JOURNAL OF MULTIDISCIPLINARY SCIENCES AND INNOVATIONS

VOLUME 04, ISSUE 09
MOPNTHLY JOURNALS

ISSN NUMBER: 2751-4390
IMPACT FACTOR: 9,08

PROCESSING OF TEXTILE MATERIALS WITH NATURAL ANTIBACTERIAL SUBSTANCES

Nabiyeva Iroda, Azamjonova Saodat

Tashkent Institute of Textile and Light Industry, Uzbekistan

e-mail: niroda@bk.ru

Abstract: This article analyzes the changes in the coloristic parameters of cotton fabric treated with natural antibacterial substances and evaluates its resistance to harmful bacteria and fungi such as Bacillus subtilis, Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli and Candida albicans. In the study, in order to reduce the negative environmental impact of conventional chemical finishes, environmentally friendly, biodegradable natural antibacterial agents coloring extracts derived from local plants such as Crocus sativus and Juniperus spp. were used as alternatives. To ensure the firm fixation of natural antibacterial substances on the fiber, a polyvalent metal salt, $CuSO_4$, was employed as a mordant. In addition, the samples were treated with Zingiber (ginger) to enhance their antibacterial properties.

As a result of the conducted experiments, various color shades resistant to aqueous treatments were obtained without negatively affecting the physical and mechanical properties of cotton fabric. Furthermore, a new resource-saving technology and coloring compositions were developed. The color intensity of the obtained samples was determined.

For the samples treated with Crocus sativus, it was found that the addition of Zingiber increased the color intensity by 18.36 %, $CuSO_4$ by 28.57 %, and the combination of $CuSO_4$ and Zingiber by 38.46 %. In the samples treated with Juniperus spp., the color intensity increased by 8.16% with Zingiber, by 25 % with $CuSO_4$, and by 35.71 % when $CuSO_4$ and Zingiber were used together.

The treated samples demonstrated moderate to good antibacterial activity against Bacillus subtilis, Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli, and Candida albicans.

Keywords: cotton fabric, natural antibacterial substances, polyvalent metal salt, color intensity, plant extract, color coordinate.

Introduction. In recent years, due to the growing attention to human health and hygienic lifestyles, the demand for environmentally friendly and safe products in the textile industry has been increasing. Since fabrics are in direct contact with the human body, the growth of microorganisms on their surface not only causes discomfort to users but can also lead to various skin diseases and reduce the quality of the fabric. Therefore, the development of antibacterial finishing technologies for textile materials has become an urgent issue today.

It has become necessary to apply antibacterial finishes to all textile products used in daily life, as this ensures a comfortable and hygienic living environment. The use of antibacterial agents in textiles provides effective protection of fabrics against microbial attacks, increases their resistance, inhibits microbial growth, and extends the service life of the material. Moreover, antibacterial treatment reduces the frequency of washing, which in turn contributes to water and energy savings, as well as a reduction in the consumption of chemical agents.

Antibacterial reagents can be applied to textile materials through various methods. The most commonly used are the exhaust, pad-dry-cure, coating, spray, and foam techniques. In the exhaust method, the fabric is immersed in a solution of antibacterial agents, allowing the substance to penetrate the fibers. In the pad-dry-cure method, the fabric is passed through the solution, the excess liquid is squeezed out, followed by drying and curing at high temperatures to fix the substance. In coating and spray methods, the antimicrobial agent is distributed over the surface of the fabric, forming a protective layer. The foam method, on the other hand, reduces water consumption and is considered environmentally friendly. In some cases, during the production of synthetic fibers, antimicrobial agents are directly added to the spinning dope, resulting in fibers with permanent protective properties [1].

Textile materials with antibacterial properties have been developed and proven effective using various agents such as metal nanoparticles [2, 3], polymer coatings [4], quaternary ammonium salts [5], guanidine compounds [6], metal oxides [8, 9], N-halamine compounds [10], and others. These studies provided antibacterial properties to textile materials using complex technologies and expensive raw materials.

