# РОЗДІЛ III. ХІМІЧНІ ТА ХАРЧОВІ ТЕХНОЛОГІЇ

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***Olena Ishchenko[1], Olha Sumska[2], Kateryna Smykalo[3], Yuliia Feshchuk[4], Daria Kuchynska[5]***

[1]Doctor of Technical Sciences, Associate Professor,
Associate Professor of Department of Chemical Technologies and Resource Saving
Kyiv National University of Technologies and Design (Kyiv, Ukraine)
**E-mail:** e_ishchenko5@gmail.com. **ORCID:** https://orcid.org/0000-0002-9510-6005
**ResearcherID**: GYV-0809-2022. **Scopus Author ID:** 57200013816

[2]PhD (Eng.), Associate Professor, Associate professor of Department of Food Technologies
Kherson State Agrarian and Economic University (Kropyvnytskyi, Ukraine)
**E-mail**: sumskaetdt@gmail.com. **ORCID**: https://orcid.org/0000-0003-1606-6103
**ResearcherID:** 91.215.68.126. **Scopus Author ID:** 57204470556

[3]Student
Kherson National Technical University (Khmelnytskyi, Ukraine),
PhD, fashion studio tutor (Lutsk, Ukraine)
**E-mail:** smykalo.kateryna@vnu.edu.ua. **ORCID:** https://orcid.org/0000-0002-9670-6563
**ResearcherID:** E-7755-2017. **Scopus Author ID:** 57809016000

[4]Laboratory Assistant of Department of Food Technologies
Kherson State Agrarian and Economic University (Kropyvnytskyi, Ukraine)
**E-mail:** yulka131417@gmail.com. **ORCID:** https://orcid.org/0000-0003-0510-6325. **Researcher ID:** JOK-4531-2023

[5]PhD student of Department of Chemical Technologies and Resource Saving
Kyiv National University of Technologies and Design (Kyiv, Ukraine)
**E-mail:** dkuchinska@gmail.com. **ORCID:** https://orcid.org/0009-0007-5928-6639

## ANTIMICROBIAL APPROACHES FOR TEXTILES

*The use of textile materials with antimicrobial treatment is one of the ways to effectively protect a person from exposure to various pathogens. The article is devoted to the topical issue of the development of innovative textile materials with prolonged antimicrobial treatment. To establish the possibility and features of obtaining innovative textile materials with long-term antimicrobial treatment. To prepare this article, many materials were considered, as well as ready-made solutions that were publicly available. Despite the fact that research on this topic was conducted, in order to obtain a prolonged effect, special attention needs to be paid to the problem of fixing the antimicrobial drug. To establish the technological features of applying a prolonged action antimicrobial treatment to textile material. The main tasks are to determine the composition of the composition and the peculiarities of the processing of the textile material; to investigate the influence of the polymer carrier and the fixing agent on the permanence of the final treatment and the stability of the antimicrobial effect. In order to obtain a prolonged antimicrobial effect, the problem of fixing the antimicrobial drug on the textile material was solved by using the developed preparation composition. The proposed finishing compound contains carboxymethylated starch, decamethoxine as a bactericidal drug and an agent for fixing them on the textile material - potassium iodide. The effect of the finishing components on the sorption of modified starch by cotton fabric was studied and a significant increase in its content on the fabric was revealed during simultaneous impregnation. The detected phenomenon is proposed to be explained by the formation of an ionic bond between carboxymethyl groups and decamethoxin. The technological features of applying a long-acting antimicrobial treatment to a textile material, which consists in the use of a one-stage technology, have been clarified. The influence of the polymer carrier and the fixing agent on the permanence of the final treatment and the stability of the antimicrobial effect is shown. The results of antimicrobial tests of prepared samples processed by various technological methods are presented. It was found that the fabric prepared according to the proposed technological regimes has an antimicrobial effect that is resistant to multiple washings. The developed technology is promising and can be implemented on the equipment of finishing factories.*

***Keywords:*** *antimicrobial protection; decamethoxine; modified polysaccharides; application; quaternary ammonium salt; textiles; antimicrobial.*
*Fig.: 5. Table: 8. References: 23.*

**Introduction.** Human body is inhabited by vast number of microorganisms which form a complex ecological community and influence the human physiology, in the aspect of both health and diseases [1]. Healthcare concerns have motivated the interest for the development of multifunctional antimicrobial cotton fabrics. Moreover, cotton textiles are also used in medical applications such as wound dressings [2]. The development of innovative textile materials with prolonged antimicrobial treatment is one of the ways to effectively protect people from exposure to various pathogens.

