INFLUENCE OF DYEING TECHNOLOGICAL CONDITIONS ON THE COLOR CHARACTERISTICS AND ANTIBACTERIAL PROPERTIES OF COTTON-POLYESTER TEXTILES

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ABSTRACT

The article is devoted to establishing the influence of an intensifier on color characteristics, color fastness indicators, and antibacterial properties of textile materials. The proposed method confirms the expediency of using the selected intensifier when dyeing cotton-polyester textile materials. Concentrations of the intensifier during their treatment were determined. The influence of the intensifier on the color intensity and its resistance to physicochemical factors was established. The antibacterial activity of the treated samples was confirmed.

KEYWORDS

Intensifier; Triclosan; Dyeing; Cotton-polyester Textile; Antibacterial Properties.

INTRODUCTION

In recent years, the textile industry has been widely developing the direction of functionalization of textile materials to provide new properties [1–5]. A special case is antibacterial functionalization. The intensive development of society has led to the mass spread of viruses and microorganisms, causing numerous epidemics and pandemics, such as smallpox, cholera, tuberculosis, yellow fever, Spanish flu and coronavirus [6].

The main and most promising direction of expanding the range and improving the properties of textile materials of various compositions is not so much the development of new types of chemicals for the production of textile fibers, but the modification of existing fibers and finished textile materials in order to give them new properties [1–9].

A fairly wide range of natural and synthetic compounds have antimicrobial activity, but many of them are dangerous for humans and animals. Therefore, only some chemical compounds can be recommended for practical use as antiseptic preparations [8, 9].

The main method of imparting antibacterial properties to textile materials is the use of antimicrobial preparations (biocides).

The requirements for biocides used for application to textile materials are as follows:

- effectiveness of action against the most common microorganisms at a minimum concentration of the antibacterial substance and a maximum duration of its action;
- non-toxicity to the human body of the biocide concentrations used;
- absence of color and odor;
- low cost of the biocide, which should not lead to a significant increase in the price of the finished product with antibacterial properties;
- no deterioration in the physical, mechanical, hygienic and other properties of the textile material due to its modification with biocidal substances;
- combination with the preparations used for processing materials and textile auxiliaries used in the production process of the material;
- light resistance, weather resistance.

Providing antibacterial properties to textile materials protects the surface of the material from the action of various microorganisms, as well as protects the human body from the action of pathogenic microflora that gets on textile materials. Otherwise, it is necessary to create conditions for a preventive attack by the textile material on pathogenic bacteria and fungi to prevent their action on the object of protection.

An effective way to protect humans from viruses and harmful microorganisms is the use of protective textile

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materials. Consumers have focused directly on medical products, and as a result, the use of textiles in the field of medicine, hygiene and health care has become much wider due to new antimicrobial drugs, functional fibers, new chemical coatings and technologies. Textile materials treated with triclosan could be a good alternative in obtaining antibacterial characteristics of textile products for medical applications, such as face masks, medical gowns and wound dressings [7, 10]. Thus, it is advisable to investigate the possibility of using triclosan as an intensifier in the dyeing of textile.

There are known studies on the improvement of various antimicrobial components in the creation of textile materials for human protection, including quaternary ammonium compounds, triclosan, polybiguanides, N-galamines and metals such as silver and antimicrobial substances of natural origin [7, 10-12]. There are various methods for obtaining antimicrobial efficiency of the fabric.

Triclosan or 2,4,4'-trichloro-2'-hydroxydiphenyl ether is a product that has antimicrobial activity and, by the mechanism of action on microorganisms, inhibits their growth, affecting the biosynthesis of fatty acids by stopping the biosynthesis of lipids through a reaction with amino acid residues of the enzymatically active center inside the membrane [12]. One of the methods for obtaining antibacterial textile material is the treatment of bleached cotton fabric with triclosan. Subsequently, it was subjected to the action of polycarboxylic acids, namely: 1,2,3,4-butanetetracarboxylic and citric acids as crosslinking agents to prolong antibacterial properties. The surface of the fibers treated with 1,2,3,4-butanetetracarboxylic acid had a larger crosslinking area, and the surface of the fabrics, under the action of citric acid, had a larger number of deformations due to mechanical and chemical effects after 50 washes [13].