In addition, natural antibacterial substances have also been widely studied. For instance, extracts derived from natural sources such as chitosan [11, 12], Aloe vera [13], Azadirachta indica, Melaleuca alternifolia, Eucalyptus globulus and Ocimum tenuiflorum are known for their environmentally safe, effective antibacterial, antifungal, and anti-inflammatory properties [14].

Unlike the above-mentioned studies, in the present work, cotton fabrics with antibacterial properties were developed using widely available plant extracts and simple technological processes that ensure economic efficiency. Moreover, these fabrics demonstrate the potential to produce a variety of color shades, adding to their practical value.

Materials. For this study, bleached cotton knit fabric (Suprem) was obtained from the limited liability company "TURON TEX" located in Tashkent city. As natural antibacterial substances, extracts from plants such as Crocus sativus and Juniperus spp. were selected, and Zingiber was used additionally to enhance the antibacterial properties. Copper sulfate was employed to improve the color fastness of fabrics dyed with natural extracts.

Crocus sativus (Saffron) – has been known since ancient times and was mainly used in medicine. Its main bioactive components: Safranal – antibacterial and antimicrobial properties, Crocin – antioxidant, anti-inflammatory, Picrocrocin – bitter compound, destroys microbes, and Flavonoids – strong protective function. These components are water-soluble and give fabrics bright yellow color, facilitating the dyeing process [15].

Juniperus spp. (Juniper) – an evergreen plant, its berries and essential oils are widely used in traditional medicine. Juniper berries have anti-inflammatory and antioxidant properties. Components: α-pinene, β-pinene – damage bacterial cell walls, sabinene, limonene – anti-inflammatory and antibacterial, tannins – bind to proteins, limit bacterial growth, terpenoids – broad-spectrum antimicrobial agents [16].

Zingiber – perennial aromatic plant of the Zingiberaceae family, strong aroma, pungent and bitter taste, bright yellow color. High antioxidant, antibacterial and antifungal activity. Components: Gingerol – strong activity against E. coli and Salmonella, Shogaol – antifungal, anti-inflammatory, Essential oils – natural antibiotic [17].

Experimental Methods.

JOURNAL OF
MULTIDISCIPLINARY
SCIENCES AND INNOVATIONS
VOLUME 04, ISSUE 09
MOPNTHLY JOURNALS
ISSN NUMBER: 2751-4390
IMPACT FACTOR: 9,08

Preparation of cotton materials for treatment. To increase the hydrophilicity of the bleached cotton knit fabric (Suprem) used in the study, it was boiled in a laboratory dyeing vat iSMART-1K at M=20, 1 % CFM, for 30 minutes at 90–95 ^{0}C, then dried in an MCT-55 model drying oven at 70 ^{0}C and ironed.

Extraction of plant materials such as Crocus sativus and Juniperus spp. Dried 1 g of Crocus sativus and 5 g of Juniperus spp. were separately boiled in 200 ml of distilled water obtained from a BE-4 bidistiller at 80–90 ^{0}C for 80 and 120 minutes, respectively, and then filtered.

Treatment of samples with mordant. Cotton fabric prepared for finishing [18] was cut into 5×5 cm pieces and weighed on a ZES 21 analytical balance with 0.0001 g accuracy. To ensure strong binding of the fiber with the natural antibacterial agent, a 5 % solution of the metal mordant $CuSO_4$ was applied at 50 M for 60 minutes in a Starlet-3 DL-6000 PLUS IR dyeing machine, followed by drying.

Treatment with natural antibiotic – Zingiber. Samples were treated with a solution of Zingiber at M=30 for 30 minutes at 40–50 ^{0}C, then washed and dried at room temperature.

Treatment of samples in natural antibacterial extract solution. Mordanted and unmordanted samples were treated with plant extracts diluted 1:1 with distilled water at M=40 for 120 minutes at 70–80 ^{0}C. As an electrolyte, 10 % NaCl relative to the fabric mass was added. Treated fabrics were dried at room temperature.