It should be noted that polysaccharides have recently been actively used in the production of innovative textile materials. Chemically modified polysaccharides can be used in drug delivery, tissue engineering, gene transport, etc [3].

**Target setting.** Antimicrobial textile materials can be produced at textile enterprises with the use of existing equipment, generally accepted processing technologies and with the use of traditional bactericidal drugs such as halogenated phenols and cresols, salicylic acid anilide and halogen-containing carboxylic acids, organophosphorus compounds, melamine derivatives, organometallic compounds, metal salts (copper , zinc, antimony, bismuth, cadmium, silver, zirconium, etc.), fluorine compounds, etc [4].

**Actual scientific researches and issues analysis.** Surface modification of cotton fibres with biopolymers (chitosan, starch) and other synthetic polymers to impart antimicrobial activity and overcome other limitations of this natural textile has been reported [5]. Quaternary ammonium salts, industrial enzymes and several metal salts have also been described as agents for the development of antimicrobial textiles [6] as well as the use of other antimicrobial products (polyhexamethylene biguanide, triclosan, N-halamine, peroxyacids) [7, 8]. Also, carboxymethyl cellulose (CMC) with different degrees of substitution with the addition of silver nanoparticles is used for the properties of treated cotton fabrics that have different degrees of polymerization [9].

In the last 10 years, disinfectants from the group of surface-active substances (surfactants) - detergents - have become widely used. According to their ability to ionize in aqueous solutions, they are divided into cationic, anionic, ampholyte and nonionic surfactants. As independent isinfectants, mainly cationic and ampholyte surfactants are used. Quaternary ammonium compounds (QACs) are widely used for disinfection of water, surfaces and instruments, as well as in the textile, leather and food industries due to their relatively low toxicity, broad antimicrobial spectrum, non-volatility and chemical stability [10; 11].

At the current stage of science, medicine and technology development, cationic surfactants quaternary as ammonium salts and quaternary salts of pyridine are increasingly developing in the practice of disinfection. These substances are used, of course, in the form of aqueous solutions for disinfecting the hands of surgeons, washing dishes, and for processing equipment at food industry enterprises. The study of the bactericidal properties of quaternary ammonium and pyridinium compounds is of great interest, because these substances to a greater extent meet the requirements for bactericides that can be used for antimicrobial treatment of textile materials [12; 13].

Quaternary ammonium compounds (QACs) are cationic agents that carry a positive charge in the N atom in the solution, usually attached to the surface of an anionic fibre by ionic interaction [14; 15]. ACs (R 4 $N^+X^-$) represent a large group of 191 compounds, and, as a rule, the term QAC refers to a subgroup of linear alkylammonium compounds consisting of a hydrophobic alkyl chain and a hydrophilic analogue. In the textile industry, compounds containing long alkyl chains (12–18 carbon atoms) are most commonly used, mainly for cotton, polyester, nylon, and wool [14, 16, 17]. The antimicrobial effect of these compounds depends on the length of the alkyl chain, the presence of a perfluorinated group and the amount of cationic ammonium group in the molecule [15].

These compounds are active against a wide range of microorganisms, such as gram-positive and gram-negative bacteria, fungi, and certain types of viruses [15; 18]. It is known to obtain poly (d, l- lactide) (PDLLA) fibrous membranes, the surface of which was modified with quaternary ammonium fragments, presenting an antibacterial efficiency of approximately 99.999% against gram-positive (Staphylococcus aureus) and gram-negative (Escherichia coli) bacteria. The authors explained that the antibacterial effect was based on the interaction of surface positive charges and cell membrane negative charges, which leads to loss of membrane permeability and cell leakage [19]. In fact, the antimicrobial effect is caused by attractive interactions between the cationic ammonium group and the negatively charged cell membrane of the microbe. After contact with cells, they can exhibit various modes of antimicrobial action, including damage to cell membranes, denaturation of proteins, and inhibition of DNA production, avoiding reproduction [14; 20].