In work [14], the effectiveness of using triclosan in imparting antibacterial properties to viscose-polyester nonwovens was proven. The purpose is achieved by using the method of dry spraying of synthesized polylactide microspheres containing triclosan onto nonwovens. The triclosan content in the microspheres ranged from 4.65 to 4.95 wt.%. The antibacterial nonwovens were investigated using the inhibition zone measurement method, having antibacterial properties against Gram (+) – Staphylococcus aureus and Gram (-) – Klebsiella pneumoniae from 4 to 9 mm [14].

Cotton-polyester textile materials have been widely used in many industries [15, 16]. The use of this range of materials in the manufacture of textile products is explained by sufficient hygienic and high strength characteristics. Providing cotton-polyester textile materials with special antibacterial properties will provide increased human protection from the pathogenic effects of the environment.

Intensifier contribute to the swelling of -polyester textile materials before dyeing. In this work, triclosan is used as an intensifier. Due to their small size and affinity for the textile material, intensifiers easily penetrate the fiber, adsorb on active centers and break the bond between neighboring polyester macromolecules. This leads to loosening of the polymer, lowering the glass transition temperature and facilitating the diffusion of the dye into the polyester fiber. And at the same time provides antibacterial properties to the cotton-polyester fabric.

According to the current State Sanitary Norms and Rules "Textile, Leather and Fur Materials and Products. Basic Hygienic Requirements of Ukraine", triclosan is not a prohibited substance. Triclosan is widely used as an antibacterial agent in various fields of application, including hygiene products, textile products and medicine; it is in the manuscript with references to literary sources. The environmental problem of triclosan with other compounds was demonstrated in the articles [7, 10], so they focused more on their original research results. We plan to determine the amount of triclosan in the used dye bath in the process of preparing for industrial use, which requires additional research.

The purpose of this work: to establish the effect of the intensifier concentration on the color intensity, color fastness, on the mechanical properties and antibacterial properties of the fabric of cotton-polyester fabric.

EXPERIMENTS

Materials

For studies as textile materials was used cotton-polyester fabric containing 53% polyester and 47% cotton. This is a fabric with a thickness of 222±5 g/m² and it has a twill weave, see Table 1.

Table 1. Properties of textile substrate.

Yarn fineness (warp)	30–40 tex
Yarn fineness (weft)	30–35 tex
Warp density	~40–45 threads/cm
Weft density	~30–35 threads/cm
Thickness	~0.5–0.8 mm
Surface density	220 g/m²

Methods

Textile materials with antibacterial properties are prepared as follows. Pretreatment of fabric samples was as follows: dispersing agent (TC-Dispergator DTS, non-ionic, on the basis of polyglycolether-derivates, Textilcolor AG, Switzerland). DTS dispersing agent was poured into a glass, then the intensifier (triclosan CAS: 3380-34-5) was added and mixed thoroughly, adding warm distilled water. The resulting solution was heated to melt the intensifier and whipped until an emulsion was formed. The emulsion for pre-treatment was poured into a vessel with fabric. Treatment of fabric samples with triclosan emulsion was carried out under the following conditions: bath module 10; DTS dispersing agent concentration – 2 g/l; intensifier concentration (triclosan) 1 – 5 g/l; duration 1 h, temperature 100°C.

Dyeing conditions of polyester fabric component: bath module 10; disperse dye blue 2 BLN CAS: 12217-79-7 (1-3% wt.) (Hongda Chemical Industrial Co., Ltd, China); DTS dispersing agent (2 g/l); acetic acid (CAS: 64-19-7) (1 g/l); duration 1 h; temperature 100°C. Dyeing conditions for the cotton component of the fabric: bath module 10; table salt (40 g/l); active blue dye V-RN (1.5-4% wt.) (Yorkshire Farben GmbH, Germany); soda ash (CAS: 497-19-8) (5 g/l); caustic soda (CAS: 1310-73-2) (2 g/l); duration 85 minutes; temperature 60°C. The dyeing conditions for the cotton component in all experiments were unchanged.

After dyeing, the samples were washed in hot and cold water, and also treated in a soap-soda solution to remove residues of unfixed dye.

The identified color values were classified according to the coordinates set by the Commission International de l'Eclaireage - CIELAB 1976 in ISO 2470 standards. To determine the color difference, a Datacolor SF 600 spectrophotometer (Datacolor, USA) was used, which performs measurements according to CIELAB-76. The values of color coordinates and reflection spectra of stained samples are systematized and displayed on a personal computer using the ProPalette program. To conduct the analysis, a reference sample was first measured (with which others were subsequently compared), then the deviation values of such indicators as E, L, C, H of samples stained with an intensifier or stained under other conditions were measured.