Analytical methods. Color intensity of the samples was determined using the X-Rite Ci7800 device at the “Kor-Uz - Textile Technopark” scientific laboratory [19].

Antibacterial properties were tested at the Institute of Microbiology of the Academy of Sciences of the Republic of Uzbekistan. Suspensions at a concentration of 5×10^5 CFU/ml in physiological solution were used according to the MacFarland standard. A total of 18 samples were tested, each in triplicate. 100 µl of bacterial suspension was layered onto the surface of nutrient agar in Petri dishes, while yeast suspensions were applied onto Sabouraud agar. After bacterial growth, fabric samples were placed on the agar, allowing diffusion of the substances, and the Petri dishes were incubated: 37 ^{0}C for bacteria and 22 ^{0}C for yeast.

Antibacterial activity was assessed based on inhibition or continuation of bacterial and fungal growth around the samples. Evaluation was performed after 48–72 hours of incubation. The diameter of the inhibition zone was measured around the sample at the edges and center of the Petri dish.

Experimental Results and Discussion.

Several methods are known for imparting antibacterial properties to textile materials, including treatment with silver nanoparticles, metal oxides, chitosan, Aloe vera, and other reagents. In this study, environmentally safe, non-toxic, and health-beneficial natural ingredient solutions were used for imparting antibacterial properties to textile materials, and the results were comparatively analyzed.

Analysis of antibacterial properties of samples treated with natural ingredients.

During the experiments, the possibility of imparting antibacterial properties to fabric samples using natural ingredients was investigated. This is particularly relevant in the current era of

JOURNAL OF MULTIDISCIPLINARY SCIENCES AND INNOVATIONS

VOLUME 04, ISSUE 09
MOPNTHLY JOURNALS

ISSN NUMBER: 2751-4390
IMPACT FACTOR: 9,08

"green" technologies, where the use of natural dyes in textile dyeing processes is increasingly important. It is known that natural dye substances obtained from plants, combined with various mordants, can produce durable colors on textile materials [20]. In this study, the potential of Crocus sativus and Juniperus spp. used specifically as dyeing agents to impart antibacterial properties to textiles was analyzed.

The experimental results for the resistance of samples treated with dye extracts from Crocus sativus and Juniperus spp. to five types of bacteria and fungi (Bacillus subtilis, Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli and Candida albicans) are presented in Table 1.

Table 1. Antibacterial properties of samples treated with dye extracts from Crocus sativus and Juniperus spp.

Plant Species	Antibacterial activity value, mm				
	Type of bacteria and fungi				
	Bacillus subtilis	Staphylococcus aureus	Pseudomonas aeruginosa	Escherichia coli	Candida albicans
Crocus sativus	3	-	3	3	-
Juniperus spp.	-	3	-	3	3

The results show that samples treated with Crocus sativus extract exhibited moderate activity against Bacillus subtilis, Pseudomonas aeruginosa, and Escherichia coli while samples treated with Juniperus spp. extract showed moderate activity against Staphylococcus aureus, Escherichia coli and Candida albicans. The antibacterial activity of the samples was evaluated using the disk-diffusion method according to the Clinical and Laboratory Standards Institute (CLSI) guidelines [21]. Growth inhibition zones of 0–2 mm were considered very low activity, 3–6 mm as moderate activity, and 7 mm or larger as high activity.

Considering that these extracts produced bright and intense colors, in subsequent experiments, the treatment solution was supplemented with the natural antibiotic Zingiber to enhance antibacterial properties. To improve color fastness, $CuSO_4$ was also added to the extract solution.

Various polyvalent salt solutions are used when treating textile materials with natural dyes to enhance color durability [22, 23]. Samples were treated with Crocus sativus and Juniperus spp. extracts in the presence of Zingiber and $CuSO_4$, and their color intensity and antibacterial properties were analyzed. The results are presented in Tables 2–3.

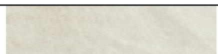
Table 2. Color intensity of samples dyed with plant extracts in the presence of Zingiber and $CuSO_4$.

