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Dyeing Wool Fabric with an Additive from a Plant(Rubia Tinctorum L)

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Abstract: The object of the present study a bleached fabric object with a surface density of 96 g/m^2, a whiteness of 36.6% and a capillary content of 134 mm/h, consisting of 100% wool fibers, has been studied. Roe (*Marena-Rubia tinctorum L.*) root powder salts Na2HPO4, CuSO4, K2Cr2O7, FeSO2, Al2(SO4)3 were used as carcinogens to carry out the dyeing process. Dyeing of wool fabric samples was carried out according to the following technological sequence: wool fabric samples that have undergone finishing processes are treated for 60 minutes at a temperature of 90-95^{0}C in a solution containing 3-10% Marena and 2.5 g/l acid, relative to the fabric mass. 3% acetic acid is added to the dye solution and the process is continued for 10 minutes at the same temperature. The color characteristics of wool fabric dyed with marena were determined on a laboratory colorimeter under standard irradiation D65. To systematize color characteristics, the color circle system, a L.a.b. color model was used. Geographic coordinates - latitude, longitude and height, etc. L *, a * i b * color values provide information on where the color is located and all relevant information. The L * coordinate indicates the color brightness, C * - the color saturation, h - the color tone, a * - the presence of red or green, b * - the presence of yellow and blue. The color properties of all samples were determined at a wavelength of 360 nm. The possibility of producing ink color and yellowish-brick colors has been proven on the basis of practical experiments.

INTRODUCTION

By the beginning of the twentieth century, synthetic dyes have almost completely replaced natural dyes in the process of dyeing textile materials and printing pattern practices. This is primarily due to the growing demand for composite fiber-based textile materials, including finished textile products, in connection with the development of the chemical industry. This situation has led to the deterioration of the environmental situation around the world, and scientists are currently conducting a number of studies to address the problem of producing eco friendly textile products (eco-textile) into the consumer market.

According to the type of process in the chemical processing of textile materials, each kilogram of fabric consumes from 77 to 108 liters of water [1]. In addition, the production of synthetic dyes consumes a large amount of fresh water, the bulk of which is discharged into waterways as wastewater. Various industry references state that the production of 1 ton of dyes requires 225 tons of water, while in the production of complex dyes the volume can increase up to 160-170 tons. Hundreds of tons of mineral and organic compounds are released into the water basins by dye manufacturers, which cause further environmental problems.

In addition to the production of synthetic dyes and their negative impact on the environment in the textile industry, bedding and clothing made from fabrics dyed with synthetic dyes can cause various allergies and other diseases in consumers suing them. In this regard, the solution of these problems is the creation and introduction into production of technologies for more efficient use of natural dyes.

THEORETICAL BASIS

As a rule, wool fiber products are dyed in a variety of ways using synthetic dyes in various formd of fibers, yarns and fabrics, including active, chromium, acidic and acidometallic complex dyes. The fact that a strong acidic environment is a prerequisite during a dying process for synthetic dyes and it has a negative effect on the morphology of the wool fiber, causing the wool to become brittle and hardened. In addition, acid-dye complex dyes contain heavy metals such as nickel, cobalt, chromium, copper, which form a strong coordination bond between the organic dye and fiber, resulting in a high concentration of such heavy metals in woolen garments. Oeko-Tex analyzes the presence of formaldehyde, heavy metals, dyes and other chlorinated substances in household textiles and ready-to-wear garments by 17 research institutes under the auspices of the international community. All technological processes are strictly controlled [2].

Wool fibers are longer than cotton fiber, have low strength but high elasticity. Wool fiber absorbs moisture well and retains its composition for a long time.

When wool is a hygroscopic fiber and dried at a temperature of 100-105^{0}C, it loses moisture, the fiber becomes rough and the mechanical properties deteriorate. Re-wetting leads to a gradual restoration of the initial properties of wool fibers.

The wool industry is one of the textile industries, where wool processing from pure wool or its other fiber mixtures produces yarns of different linear densities, woolen fabrics, various technical and special fabrics, carpets and rugs and non-woven materials, and this issue is very relevant. Washing of wool fiber accelerates the primary processing of it, physical modification of the fiber surface in order to improve it, the use of oxidation- reduction-reduction systems in the finishing process, plasma processing, chitosan solutions [3] recommended for use.