The color fastness of the obtained textile material samples to washing (DSTU ISO 105-S06:2009), sweat (DSTU ISO 105-E04:2009), and dry and wet friction (DSTU ISO 105X12:2009) was studied in accordance with standard test methods.

The antimicrobial activity of the samples was determined by the method of zones of inhibition of growth of test strains of microorganisms (DSTU EN 13727:2019). An indicator of the antimicrobial activity of materials is the zone of inhibition of growth of test strains (gram-positive opportunistic microorganisms Staphylococcus aureus and gram-negative Escherichia coli) around the sample of the tested material.

RESULTS AND DISCUSSION

Textile materials containing polyester fiber systems are characterized by a dense structure. This significantly slows down diffusion processes, therefore, when dyeing such textile materials, high-temperature dyeing methods are used (at a temperature of 130 – 140 ° C under pressure or a thermosol method with a temperature above 200 ° C). At boiling temperatures, only light color shades can be achieved. To reduce the density of the polymer structure and obtain medium and dark colors at low temperatures, dyeing processes using intensifiers (carriers) have been developed [17-19].

Thus, it is relevant to study the dyeing process of cotton-polyester textile materials with an intensifier - triclosan (5-chloro-2(2,4-dichlorophenoxy)phenol), which has confirmed antibacterial and antimicrobial properties of a wide spectrum of action. The use of this component as an intensifier before the dyeing process of textile materials with a polyester component will allow not only to reduce the temperature, but also to eliminate bactericidal treatment at the stage of final finishing.

Methods of dyeing polyester fabrics using intensifiers make it possible to use less dye and energy resources, diminish the temperature of dyeing and maturation during the obtaining durable and intense colors.

Samples dyed with different concentrations (C, g/l) of intensifier and dye are demonstrated below in Table 2.

As can be seen from the samples, the color intensity increases with increasing concentration of the intensifier. To determine the exact color difference between the samples, we performed an instrumental analysis of the color characteristics. The samples dyed at 130°C were used as reference samples. The samples were analyzed for color differences using a Datacolor SF 600 spectrophotometer (Datacolor, USA). The results are summarized in Table 3.

As can be seen from the data above, with an increase of the intensifier concentration, the general color difference increases, the samples are visibly darker and more saturated, which indicates greater penetration and fixation of the dye inside the fabric.

Furthermore, it can be concluded that achievement of the color intensity obtained under production conditions at 130°C, it is sufficient to use an intensifier in the amount of 1-2 g/l and carry out the dyeing process at 100°C [20].

Comparing the results of the above studies, we can present the results in the form of graphs of dependence of the difference in brightness and general color difference based on the intensifier concentration (C, g/l) (Figures 1, 2).

Under operating conditions, textile materials are exposed to light, moisture, temperature, mechanical forces and various chemical reagents as a result of light exposure, washing, ironing, sweat, dry cleaning, friction, etc.

Under the influence of the above factors, physical-chemical changes occur in the structure of dyes and a violation of the durability of their bond with fibers, which leads to irreversible changes in the color of the material and coloring of the surface it contact with.

Table 2. Samples of cotton-polyester fabrics dyed under different conditions.

Dyeing conditions	Dispersed blue dye 2 1%, (active blue V-RN 1.5%)	Dispersed blue dye 2 2%, (active blue V-RN 2.5%)	Dispersed blue dye 2 3%, (reactive blue V-RN 4%)
Without intensifier, t=130°C			
With an intensifier 1 g/l, t = 100°C			
With an intensifier 2 g/l, t = 100°C			
With an intensifier 3 g/l, t = 100°C			
With an intensifier 4 g/l, t = 100°C			
With an intensifier 5 g/l, t = 100°C			

Table 3. Analysis of samples by color differences.

C of disperse dye (active)	C of the intensifier	Brightness *ΔL*	Saturation *ΔC*	Color saturation *ΔH*	General color difference *ΔE*
1% (1,5%)	1 g/l	0,03	-0,19	0,021	0,19
	2 g/l	-0,31	-0,27	0,03	0,41
	3 g/l	-0,39	-0,20	0,022	0,44
	4 g/l	-0,50	-0,29	0,34	0,67
2% (2,5%)	1 g/l	0,05	-0,023	0,16	0,16
	2 g/l	-0,01	-0,19	0,00	0,19
	3 g/l	-0,30	-0,21	0,73	0,82
	4 g/l	-0,90	-0,50	0,07	1,21
	5 g/l	-1,21	-0,63	1,11	1,76
3% (4%)	1 g/l	0,23	0,09	0,54	0,59
	2 g/l	-0,46	-0,33	0,68	0,89
	3 g/l	-0,60	-0,55	0,68	1,06
	4 g/l	-0,67	-1,13	0,13	1,32
	5 g/l	-1,37	-1,26	0,67	1,98

