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Investigation of the Possibilities of Dyeing Fibrous Textile Materials with Natural Biopolymers

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Annotation. In this article, the possibility of eco-friendly dyeing of natural silk fabric was investigated. As an alternative to synthetic dyes, biopolymers and aromatic compounds derived from various industrial waste sources were utilized. The research compared three different samples, demonstrating that an increase in the number of functional groups in the composite composition led to changes in color intensity. As a result,, the color intensity of Sample 3 increased by 69.52 % compared to Sample 1 and by 13.47 % compared to Sample 2. The L value (lightness) decreased by 23.7 units, and the h* value (hue) dropped by 27.8 units after the addition of IPEK and biopolymers. In contrast, the C* value (color saturation) of Sample 3 increased by 14.77 % compared to Sample 1 and by 7.5 % compared to Sample 2. According to the CIELAB color space diagram, the a* and b* coordinates of the samples shifted respectively from green to red and from yellow to blue. The samples also exhibited excellent to good color fastness to soap treatment, indicating high durability of the dyed fabrics.*

Keywords: silk, polyvalent metal salt, aromatic compounds, natural biopolymers, color intensity, color saturation.

In recent years, the increasing quality requirements for textile products and strong competition have posed the task of implementing resource-efficient, biodegradable, and environmentally friendly innovative technologies for manufacturers. If the creation of highly eco-friendly products is intended, treating natural fiber materials with natural biopolymers and various dyeing compositions is considered the most optimal choice. Although natural biopolymers and various dyeing compositions are environmentally friendly, many researchers have focused on technical problems and shortcomings that hinder their widespread industrial application. The main problem for the industry is their low durability, poor adhesion, and uneven distribution. To improve dye fastness and fixation on fabric, metal salts (mordants) are usually required [1]. The type of bonding between natural biopolymers and various dyeing compositions directly affects dye fastness. Chemical fibers are incompatible with natural biopolymers; natural biopolymers are used only for dyeing natural fibers. Cotton, silk, wool, flax, hemp, and other natural fibers have always been preferred over chemical fibers due to their unique properties. Additionally, among natural fibers, protein fibers are easier to dye because they contain ion groups [2]. For example, silk fibers are gaining popularity in the textile industry due to their aesthetic brightness, high affinity to natural extracts, environmental friendliness, and good compatibility with various dye classes [3]. Due to its softness, high breathability, antibacterial and photoprotective properties, and prevention of many diseases harmful to human health, silk is becoming increasingly popular [4, 5]. Therefore, there is a need for new innovative technologies for the production, dyeing, and finishing of natural silk fabric.

Taking the above into account, within the scope of this scientific work, the possibilities of using various compositions to produce colors that meet modern requirements on natural silk fabric were studied. Instead of using any class of dyes, colors were created using polyphenol, biopolymers, and polyvalent metal salts, according to their nature.

Methodology section

For the study, 100 % natural silk fiber with a whiteness degree of 87 % and linear density of 9.8 g/m² was used. As polyvalent metal salts, $CoCl_2$, $NaNO_2$, CH_3COONa and resorcinol were employed.

Dyeing of natural silk fabric with polyvalent metal salts

Accordingly, all reagents were prepared under laboratory conditions (2 g/l polyvalent metal salt, 1.5 g/l $NaNO_2$, 1 g/l CH_3COONa, 1 g/l SAM, 2 g/l polyphenol) and calculated at M = 100 for 5×5 cm natural silk (organza) fabric. The fabric was soaked in distilled water obtained from BE-4 bidistiller and heated to boiling temperature before adding the fabric. The dyeing process was carried out for 20 minutes, followed by washing once with hot water and three times with cold water. The fabric was then dried in an MST-55 model drying oven at

75–80 ºC for 10 minutes and subsequently ironed.