The presence of chromium and other heavy metals in the synthetic dyes used in the dyeing process of wool fiber materials, as well as the fact that most acidic and active dyes are azo dyes, that all allows us to assume that these products do not ensure human health and environmental safety.

There are three ways to reduce the environmental problems faced by textile enterprises, which are:

- In depth analysis of technological procedures and components for the greening of certain technologies;
- An introduction of completely new environmentally friendly technologies;
- A purification and treatment of technological wastewater

These areas include reducing the amount of synthetic dyes in the chemical processing of textile materials, including protein fibers, reducing the consumption of dyes in the dyeing of wool fibers [4], as well as the effective use of natural dyes in the process [5,6]. The use of natural dyes in dyeing processes is important not only for their ecological safety over synthetic dyes, but also for the complexity of their composition, a possible emergence of various negatives effects, a formation of colors that otherwise cannot be formed with synthetic dyes. In a production of natural dyes, the passage of plant wastes into the wastewater, rather than toxic compounds, allows them to be used as fertilizers, and this provides a closed-loop system in textile chemical technology [7].

In the study of the possibility of dyeing wool fibers with natural dyes, experimental work was carried out on the intensification of the process of plant extraction of the dye and the strengthening of the color with small concentrations of irritating salts. The following complex-forming agents were used as stimulants: $CuSO_4$, $FeSO_4$, $K_2Cr_2O_7$, $KAl(SO_4)_2$ From the analysis of the experimental results, when Fe^{2+} and Cu^{2+} sulfate salts were used as irritants, higher intensity colors were formed than when the remaining irritants were used in wool fibers.

Due to the nature of the salts, the wool fibers were dyed with dyes derived from onion peel, resulting in a light, medium and dark brown color. It was also found that the color intensity of samples stained with the dye used in the electrolyte separation process was higher than the color intensity of the samples stained with the dye isolated under electrolyte conditions [8].

Roya (Marena - Rubia tinctorum L.) plays a special role in dyeing wool fiber materials with natural dyes. The use of Royan in the dyeing process was known as back as in the 3rd century BC. The roots and rootstock of roya are used to obtain dyes. An average of 13-14 quintals of dry roots can be harvested from each hectare of land [9].

METHODICAL PART

In the study, a bleached fabric with a surface density of 96 g / m2, a whiteness of 36.6% and a capillary content of 134 mm / h, consisting of 100% wool fibers, was studied as an object. Ruyan root powder offered by Yodgorlik LLC was used as a natural dye. Salts of sodium hydrogen phosphate (Na_2HPO_4), copper sulfate ($CuSO_4$), potassium dichromate ($K_2Cr_2O_7$), iron sulfate ($FeSO_2$), aluminum sulfate ($Al_2(SO_4)_3$) were used as astringents.

Dyeing of wool fabric samples was carried out according to the following technological sequence: wool fabric samples that underwent finishing processes were treated in a solution of 3-10% Marena (Rubia tinctorum L.) and 2.5 g/l at a temperature of 90-95^0 C for 60 minutes, then 3% acetic acid was added to the dye solution and the process continued for 10 minutes at the same temperature. After the dyeing process, the samples were compressed (compression ratio -100%) and washed. The first washing process was carried out at a temperature of 40^{0}C in a solution containing 2 g/l SAM for 10 minutes, the subsequent washing processes were carried out in warm and cold water for 10 minutes each.

The color and quality characteristics of the samples were tested in the scientific laboratory

"Kor-Uz Textile Technopark" using a device model X-Rite Ci7800 [10].

OUTCOME ANALYSIS

Wool fiber is a protein fiber that is distinguished by its heat resistance, hygroscopicity, fire resistance, antistatic properties and specific odor. However, wool fibers have its own serious drawbacks, for example, wool fibers shrinks significantly during washing. By controlling the technological procedure in the dyeing process, while maintaining the positive properties of wool fiber materials, it is possible to reduce shrinking. By dyeing protein- fiber textile materials with natural dyes, there is a better chance for the production of eco-textile products. It is important to change the process of chemical treatment of natural fibers to environmental technologies by introducing environmentally friendly, natural, competitive, plant-based dyes to local manufacturers.

The present study looks at the possibility of dyeing wool fiber fabrics with a natural dye - Roya (Marena - Rubia tinctorum L.). In the process of dyeing with natural dyes, the type of dye and its concentration affect the color intensity and formation in wool fiber materials [11].