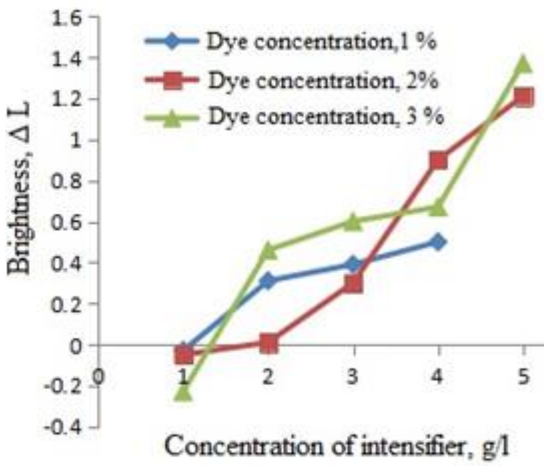

Figure 1. Dependence of the Δ L on the concentration of the intensifier.

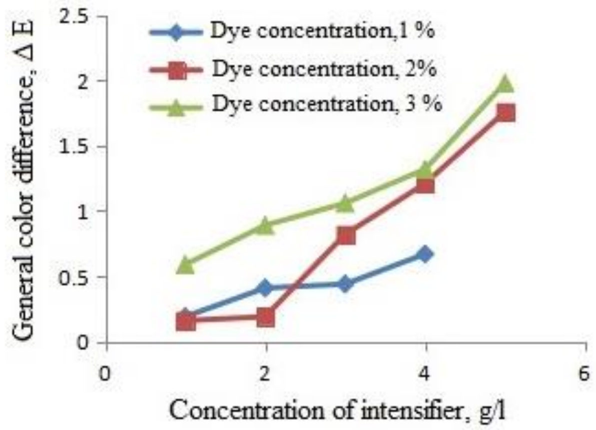

Figure 2. Dependence of the Δ E on the concentration of the intensifier.

Color fastness refers to the ability of textile materials to retain color under the influence of various physical-chemical factors. The resistance of fabrics to various physical-chemical effects is evaluated in points by comparing the test samples with the control samples.

The scales of blue and gray reference colors are used as standards. One sample of each scale has the original color and the other samples have colors that differ to some extent from the original, with a score. Moreover, the more stable the color, the higher the score.

Table 4 shows the test results of the colored samples in terms of their color fastness.

All samples dyed at T=130°C without an intensifier and at T=100°C with an intensifier have high resistance to friction and wet treatment.

Based on the data obtained, it can be said that the treatment of fabrics with an intensifier before dyeing does not change the value of indicators of color fastness to physical (friction) and chemical influences (washing and sweat).

It can also be observed that at higher concentrations of the intensifier, the durability of the color increases slightly. This proves that a larger amount of intensifier allows the dye to penetrate deeper into the fiber.

In the process of manufacturing and exploitation, textile materials are suffered of deformation by stretching, bending, and compression. Indicators of mechanical properties have a great importance into assessing the quality of materials, making a reasonable choice for a product, developing the product design and parameters of the technological process.

To determine the tensile strength characteristics, were used tensile machines we tested untreated polyester and textile material treated with an intensifier (2 g/l) with a DTS dispersing agent (2 g/l) at 100°C for 60 minutes. Tests were also conducted on the fabric to find out how much the intensifier treatment would reduce its strength. For this purpose, several samples of polyester fabric were prepared: dyed at 130°C without the use of an intensifier and samples dyed at 100°C with pretreatment with an intensifier (2 g/l). The results of the yarn and fabric tests are summarized in Table 5.

Based on the data obtained, it follows that the use of an intensifier slightly reduces the strength of the yarn and increases the elongation at break. This is due to the fact that the intensifier breaks the bond between the macromolecules of the polymer and thereby loosens it.

The results of the fabric tests showed that with the use of the intensifier, the breaking load decreased by 2.9% on the warp and 3.3% on the weft, and the elongation increased by 14% on the warp and 12% on the weft. It can be concluded that the use of the intensifier slightly reduces the strength of the thread and to a much lesser extent it affects the fabric.