Despite the effectiveness of quality control, they have a drawback, namely leaching from the textile due to the lack of physical connection, which leads to a rapid decrease in the concentration in the textile. In the case of commercial polyester fibers Acrilan ® and Orlon ® , for example, containing carboxylic or sulfonate groups, QACs can be directly lost under near-boiling conditions during washing [21; 22]. Moreover, there are also commercial products based on QAC as isolated active substances, such as BIOGUARD ® (Hamilton, New Zealand), Sanigard KC and Sanitized ® (Burgdorf, Switzerland) [15].

**Uninvestigated parts of general issues defining.** Analyzing the scientific and technical literature, it was noted that the issue of providing antimicrobial properties is complex. To preserve textile materials with antimicrobial properties, it is necessary to choose a polymer and a bactericidal reagent in such a way that there are strong chemical bonds between them. This will provide opportunities to preserve the antimicrobial properties of the material after water treatments. Thus, in order to obtain a prolonged effect, special attention needs to be paid to the problem of fixing the antimicrobial drug.

Polymers that have antimicrobial properties represent a valuable alternative to conventional antibiotics and are currently gaining interest in coatings, personal care and active food packaging, and biomedical applications. The interest in starch as an antimicrobial agent carrier is accrued from its film-forming properties and high molecular weight. Also, the poor solubility of starch in cold water limits its potential applications. Thus, starch modification is desirable not only to mitigate these challenges but also to bring about other functional properties.

**The research objective.** The purpose of the work is to establish the technological features of applying a prolonged action antimicrobial treatment to textile material. The main tasks are to determine the composition of the composition and the peculiarities of the processing of the textile material; to investigate the influence of the polymer carrier and the fixing agent on the permanence of the final treatment and the stability of the antimicrobial effect.

**The statement of basic materials.**

*Textile material*

The research was conducted on cotton dyed fabric for medical purposes (Table 1).

*Table 1 – Structural characteristics of textile samples*

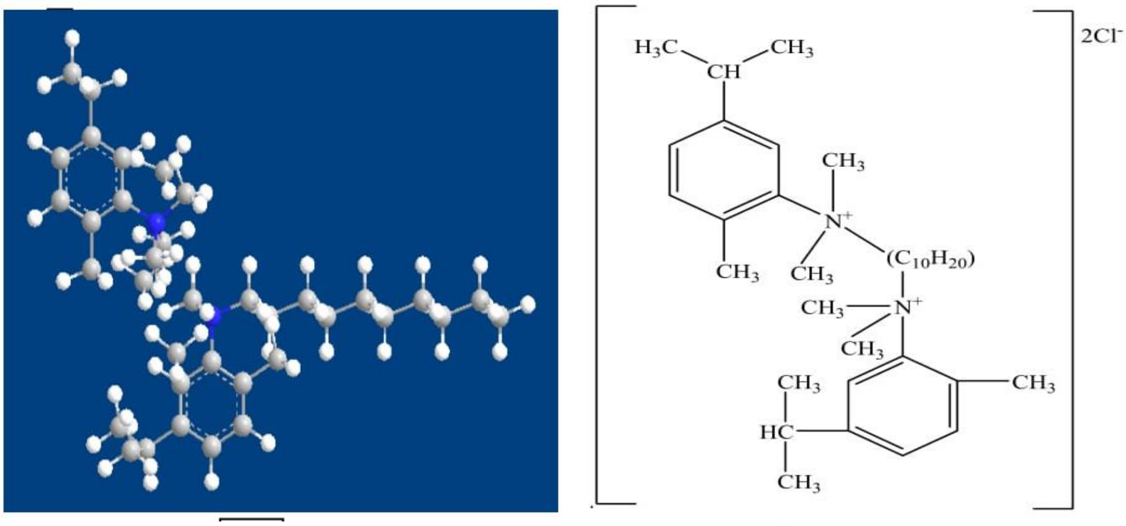
| Textile materials | Vendor code | Width, sm | Surface density, g/m$^2$ | Number of threads per 10 cm | |
|---|---|---|---|---|---|
| | | | | Warp | Weft |
| Calico<br>TO 17 MD<br>13–26-96 | 2C–3213 ГОТ | 215+2,5 | 133-7 | 252+5 | 223+7 |

Preparations for final processing Carboxymethylated starch (CMS) (TU U 6-04872 671.061-96) was used as a polymeric matrix for antimicrobial treatment of textile materials.