In the study, 4 wool fabric samples were dyed under the same conditions and in the same concentration of yarns and four different concentrations of dye solution in order to study the effect of the yarn type on the woolen fabric color quality.

The roya root powder was thoroughly mixed in cold water to the required volume with the required amount of water, and the dyeing process was carried out by adding 4 different dye solutions to the dye solution. The color characteristics of wool yarn dyed with roya were tested on a laboratory colorimeter at D65 standard irradiation. To systematize color characteristics, the color circle system and L.a.b. color model was used (Figure 1).

Geographic coordinates - latitude, longitude and height, etc. L *, a * and b * color values provide information on where the color is located. The presence of color, b * - indicates the presence of yellow and blue. The color properties of all samples were determined at a wavelength of 360 nm, the results obtained are given in Table 1.

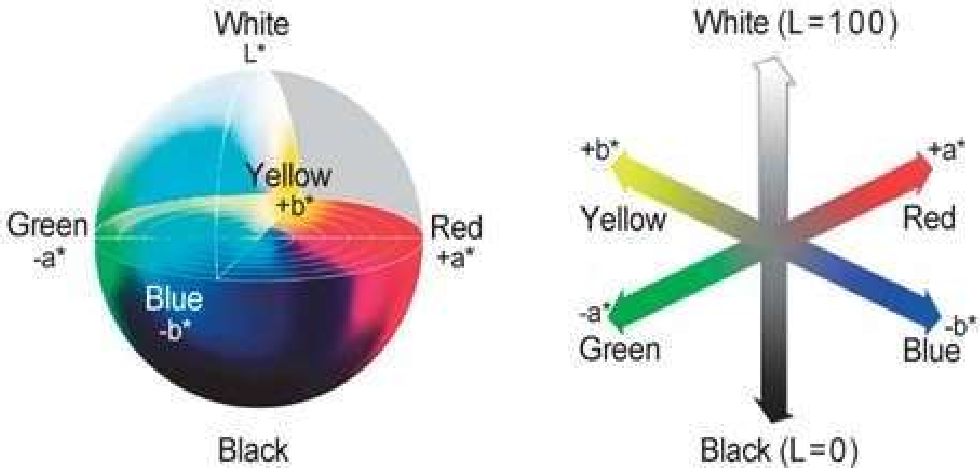


FIGURE 1. CiE Lab color field model (source: www.diesopranos.de/cie-lab)

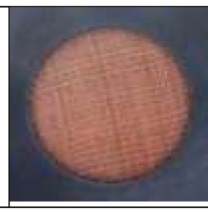
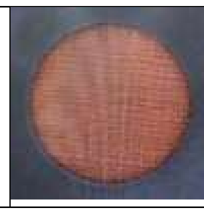
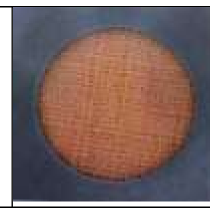
TABLE 1. Dependence of color performance of wool fiber fabrics on the concentration of the dye and the type of dye.

Salt types	Dye concentration %	Colour lightness, L*	Colour intensity,C*	Colour coordinates	
				a*	b*
Na2HPO4	3	71.87	24.00	14.97	18.76
	5	67.86	27.36	19.51	19.17
	7	66.06	30.69	22.21	21.18
	10	61.32	23.83	18.89	14.53
CuSO4	3	67.89	24.68	10.82	22.18
	5	69.44	22.58	6.28	21.69
	7	62.81	25.86	12.78	22.48
	10	57.81	22.74	5.84	21.98
K2Cr2O7	3	57.31	31.39	9.20	30.01
	5	57.41	23.22	7.76	21.88
	7	53.03	23.13	11.27	20.20
	10	40.87	21.50	19.93	8.07
FeSO2	3	62.49	19.95	11.22	16.50
	5	63.28	18.32	9.31	15.78
	7	64.11	18.89	10.06	15.98
	10	52.78	21.05	10.91	18.00
	3	71.69	23.93	16.97	16.88
	5	70.20	28.00	20.89	18.64

$Al_2(SO_4)_3$	7	66.33	32.17	25.90	19.08
	10	69.85	29.65	18.58	23.10

The results show that bright colors are formed when sodium hydrophosphate and aluminum sulfate are used as irritants. When the dyeing process is carried out in the presence of Na_2HPO_4, we can see that the concentration of the dye increases from 2% to 7%, the b * coordinate shifts from blue to yellow and the a * coordinate shifts from green to red. Therefore, in the presence of this irritant, pink colors were formed at all concentrations of the dye (Table 2).