The phenyl-phenolic intensifier we use not only loosens the structure of polyester fiber, but also has bactericidal properties. To determine the degree of bactericide properties of samples dyed with the intensifier. An indicator of the antimicrobial activity of the materials was the zone of inhibition of growth of test strains (gram-positive opportunistic pathogens Staphylococcus aureus and gram-negative Escherichia coli) around the sample of the tested material.

Fabric samples were examined:

- with different concentrations of the intensifier (2 g/l and 3 g/l);
- after 5 washings.

The results of the study are summarized in Table 6.

The samples dyeing with the intensifier, high antimicrobial activity is observed for intensifier concentrations of 2 and 3 g/l. From the presented results, it follows that increasing the concentration of the intensifier (above 2 g/l) does not affect the antimicrobial activity.

Table 4. Indicators of color fastness.

C of Inten-sifier (dyeing t°C)	C of dye	Color fastness, points			
		sweat	soap	wet fric-tion	dry fric-tion
without inten-sifier (130°C)	1%	5/5	5/5	4	4
	2%	5/4-5	5/5	4	4
	3%	5/4-5	5/5	4-3	3-4
1 g/l (100°C)	1%	5/5	5/5	4	4
	2%	5/4	5/4-5	4	4
	3%	4/4	5/4	4	3
2 g/l (100°C)	1%	5/5	5/5	4	4
	2%	5/4	5/4-5	4	4
	3%	5/4	5/4	4	4
3 g/l (100°C)	1%	5/5	5/5	4-5	4
	2%	5/4	5/5	4	4
	3%	4/4	5/5	4	3-4
4 g/l (100°C)	1%	5/5	5/5	4-5	4
	2%	5/5	5/5	4-5	4
	3%	5/5	5/5	4	4
5 g/l (100°C)	1%	5/5	5/5	4-5	4
	2%	5/5	5/5	4	4
	3%	5/5	5/5	4	4

Table 5. Indicators of tensile strength.

Sample	Breaking load P_b [N]	Elongation at the moment of break [%]
Polyester		
Control sample	19,27± 0,3	7,13±1
After treatment with intensifier	18,25± 0,3	13,06±1
Dyed fabric (base)		
without intensifier	615±5	22,9±1
with pre-treatment by an intensifier	597±5	26,2±1
Dyed fabric (weave)		
without intensifier	575±5	30,4±1
with pre-treatment by an intensifier	556±5	34,1±1

Table 6. Evaluation of antimicrobial activity.

Sample	The value of the indicator	Actual value
1 sample (C = 2 g/l)	not less than 4 mm	*S. aureus 49 mm *E. coli 36 mm
2 sample (C = 3 g/l)	not less than 4 mm	*S. aureus 46 mm *E. coli 34 mm
3 sample (C = 2 g/l) after 5 washings	not less than 4 mm	*S. aureus 34 mm *E. coli 0 mm

*S. aureus ATCC 6538 test strains for Staphylococcus aureus;
*E. coli ATCC 8739 test strains for Escherichia coli.

CONCLUSION

The proposed method confirms the feasibility of using the selected intensifier when dyeing cotton-polyester textile materials. The concentrations of the intensifier during their finishing were determined. Dyeing cotton-polyester textile material using triclosan as an intensifier allows to reduce the dyeing temperature to 100ºC. The use of triclosan concentrations when finishing textile materials before dyeing from 1 g/l to 5 g/l increases the intensity of the dyeing, which especially affects the obtaining of deep and saturated color characteristics. At intensifier concentrations of 4 g/l and 5 g/l, the resistance of the dyeing to physicochemical influences increases, therefore, the intensifier allows the dye to penetrate deeper into the fiber structure. The introduction of triclosan in an amount of 2 g/l is sufficient to obtain high-quality antibacterial characteristics of dyed textile materials.

Thus, the effect of the intensifier on the intensity of the color and i+ts resistance to physicochemical factors was established. The effective use of the intensifier with antibacterial action in the dyeing of cotton-polyester textile materials was confirmed.