Determination of color intensity K/S

The color intensity of the dyed samples was studied using a CCM-Computer Color Matching X-rite spectrophotocolorimeter device at the "Kor-Uz Textile Technopark" scientific laboratory [6].The CIELAB formula, recommended by the International Commission on Illumination for determining color quality parameters and lighting, was used [7]. The Lab color model was employed to evaluate color characteristics. Similar to geographic coordinates of longitude, latitude, and altitude, the L*, a*, and b* color values allow for identifying and conveying information about the color. The L* coordinate describes lightness, a* represents the red or green component, b* indicates the yellow or blue component, c* represents color saturation, and h* expresses hue.

Resistance to soap washing

To determine the colorfastness of dyed fabrics to soap solution, a sample was prepared by stitching a white untreated fabric on one side of the fabric and another white fabric dyed with the tested dye on the other side. The resistance to soap washing was tested using a Wash Fastness DL-2002 washing machine with a bath ratio of 50. A soap solution of 5 g/l was heated up to 40 ºC and the treatment was carried out for 30 minutes. After the treatment, the sample was rinsed in cold water and dried. The samples were evaluated against a color standard. The rating consists of three numbers: the first indicates the color of the sample, the second shows the staining degree on the white fabric stitched to the right side of the sample, and the third represents the staining degree on the white fabric stitched to the reverse side of the sample (for example, 4/3/4).

Experimental section

Within the scope of this scientific work, the dyeing process of silk fabric was carried out not using chemical dyes but using various dyeing compositions and mordants for color fixation. Ferric sulfate ($Fe_2(SO_4)_3$) was used as the polyvalent metal salt, and dyeing was performed for different durations to study color intensity. The physico-chemical indicators of the samples dependence on time are presented in Table 1.

Table 1– Color quality and soap fastness indicators of natural silk fabric dyed with polyphenol, IPEK, biopolymer, and $CoCl_2$ metal salt

№	Samples	L*	a*	b*	C*	h°	Soap fastness, rating
1	2	3	4	5	6	7	8
1		52,66	10,48	30,91	32,64	71,27	5/5/5

End of table 1

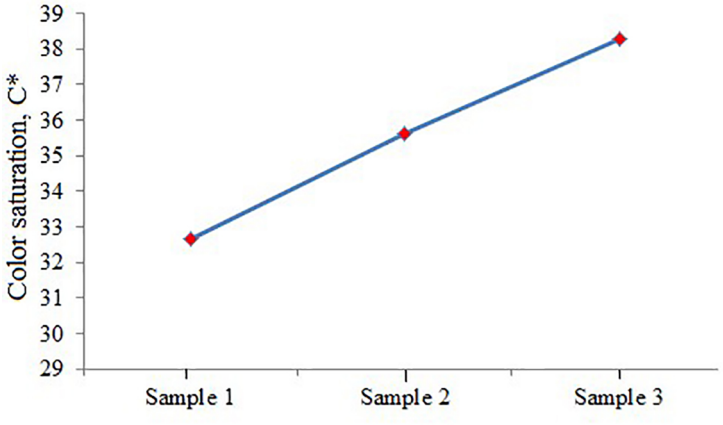
1	2	3	4	5	6	7	8
2		26,30	27,28	22,94	35,64	40,07	4,5/4,5/4
3		28,96	27,79	26,35	38,30	43,47	4,5/5/4,5

The color quality indicators of the samples are also shown in Table 1. Accordingly, Sample 1 was dyed with polyphenol and metal salt, Sample 2 with polyphenol, IPEK, and metal salt, and Sample 3 with polyphenol, IPEK, biopolymer, and metal salt.

According to the indicators presented in the table, the L* value (color lightness) decreased by 23.7 units and the h* value (hue) decreased by 27.8 units after the addition of IPEK and biopolymer, while the C* value (color saturation) increased. Figure 1 below shows the relationship between the increase in the number of functional groups and the C* color saturation.

According to the provided data, the color saturation of Sample 3 increased by 14.77 % compared to Sample 1 and by 7.5 % compared to Sample 2.