TABLE 2. Dependence of the color of dyed wool fabric in the presence of Na_2HPO_4 on the dye concentration.

Dyed wool fabric samples			
			
Dye concentration, %			
3	5	7	10

The change in the concentration of the dye in the dye solution in the presence of of $Al_2(SO_4)_3$ did not affect the shift of color coordinates, and at all its concentrations light and bright brick colors were formed (Table 3).

The mummification of dull colors by the application of copper sulphate and ferrous sulphate metal salts in the dyeing process is explained by the color brightness values in Table 1. However, an increase in the concentration of the dye in the solution leads to an increase in color and the formation of dull but dark colors.

TABLE 3. Dependence of the color of woolen fabric dyed in the presence of $Al_2(SO_4)_3$ on the concentration of the dye

Dyed wool fabric samples			
			
Dye concentration, %			
3	5	7	10

During the dyeing process in the presence of potassium dichromate salt, the concentration of the dye causes the a * and b * coordinates to shift in opposite directions without affecting the color brightness. The result was an additional reddish-purple color without mixing the two primary colors, i.e., blue and red (Figure 2). From the data given in the table, we can see that the color saturation decreases with increasing dye concentrations in solution during the dyeing process with all salts other than aluminum sulfate. The degree of color saturation in these samples indicates that at high concentrations the colors approach the central axis in the color field L *, a *, b *, i.e. the color purity decreases.

