mixtures [1, 2].

Cellulose is resistant to alkalis, but proteinaceous fibrous materials are degraded in an alkaline environment, depending on the temperature and concentration of the alkali. Therefore, at the first stage of the experiments, in the following figure, the correlation of the color intensities of the samples at different pH environments with the destruction of the fiber was studied.

A number of technological and consumer properties of wool fiber materials are to some extent related to the structure of the fiber cuticle (coin-like layer on the fiber surface). However, while the exposure to wool fibers is minimal under low-temperature processing conditions, the prolongation of the dyeing process makes it difficult to obtain smooth and durable colors. In the production of woolen fiber-based textile materials, almost all the processes from their primary processing to fabric desalination - finishing are carried out on the basis of wet processing [3]. In the process of wet processing there are specific changes in the deformation properties of wool fiber materials. Such changes in wool fiber materials can be controlled by carrying out processing stages at different pH environments and temperatures.

It is known that when the dyeing process of wool fiber materials is carried out at boiling temperature, the macromolecular structure of keratin is disrupted and the fiber becomes coarse [4]. In this direction, there are known technologies for the synthesis of dyes in fiber, that is, the dyeing of fibrous materials in a cold way - with waterinsoluble azo dyes.

One of the ways to obtain stable wool dyes is the use of insoluble azo dyes synthesized directly on the fiber as a result of the azo coupling reaction between the azo component and the diazonium salt [5]. In recent years, particular attention has been paid to the development of resource-saving and environmentally friendly dyeing technologies that reduce energy costs and minimize the negative impact on the fiber structure. One promising area is the use of

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nanodispersed forms of dyes, which have increased reactivity and the ability to be more evenly distributed within the structure of the material.

A pressing challenge is to develop a method for cold dyeing wool that would eliminate the preliminary azotolization stage and the use of alkaline solutions of azo components, while ensuring the production of stable and intense colors while maintaining the physical and mechanical properties of the fiber. In this regard, it is of scientific and practical interest to study the possibility of using the side radicals of the amino acid tyrosine of the keratin macromolecule as an azo component for the azo coupling reaction with diazonium salt nanoparticles.

Materials and methods of research

The object of the study was wool fiber, previously subjected to standard preparation for dyeing (washing, degreasing and carbonization).

Diazol Orange O (double zinc chloride salt of 2-nitrobenzene-1-diazonium sulfate) was used as a diazo compound. The diazonium salt was used in a nanodispersed state with an average particle size of about 23 nm. The concentration of dye in the working solution was 10 g/l. The dyeing was done using the cold method. Wool samples were treated with a diazonium salt solution at a bath ratio of 1:50 for 15–20 min at a temperature of 20–25 °C. During the study, the pH of the dyeing medium was varied within the range of 4–8. After completion of the dyeing process, the samples were washed in a solution containing 1 g/l of technical detergents at a temperature of 80 °C for 10–15 min, then finally washed with water and dried at room temperature [6].

The reaction of formation of a colored compound was carried out directly on the fiber due to the azo coupling reaction of a diazonium salt with the side radical of the amino acid tyrosine of the keratin macromolecule.

To assess the influence [7] of dyeing conditions on the properties of the material, the color characteristics (color tone h*, saturation C*) were determined.

The results obtained and their discussion

The coloristic characteristics of the obtained colored samples demonstrate high saturation and stability of the resulting colors throughout the entire studied pH range (Fig. 1). The resistance indicators (Tab. 1) to the action of soap, sweat and friction are 4–5 points, which meets the quality requirements for textile materials for household and technical purposes.

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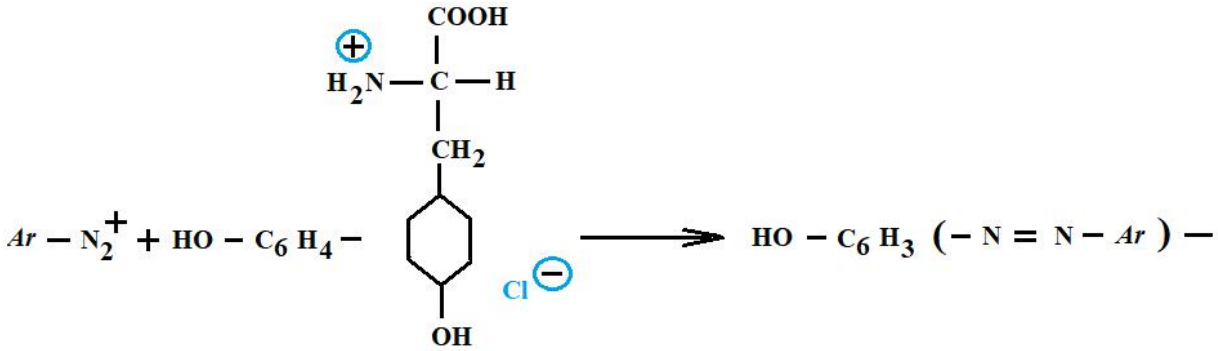
Figure 1. The color intensity of the samples is the process of dyeing pH depends on the environment