Composition of the solution	Samples	Color intensity, K/S

JOURNAL OF
MULTIDISCIPLINARY
SCIENCES AND INNOVATIONS

VOLUME 04, ISSUE 09
MOPNTHLY JOURNALS

ISSN NUMBER: 2751-4390
IMPACT FACTOR: 9,08

Crocus sativus+		0,8
Crocus sativus+Zingiber		0,98
Crocus sativus+$CuSO_4$		1,12
Crocus sativus+$CuSO_4$+Zingiber		1,3
Juniperus spp		0,9
Juniperus spp+Zingiber		0,98
Juniperus spp+$CuSO_4$		1,2
Juniperus spp+$CuSO_4$+Zingiber		1,4

According to the table results, during the treatment of samples with Crocus sativus and Juniperus spp. extracts in the presence of a mordant, the increase in color intensity and improvement in color fastness were achieved due to the formation of intermolecular bonds between the fiber macromolecules and the natural dye molecules in the plant extract, along with the formation of coordination bonds.

For samples treated with Crocus sativus, the addition of Zingiber increased color intensity by 18,36 %, $CuSO_4$ by 28,57 % and the combination of $CuSO_4$ and Zingiber by 38,46 %.

For samples treated with Juniperus spp., the addition of Zingiber increased color intensity by 8,16 %, $CuSO_4$ by 25 %, and the combination of $CuSO_4$ and Zingiber by 35,71 %.

Table 3. Dependence of the antibacterial properties of samples on the composition of the treatment solution.

Plant Species	Antibacterial activity value, mm				
	Type of bacteria and fungi				
	Bacillus subtilis	Staphylococcus aureus	Pseudomonas aeruginosa	Escherichia coli	Candida albicans
Crocus sativus +Zingiber	3	-	4	4	-
Juniperus spp. +Zingiber	-	3	-	4	5
Crocus sativus + $CuSO_4$	3	-	3	3	-

Juniperus spp. + $CuSO_4$	-	3	-	3	4

The results show that in Crocus sativus samples, when treated with the natural antibiotic Zingiber, activity against Bacillus subtilis remained unchanged at 3 mm, while activity against Pseudomonas aeruginosa and Escherichia coli increased from 3 to 4 mm. In Juniperus spp. samples, addition of Zingiber kept activity against Staphylococcus aureus at 3 mm, increased activity against Escherichia coli from 3 to 4 mm, and against Candida albicans from 3 to 5 mm.

When $CuSO_4$ was added, changes in antibacterial activity were related not to the mordant salt itself, but to the amount of plant extract bound to the fiber. Therefore, in Crocus sativus samples, activity against Candida albicans and Staphylococcus aureus remained unchanged. In Juniperus spp. samples, activity against Candida albicans increased from 3 to 4 mm.

Table 5. Antibacterial activity of samples dyed with plant extracts in the presence of Zingiber and CuSO4.

Plant Species	Antibacterial activity value, mm				
	Type of bacteria and fungi				
	Bacillus subtilis	Staphylococcus aureus	Pseudomonas aeruginosa	Escherichia coli	Candida albicans
Crocus sativus + $CuSO_4$+Zingiber	5	-	6	7	-
Juniperus spp.+ $CuSO_4$+Zingiber	-	4	-	5	5

The experimental results showed that cotton fabric samples treated with Crocus sativus+CuSO4+Zingiber exhibited increased activity from moderate to high against Bacillus subtilis, Pseudomonas aeruginosa, and Candida albicans. Similarly, samples treated with Juniperus spp.+CuSO4+Zingiber showed increased activity against Staphylococcus aureus (from 3 mm to 4 mm), Escherichia coli (from 3 mm to 5 mm), and Candida albicans (from 3 mm to 5 mm).

Conclusion. The study demonstrated that cotton fabrics treated with natural antibacterial compounds extracted from plants such as Crocus sativus and Juniperus spp. gained antibacterial properties. At the same time, natural pigments in these extracts bonded with the cotton fibers, producing various color shades.