Kolosyl M is a microemulsion of a modified silicone softener for the final treatment of all types of textile materials by the methods of adding and selecting.

Potassium iodide (CAS 7681-11-0).

In this work, the drug decamethoxin (Decamethoxinum, DKM®) was used to provide antimicrobial properties to textile materials, which was produced at the Experimental Production of the Institute of Organic Chemistry of the National Academy of Sciences of Ukraine (Fig. 1). Registration certificate UA/12128/01/01.




*a* *b*

*Fig. 1. Decamethoxin spatial model (a); structural formula (b) [23]*

*2.2. Technology of Antimicrobial Approaches for Textiles*

According to the selected one-stage continuous method of preparation, the fabric sample is soaked in a solution containing CMS, a softener, an antimicrobial composition of decamethoxin and potassium iodide, then twice spun with a degree of spin of 70-80% and dried at a temperature of 95-105 °C. The composition of the finishing and the concentration of the working solutions are given in the Table 3.

*Table 2 – Finishing composition and concentration of working solutions for one-stage continuous finishing method*

| Drug name | Finishing composition number | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| CMS, g/l | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Colosyl M, g/l | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| Decametoxin, g/l | – | 0,005 | 0,01 | 0,02 | 0,005 | 0,01 | 0,02 |
| Potassium iodide, g/l | – | – | – | – | 0,01 | 0,02 | 0,04 |

*2.3. Gravimetric method of determining the main substance presence*

The bottles, which will contain the substance to be determined, are weighed, washed well, the washed bottles are heated in a drying oven for 4-6 hours, and weighed again. Then, 10g of the substances under investigation solutions are poured into the bottles, weighed and again put in the drying oven for 4-6 hours, weighed again.

The presence of the main substance is determined according to the formula (1):

$$n = \frac{m_n - m_k}{m_n} \cdot 100\%, \quad (1)$$

where $m_n$ – initial mass of the bottle with solution, g;

$m_k$ – the mass of bottle with a solution that has been roasted for 4-6 hours, g.

*2.4. Antimicrobial studies*

The effectiveness of antimicrobial treatment was tested by the agar method. To do this, after cooling to 45 °C, the liquid agar nutrient medium is infected with microbes grown in 24 hours, for example, *Staphylococcus aureus*, and then poured into sterile cup of Petri. After solidification, fabric samples measuring 20×20 mm (no more than two samples in one cup) are placed on the agar layer, if necessary, slightly pressing them, and left for 24-48 hours.

The action of the antimicrobial drug is characterized by the fact that there is no population growth under the tissue, and around the tissue there is a zone of complete growth retardation, which passes into a zone of strong retardation and then into a zone of partial retardation of the development of microbes. Zone sizes are expressed in millimeters. The number and size of microorganisms increase as they are removed from the tissue (observed under a microscope).

- The agar layer under the sample is characterized by the same (or almost the same) growth force as the environment (score 1);
- the agar layer under the sample includes few (units) of bacteria compared to the environment (score 2);
- in the agar layer under the tissue, there are no microbes (full retarding effect), but in the following layers, a certain number of microbial colonies matured to the sample (score 3);
- there are no microbes in the agar layer under the sample and at a distance of 2 mm from it in all directions (score 4);
- the total dead zone around the sample is more than 3 mm (score 5).

In this work, a modified agar method is used, it differs in that the cultivation of microorganisms in a liquid agar nutrient medium poured into cups is carried out from air, then it is cooled to 45 °C, and after that, samples of treated tissues with a diameter of 20 mm are cut out and applied to a solidified agar layer. The cup of Petri with samples is placed in a thermostat for 4-5 days at the same temperature – then conclusions are drawn. The score remains the same.

The method of determining the bactericidal properties of samples and resistance to *Esheriehia coli, Staphylococcus aureus, Bacillus subtilis* and *Fusarium oxusporum fungi.*

The bacteria were grown on meat-peptone agar (MPA). Cultures obtained from the collection of the Institute of Microbiology and Virology were transplanted twice onto shoals (for revitalization), bacteria were incubated in a thermostat at a temperature of 30-350C, fungi at 23-25$^0$C. A suspension with a titre of 109 cells in 1 ml (according to the turbidity standard) was prepared from the bacteria that grew during the day. Mushroom suspension was prepared from a five-day culture. The resulting suspension in the amount of 1 ml was placed in a sterile cup of Petri, poured with melted and cooled to 40-450C appropriate agar, vigorously mixed (for uniform distribution of microbes in the agar) and tissue samples were quickly dipped into the warm, non-solidified agar. Results were processed for bacteria after 2-6 days and for fungi after 5-7 days. The bactericidal and bacteriostatic effects of the substances contained in the fabric were taken into account.