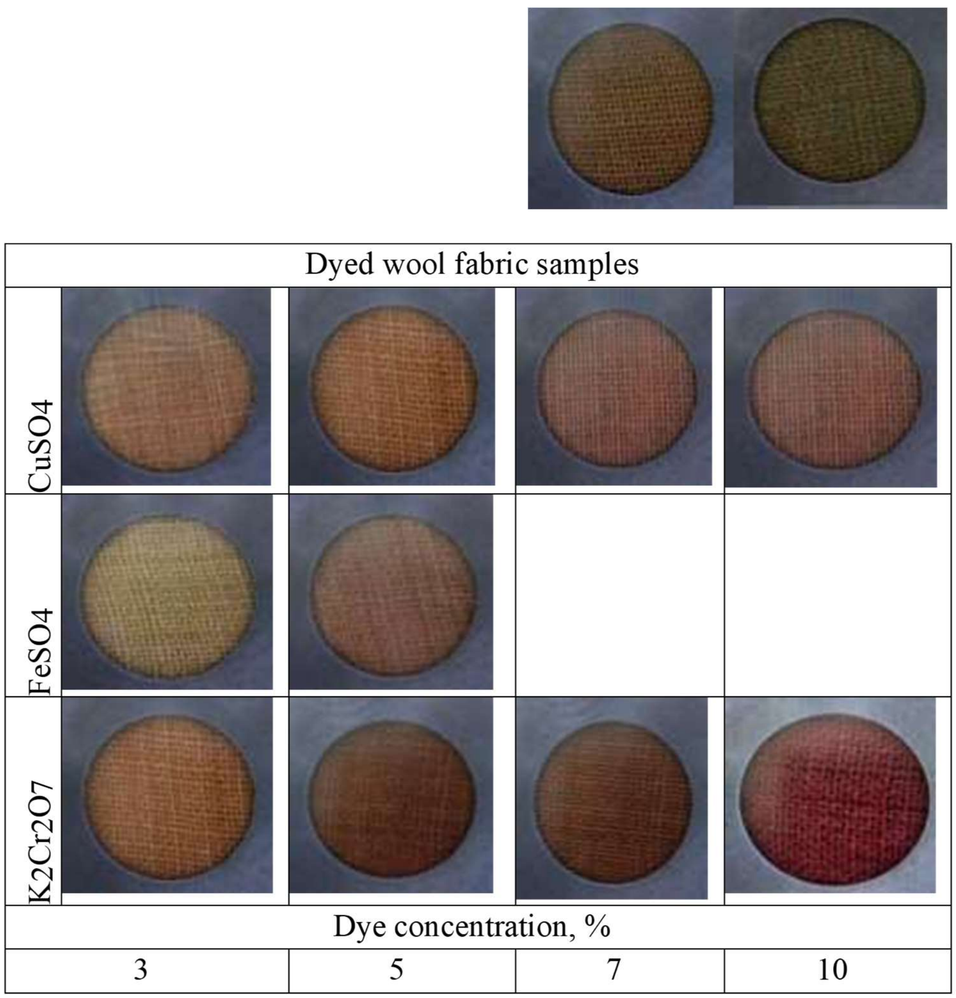


FIGURE 2. Dependence of the color of woolen fabric dyed in the presence of CuSO4, FeSO2, K2Cr2O7 on the concentration of the dye.

Color defines the position of a color in the spectrum, which is the main characteristic of a color. The spectral return coefficient is of particular importance in the evaluation of color quality indicators. This indicator can be used to set the color intensity. The results of the study on the effect of the type of dye and the concentration of the dye on the color and spectral reflection coefficient of woolen fabrics dyed with rye are presented in Table 4.

TABLE 4. Dependence of the color and spectral return coefficient of wool fabric dyed with roya on the type and concentration of rust

Salt types	Dye concentration	Colour shade (h^0)
Na_2HPO_4	3%	51.41
	5%	44.50
	7%	43.65
	10%	37.57
$CuSO_4$	3%	64.01
	5%	73.86
	7%	60.39
	10%	75.13
$K_2Cr_2O_7$	3%	72.96
	5%	70.47
	7%	60.84
	10%	22.06
$FeSO_2$	3%	55.78
	5%	59.46
	7%	57.81
	10%	58.77
$Al_2(SO_4)_3$	3%	44.85
	5%	41.74
	7%	36.37
	10%	51.18

Although the concentration of the dye in the solution has varied by the same values during treatment with all the abrasives, the color of the wool fabric samples changed differently. This may be due to the color of the saline solution. Due to the fact that the salts of aluminum sulfate and sodium hypophosphate formed a transparent colorless solution, the color of the sample did not change with increasing concentration of the dye in the solution. Because ferrous sulfate formed a light brown color, the resulting colors were dull and it significantly affected the color tone. Copper sulphate and potassium dichromate salts form brick-colored and air- colored solutions, respectively, with the help of which we can see that blue and red hues appear in the hues of thedyed samples.

Color determines the position of a color in the spectrum, which is the main characteristic of color. The spectral return coefficient is of particular importance in the evaluation of color quality indicators. This indicator can be used to set the color intensity. The results of a study on the effect of the type of yarn and the concentrationof the dye on the color intensity and spectral return coefficient of dyed woolen fabrics are presented in Table 5.

TABLE 5. The dependence of the color intensity of wool fiber fabric on the concentration of the dye and the type of irritant.

Salt types	Dye concentration	Color intensity, K/S	Reflection coefficient, R
Na_2HPO_4	3	10.2	17
	5	11.5	16
	7	13	14
	10	14	12
$CuSO_4$	3	15	11
	5	15.8	10
	7	16.4	9
	10	17.6	7
$K_2Cr_2O_7$	3	17.6	7
	5	18.2	6
	7	19.4	5
	10	20.1	4
$FeSO_2$	3	14	12
	5	15	11
	7	15.8	10
	10	19.4	5
$Al_2(SO_4)_3$	3	9.3	18
	5	10.2	17
	7	11	15
	10	14	12

The results of all experiments studied showed that the color intensity had correspondingly high values with increasing concentration of the dye in the dye solution depending on the type of dye. Depending on whether the caustic solution is transparent or colored, the color intensity increases from 14% to 50,5% according to the dye concentration.

That is, high-intensity copper sulphate and potassium dichromate were obtained when crushers were used. The data in the table show that the use of potassium dichromate in the process of dyeing the same fiber substrate in the same technological process can obtain darker colors than other chlorinators. This saves on dye consumption and energy resources.

CONCLUSION

The ability to create pink, reddish-black and yellow-brick colors with multiple shades and brightness witha single dye by selecting the type of dyes and changing the concentration of the dye in the dye solution during the natural dyeing process of natural fibers, including wool fibers has been proved based on experiments.

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