In this case, dyeing a fabric made of woolen fibers with a solution of diazole red-brick color O in a medium with pH = 6-8; different colors were obtained without negatively affecting the physical and mechanical properties of the fabric. The use of the amino acid triazine in the keratin macromolecule as a nitrogen-fixing agent allows the formation of color in wool fibers with only the diazole-forming component. That is, the azo addition reaction takes place between the hydroxy compound and the diazonium salt.

The most saturated colors are observed in neutral and slightly alkaline environments, which is associated with the peculiarities of the azo coupling reaction. The use of a nanodispersed form of diazonium salt with an average particle size of about 23 nm helps to intensify the dyeing process.



Nanoparticles have an increased specific surface area and reactivity, which ensures a more uniform distribution of the reagent in the volume of the solution and facilitates its diffusion into the surface layers of the wool fiber. This, in turn, promotes a more efficient azo coupling reaction with the functional groups of keratin and the formation of a strong bond between the dye and the fiber without the need for preliminary introduction of azo components from the outside.

Table 1. Color characteristics and indicators of wool color intensity.

№	pH environment	Color tone, h*	Color saturation, C*	Color fastness, points		
				Washing 1/2/3*	Sweating 1/2/3*	Rubbing 4/5*
1	8	74.42	49,78	5/5/5	4/5/5	4/5

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2	7	70,25	43,74	5/5/5	4/5/5	4/5
3	6	68.64	41,06	5/5/5	5/5/5	5/5
4	5	69.47	32,36	5/5/5	5/5/5	5/5
5	4	68.92	36,15	5/5/5	5/5/5	5/5

*Note: 1-change in original color; 2-coloring of white sample; 3-coloring of adjacent sample; 4-lightening of original color; 5-coloring of white sample.

Thus, the set of experimental data indicates that the proposed method ensures the production of intense, stable and uniform wool colours while maintaining its structure and performance properties, which confirms the scientific validity and technological feasibility of the developed approach.

Conclusions.

As a result of the conducted research, the possibility of cold dyeing of wool fiber with insoluble azo dyes was established without the stage of preliminary azotolization and the use of alkaline solutions of azo components. It has been shown that the use of nanodispersed diazonium salt in combination with the reactivity of the side radical of the amino acid tyrosine of the keratin macromolecule ensures the efficient occurrence of the azo coupling reaction directly in the fiber structure. The resulting colors are characterized by high saturation and resistance to soap, sweat, and friction (4–5 points), which confirms the strong fixation of the resulting azo dye in the fiber structure. Implementation of the process at a temperature of 20–25 °C and a reduced processing time ensures a reduction in energy and labor costs compared to traditional technologies. Thus, the developed method represents a scientifically and technologically effective solution for resource-saving dyeing of wool while preserving its performance properties.

References

1. Islamova Z.Sh., Nabieva I.A., Mirataev A.A. // Cold dyeing of wool // Modern Problems of Polymer Science 16th St. Petersburg Conference of Young Scientists with International Participation. St. Petersburg 2022, October 24–27. - p. 297
2. I. Nabieva, Z. Islomova, I. Tuychiev, A. Akhunbabaev and Z. Akhmedova, Science and Innovative Development 3, pp. 120-127 (2020).
3. Z. Islomova, A. Mirataev, I. Nabieva, An effective way to wash wool fibers (2019), pp. 103-105.
4. Z. Islamova, I. Nabieva and A. Mirataev, Scientific-methodical journal "Bulletin of Science and Education 13, pp.41-44 (2018).
5. Bilandžija, H.; Ma, L.; Parkhurst, A.; Jeffery, W.R. A potential benefit of albinism in astyanax cavefish: Downregulation of the oca2 gene increases tyrosine and catecholamine levels as an alternative to melanin synthesis. PLoS ONE 2013, 8, p. 80823.
6. Islamova Z.Sh., Nabieva I.A., Mirataev A.A. Cold dyeing of wool fabric // AIP Conference Proceedings, 24 January 2022, -pp. 1-6.
7. Compyuter color matching system operation and maintenance manual (Korea industrial technology ODA, 2012), p. 79.