*2.5. Determination of the final treatment resistance to washing*

To obtain data on the resistance of treated samples to washing, the following technique was used: samples of treated fabric are soaked at a temperature of 40 °C in a solution containing 5 g/l of oleic soap (60%) and 3 g/l of sodium bicarbonate for 10 minutes. Then the water-soaked fabric is subjected to friction (fabric against fabric) - 15 movements along the base and 15 movements along the weft. After that, the sample is washed with water at a temperature of 35–40 °C 2 times, and then washed with running cold water for 3–5 minutes until the soap is completely removed and dried in a dryer. The loss of samples mass is considered as a loss of finishing solution.

For greater visibility of the results obtained, showing the total weight loss of the samples, the percentage weight loss of the finishing, calculated according to the formula (2), will be shown:

$$\text{Percentage loss} = \frac{m_1 - m_2}{m_1} \cdot 100\% \qquad (2)$$

where $m_1$ is the mass of sample before washing and $m_2$ is the mass of sample after washing.

*2.6. Study of fabric stiffness*

A test strip of fabric (100*30 mm) is placed on a horizontal bearing surface and a lever is installed on it. With the help of a toggle switch the mechanism for lowering the bearing surface sides is turned on. After 5 minutes have passed since the separation of the test strip from the surface of the site, the bending of the test strip ends is measured using the bending indicators.

Stiffness (EI) in μN*cm$^2$ by the cantilever method is calculated by the formula (3):

$$\mathrm{EI} = 42046 \cdot \frac{m}{A}, \tag{3}$$

where $m$ – mass of the strip, g;

$A$ – relative bending function ($f_0$).

The relative bending ($f_0$) is calculated according to the formula (4):

$$f_0 = \frac{f}{l} = \frac{f}{7}, \tag{4}$$

where $f$ – final bending of test strips;

$l$ – the length of the hanging ends of the test strips, $l$ = 7cm.

*2.7. Study of hygroscopicity of treated fabrics*

A test strip of fabric (100*30 mm) is weighed on analytical scales, kept in a desiccator with 100% relative humidity for 4 hours, weighed again and dried to a constant weight at a temperature of 105-110 $^0$C. Weighing samples and calculating moisture are carried out according to the formula (5):

$$W = \frac{g_o - g_c}{g_c} \cdot 100, \tag{5}$$

where W – moisture content in the sample in %;

$g_o$ – sample weight before drying, g;

$g_c$ – dry sample weight, g.

*2.8. Determination of the treated tissues capillarity*

A strip of fabric 30 cm long (along the warp) and 5 cm wide (along the weft) is suspended by one end over a crystallizer with a solution of potassium dichromate of 5 g/l. The other end is dipped into the solution and observed the rise of the coloured liquid. The rise of the liquid is marked with a ruler, the zero point of which coincides with the liquid level. The countdown is carried out after 1, 5, 10, 20, 30 minutes and after 1 hour.

The effect of finishing components on the sorption of modified starch by cotton fabric was studied. The results are presented in Fig. 2.

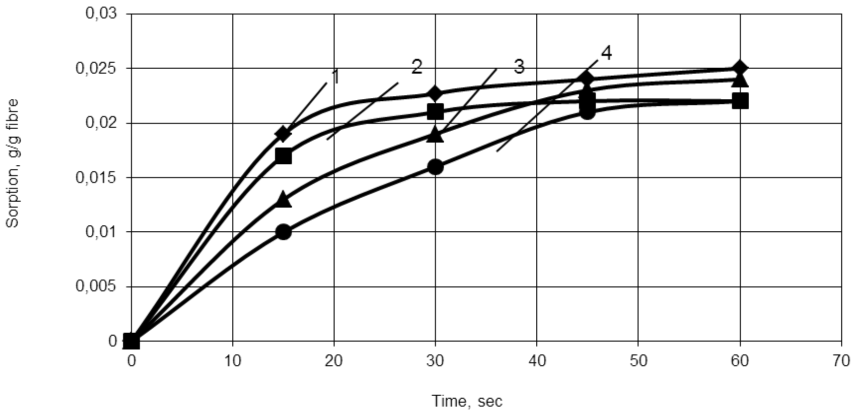



*Fig. 2. Sorption of CMS when adding an antimicrobial finish to cotton fabrics from the apret: 1 – № 4; 2 – № 7, 3 – № 3, 4 – № 1*