REFERENCES

1. Red'ko Y.V., Romankevich O.V.: Fiber Decorated with Magnetite Using Heterocoagulation, Fibre Chemistry, 46(4), 2014, pp. 257–261. http://doi.org/10.1007/s10692-014-9601-x
2. Suprun N., Vlasenko V., Ostrovetchkhaya Y.: Some aspects of medical clothing manufacturing International Journal of Clothing Science and Technology, 15(3-4), 2003, pp. 224–230.
3. Garanina, O., Panasyuk, I., Romaniuk, I., et al.: Influence of superficial modification on electrical conductivity of polyacrylonitril fiber, Vlakna a Textil, 2020, 27(2), pp. 49–53.
4. Red'ko Ya., Brik A., Suprun N.: Investigation of properties of electroconducting nanozones in materials of various nature by the electron paramagnetic resonance method, Eastern-European Journal of Enterprise Technologies, 3(5), 2017, pp. 24- 30. https://doi.org/10.15587/1729-4061.2017.104055
5. Pashkevich K.L., Kolosnichenko M.V., Ostapenko N.V. Research of some physical and mechanical characteristics of suiting fabrics for designing the clothes, Vlakna a Textil, 23(1), 2016, pp. 3–8.
6. Komisarenko, S.V.: The state of biosafety in Ukraine and ways to improve it: Transcript of the report at the meeting of the Presidium of the National Academy of Sciences of Ukraine on April 13, 2022, pp. 53–58. https://doi.org/10.15407/visn2022.06.053
7. Orhan M., et al: Triclosan applications for biocidal functionalization of polyester and cotton surfaces, Journal of Engineered Fibers and Fabrics, 15, 2020. https://doi.org/10.1177/1558925020940104
8. Jean-Yves Maillard: Antimicrobial biocides in the healthcare environment: efficacy, usage, policies, and perceived problems, Ther Clin Risk Manag, 2005, pp. 307–320.
9. Simoncic, B., Tomsic B.: Structures of novel antimicrobial agents for textiles, Textile Research Journal, 80(16), 2010, pp. 1721-1737. https://doi.org/10.1177/0040517510363193
10. Zhang Y., et al.: Eco-friendly versatile protective polyurethane/triclosan coated polylactic acid nonwovens for medical covers application, Journal of Cleaner Production, 282, 2021, pp. 124455. https://doi.org/10.1016/j.jclepro.2020.124455
11. Simončič B., Klemenčič D.: Preparation and performance of silver as an antimicrobial agent for textiles: a review, Textile Research Journal, 86(2), 2015, pp. 210–223. https://doi:10.1177/0040517515586157
12. Ahmed F., et al. Developments in Health Care and Medical Textiles, Pakistan Journal of Nutrition, 13(12), 2014, pp. 80–783. https://doi.org/10.3923/pjn.2014.780.783
13. Orhan M., et al.: Improving the antibacterial activity of cotton fabrics finished with triclosan by the use of 1,2,3,4-butanetetracarboxylic acid and citric acid, Journal of Applied

Polymer Science, 111(3), 2009, pp. 1344–1352. https://doi.org/10.1002/app.25083
14. Karaszewska A., et al.: Preparation and properties of textile materials modified with triclosan-loaded polylactide microparticles, Polymers for Advanced Technologies, 28(9), 2017, pp. 1185–1193. https://doi.org/10.1002/pat.4030
15. Subramanian K., et al.: An overview of cotton and polyester, and their blended waste textile valorisation to value-added products: A circular economy approach – research trends, opportunities and challenges, Critical Reviews in Environmental Science and Technology, 2021, pp. 1–22. https://doi.org/10.1080/10643389.2021.1966254
16. Bensah E.C. Chemical Pretreatment Methods for the Production of Cellulosic Ethanol: Technologies and Innovations, International Journal of Chemical Engineering, 2013, pp. 1-21. https://doi.org/10.1155/2013/719607
17. Konovalova M.V., Rabaeva Y.M.: Surface modification and dyeing of polyester fibres using magnetically activated aqueous solutions, Fibre Chemistry, 39(4), 2007, pp. 318–321. https://doi.org/10.1007/s10692-007-0070-3
18. Zheng L., et al. Dyeing Procedures of Polyester Fiber in Supercritical Carbon Dioxide Using a Special Dyeing Frame, Journal of Engineered Fibers and Fabrics, 10(4), 2015, pp. 155892501501000. https://doi.org/10.1177/155892501501000414
19. Mohaddes F. Improving the colour fastness of dyed nylon-6 fabric by graft copolymerisation and curing of acrylic acid, Coloration Technology, 132(3), pp. 249–254. https://doi.org/10.1111/cote.12211
20. Pat. 28450 Ukraine, MPK D 06 R 1/32. Method of dyeing fibrous materials / Romankevych O.V., Garanina O.O.; applicant and patent owner KNUTD. – No. 200708676; Appl. 27.07.2007; Publ. 10.12.2007. Bull. No. 20. – 6 p.