Based on the a* and b* coordinate values interpreted from the CIELAB color diagram [8], the samples shifted respectively from green to red and from yellow to blue. Movement toward the edge of the colorfulness range indicates an increase in lightness and purity of the color.



Sample 1 contains polyphenol and metal salt;
Sample 2 contains polyphenol, IPEK, and metal salt;
Sample 3 contains polyphenol, IPEK, biopolymer, and metal salt

Figure 1 – Dependence of C* color saturation on the presence of biopolymer in silk fabric dyed with polyvalent metal salt

Color fastness to soap washing was tested using the Wash Fastness DL-2002 washing machine. According to the results, Sample 1 was rated excellent, while the other samples were rated good to excellent.

According to the data presented in Figure 2, the increase in the number of functional groups in the composition leads to an increase in the color intensity of the

samples. Specifically, the color intensity of Sample 3 increased by 69.52 % compared to Sample 1 and by 13.47 % compared to Sample 2.

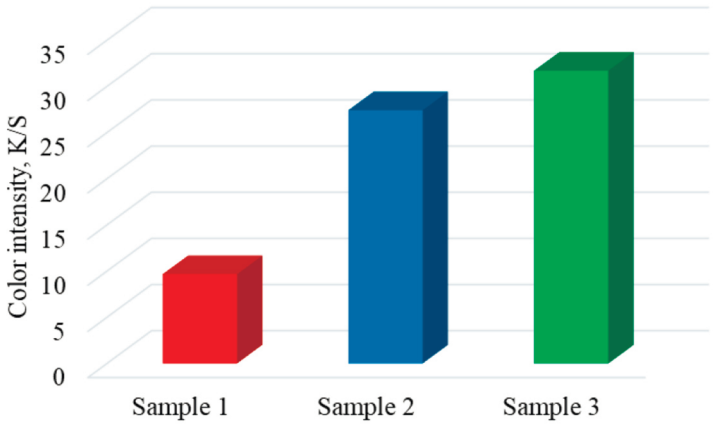


Figure 2 – Dependence of color intensity on the presence of biopolymer in silk fabric dyed with polyvalent metal salt

Conclusion

The present study demonstrates that dyeing natural silk fabric with polyvalent metal salts, while incorporating natural biopolymers that are eco-friendly and beneficial to human health, enables expansion of the color palette without the use of synthetic dyes. This approach facilitates a straightforward and energy-efficient dyeing technology, reducing processing time and energy consumption, as confirmed by spectrocolorimetric analyses. Consequently, the range of achievable colors was significantly broadened.

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Получение эфира целлюлозы и применение его в текстильной промышленности

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Реферат. В данной работе приведены исследования по получению водорастворимого эфира гидроксипропилметилцеллюлозы из хлопковой целлюлозы на основе щелочного метода, для применения в качестве загущающего компонента печатной краски с целью печатания текстильных материалов активными красителями. Из щелочной целлюлозы при дальнейшем реагировании её с метилхлоридом и пропиленоксидом получен эфир гидроксипропилметилцеллюлозы. Проведен анализ показателей ИК-Фурье спектроскопии химического строения эфира целлюлозы. Оценены такие характеристики ГПМЦ, как белизна, прозрачность, температура геля, содержание золы и Ph. Для проведения экспериментальных анализов отобраны пробы из 5 различных по структуре образцов готового порошка, вязкость которых отличается. Для дальнейших исследований данного эфира в качестве загустителя для печатания х/б тканей активными красителями одностадийным запарным и термофиксационным способами отобран образец №5. Для печатания использовался активный краситель BEZEMA ROT S-3B150 RED ACTIVE (X) Na_2SO_3-Kp-T-X (ДХТА). По традиционной технологии приготовлен загуститель на основе альгината натрия в виде 8 % раствора. Вязкость такой концентрации раствора альгината натрия приравнивается к 1 % раствору водорастворимого эфира. Тем самым доказывается экономичность использования данного эфира в качестве загустителя для печатания текстильных материалов активными красителями.