Samples treated with Crocus sativus extract showed moderate activity against Bacillus subtilis, Pseudomonas aeruginosa, and Escherichia coli, while those treated with Juniperus spp. extract exhibited moderate activity against Staphylococcus aureus, Escherichia coli, and Candida albicans.

Adding Zingiber to Crocus sativus treated samples increased color intensity by 18,36%, adding CuSO4 increased it by 28,57 %, and combining $CuSO_4$ + Zingiber resulted in a 38,46 % increase.

For Juniperus spp. treated samples, adding Zingiber increased color intensity by 8,16 %, $CuSO_4$ by 25 %, and $CuSO_4$ + Zingiber by 35,71 %.

References:

1. Zakaria Ahmed. Antimicrobial finishing of jute cotton union fabric using extract of different natural antimicrobial agents. **Revelation and Science. Vol. 14, No. 02 (1446H/2024) 47-64.** https://journals.iium.edu.my/revival/index.php/revival/article/view/479.

2. Cijun Shuai, Xun Yuan, Wenjing Yang, Shuping Peng, Guowen Qian, Zhenyu Zhao. Synthesis of a mace-like cellulose nanocrystal@Ag nanosystem via in-situ growth for antibacterial activities of poly-L-lactide scaffold. Carbohydrate Polymers. Volume 262, 15 June 2021, 117937. https://doi.org/10.1016/j.carbpol.2021.117937.

3. Yuanxiang Xiao, Wenyue Liu, Hongfu Ru, Yuyun Yu, Shuangfei Xiang, Shujun Zhao, Feiya Fu, Hongyan Diao, Xiangdong Liu. Highly stable, antiviral, antibacterial cotton textiles via surface engineering. International Journal of Biological Macromolecules. Volume 283, Part 4, December 2024, 137961. https://doi.org/10.1016/j.ijbiomac.2024.137961.

4. Qiaohua Qiu, Chuan Yang, Yanming Wang, Cherylette Anne Alexander, Guangshun Yi, Yugen Zhang, Xiaohong Qin, Yi Yan Yang. Silane-functionalized polyionenes-coated cotton fabrics with potent antimicrobial and antiviral activities. Biomaterials. Volume 284, May 2022, 121470. https://doi.org/10.1016/j.biomaterials.2022.121470.

5. Weili Shao, Junli Li, Yuting Zhang, Ning Sun, Ting Wu, Mengmeng Yan, Fan Liu, Huadong Jiang, Xiaogang Chen, Jianxin He. Polyvinylidene fluoride multi-scale nanofibrous membrane modified using N-halamine with high filtration efficiency and durable antibacterial. Journal of Colloid and Interface Science. Volume 628, Part B, 15 December 2022, Pages 627-636. https://doi.org/10.1016/j.jcis.2022.08.077.

6. Jie Zhang, Liwei Hu, Qian. Polyhexamethylene guanidine hydrochloride modified sodium alginate nonwoven with potent antibacterial and hemostatic properties for infected full-thickness wound healing. International Journal of Biological Macromolecules. Volume 209, Part B, 1 June 2022, Pages 2142-2150. https://doi.org/10.1016/j.ijbiomac.2022.04.194.

7. Issa M. El-Nahhal, Abdelraouf A. Elmanama, Nadia Amara, Fawzi S. Qodih, Mohamed Selmane, Mohamed M. Chehimi. The efficacy of surfactants in stabilizing coating of nano-structured CuO particles onto the surface of cotton fibers and their antimicrobial activity. Materials Chemistry and Physics. Volume 215, 15 August 2018, Pages 221-228. https://doi.org/10.1016/j.matchemphys.2018.05.012.

8. Ahmad Tavakoli, Mohammad Sadegh Hashemzadeh. Inhibition of herpes simplex virus type 1 by copper oxide nanoparticles. Journal of Virological Methods. Volume 275, January 2020, 113688. https://doi.org/10.1016/j.jviromet.2019.113688.

9. Yue Chen, Xiaoming Qiu, Li-Zhen Fan. Nitrogen-rich hierarchically porous carbon foams as high-performance electrodes for lithium-based dual-ion capacitor. Journal of Energy Chemistry. Volume 48, September 2020, Pages 187-194. https://doi.org/10.1016/j.jechem.2020.01.024.

10. Ling An, Phil Perkins, Runlin Yi, Tian Ren. Development of polylactic acid based antimicrobial food packaging films with N-halamine modified microcrystalline cellulose. International Journal of Biological Macromolecules. Volume 242, Part 1, 1 July 2023, 124685. https://doi.org/10.1016/j.ijbiomac.2023.124685.

11. Amira M. El-Shafei, Abeer M. Adel, Atef A. Ibrahim, Mona T. Al-Shemy. Dual functional jute fabric biocomposite with chitosan and phosphorylated nano-cellulose (antimicrobial and thermal stability). International Journal of Biological Macromolecules. Volume 124, 1 March 2019, Pages 733-741. https://doi.org/10.1016/j.ijbiomac.2018.11.137.

12. Xing Cao, Yuan-Yuan Huang, Xin-Yu Tian, Yan-Peng Ni, Yu-Zhong Wang. Facile and atom-economical synthesis of highly efficient chitosan-based flame retardants towards fire-retarding and antibacterial multifunctional coatings on cotton fabrics. International Journal of Biological Macromolecules. Volume 300, April 2025, 140205. https://doi.org/10.1016/j.ijbiomac.2025.140205.

13. Raquel Gallardo-Rivera, María de los Ángeles Aguilar-Santamaría, Phaedra Silva-Bermúdez, Julieta García-López, Alberto Tecante, Cristina Velasquillo. Polyelectrolyte complex of Aloe vera, chitosan, and alginate produced fibroblast and lymphocyte viabilities and migration. Carbohydrate Polymers. Volume 192, 15 July 2018, Pages 84-94. https://doi.org/10.1016/j.carbpol.2018.03.044.

14. Hetal Mistry, Suman Mundkur, Anju Tulshyan. Antibacterial Treatment on Cotton Fabric from Aloe Vera. SSRG International Journal of Polymer and Textile Engineering (SSRG-IJPTE) – Volume 7 Issue 1 – Jan - April 2020. https://doi.org/10.14445/23942592/IJPTE-V7I1P107

15. Fatemeh Anaeigoudari, Akbar Anaeigoudari, Aliasghar Kheirkhah-Vakilabad. A review of therapeutic impacts of saffron (Crocus sativus L.) and its constituents. Physiological Reports. 2023 Aug 3;11(15):e15785. https://pmc.ncbi.nlm.nih.gov/articles/PMC10400758/?utm_source

16. Halil Özdemir. Dyeing Properties of Natural Dyes Extracted from the Junipers Leaves (J. excelsa Bieb. and J. oxycedrus L.). Journal of Natural Fibers. September 2016. 14(1):1-9. DOI:10.1080/15440478.2016.1184602.

17. Rajkumari Sanatombi, K.Sanatombi. Biotechnology of Zingiber montanum (Koenig) Link ex A. Dietr. A review. Journal of Applied Research on Medicinal and Aromatic Plants.Volume 4, March 2017, Pages 1-4. https://doi.org/10.1016/j.jarmap.2016.09.001.

18. I.A.Nabiyeva, T.B.Tashkenbayeva, S.Sh.A'zamjonova. To'qimachilik materiallariga tabiiy antibakterial moddalar bilan ishlov berish jarayonida uning koloristik ko'rsatkichlarini o'zgarishi. Textile Journal of Uzbekistan №3/2025.

19. Compyuter color matching system operation and maintenance manual. Korea industrial technology ODA. 2012. P.79.

20. Nabiyeva, I., Matkarimova, D., Islamova, Z., & Abdumajidov, A. (2024). RETRACTED: Properties of wool fiber, and environmental problems and solutions of its finishing. In E3S Web of Conferences (Vol. 538). EDP Sciences.