The results obtained are most likely explained by the formation of an ionic saint between the carboxymethyl groups of Na-KMK and decamethoxine according to the scheme:

$$2\left[Starch-CH_2-\underset{\underset{O}{\|}}{C}O^-\right]Na^+ + RN_2^{2+}\left[Cl^-\right]_2 \rightarrow \left[Starch-CH_2-\underset{\underset{O}{\|}}{C}O^-\right]_2 RN_2^{2+} + 2Na^+Cl^-$$

Thus, when imparting an antimicrobial finish by sizing with a composition containing Na-CMS and decamethoxin, the compound

$$Starch-CH_2-\underset{\underset{O}{\|}}{C}O-\text{decamethoxin.}$$

The degree of sorption of such a compound is higher than the sorption value of Na-CMS in mass terms. Thus, when imparting an antimicrobial finish by sizing with a composition containing Na– CMS and decamethoxin, the compound is sorbed from the sizing.

For the application of antimicrobial powers, it is a one-stage, uninterrupted method of treatment. After processing the scientific literature [5] for fixing decamethoxin, it was proponated with potassium iodide, so when it interacts with some cationic superficially active speeches, it is possible to establish stable low-grade diseases in water. Also, potassium iodide by itself exhibits antimicrobial activity, which can increase the overall antimicrobial power of pretreated fabrics.

The results of studies on antimicrobial properties determination of the samples are shown in Table 3.

*Table 3 – Results of antimicrobial tests of prepared samples processed by a single-stage continuous method*

| No. of the sample | Zone of delay, mm | Total zone, mm | Point assessment |
|---|---|---|---|
| 1 | 0 | 25 | 1 |
| 2 | 0 | 23 | 2 |
| 3 | 0 | 24 | 3 |
| 4 | 2 | 24 | 4 |
| 5 | 2 | 23 | 4 |
| 6 | 4 | 23 | 5 |
| 7 | 6 | 26 | 5 |

The results of antimicrobial tests of the obtained samples were as follows. Brown moss growths of irregular shape were observed on the sample treated with composition No. 1 (see Table 2), there were also colonies of bacteria of irregular shape, homogeneous structure of white and yellow colour, as well as small fungi of heterogeneous structure. A small number of small colonies of white and yellow bacteria with a uniform structure of regular and irregular shape were observed around the samples treated with formulations No. 3, 4, 6, and 7.

The obtained results indicate that tissue samples treated with decamethoxine and potassium iodide additives show antimicrobial activity against microorganisms from the air environment, they sufficiently delay the growth of microorganisms on the surface and around the studied material, and antimicrobial activity increases with an increase in the content of the antimicrobial drug in the finishing.

Results of bactericidal properties determination for samples and its resistance to Staphylococcus aureus, Esheriehia coli, Bacillus subtilis and Candida albicans fungi are shown in Table 4.

*Table 4 – Results of antimicrobial activity determination for tissue samples*

| Processing composition | Activity, points | | | |
|---|---|---|---|---|
| | S. aureus | E. Coli | B. subtilis | Candida albicans |
| 1 | 1 | 1 | 1 | 1 |
| 2 | 2 | 1 | 2 | 1 |
| 3 | 4 | 2 | 4 | 2 |
| 4 | 4 | 3 | 4 | 4 |
| 5 | 4 | 3 | 4 | 3 |
| 6 | 5 | 4 | 5 | 4 |
| 7 | 5 | 4 | 5 | 4 |

Washing resistance testing of finished textiles is one of the mandatory requirements for all finished products. In order to determine the resistance of the antimicrobial treatment to household washings, laboratory studies of tissue samples were carried out. The results of the study of the finishing content during washing are presented in Table 5 and Table 6.

*Table 5 – The results of tests of finished samples for resistance to washing by the gravimetric method of determination*

| | Sample number* | Without washing | Number of washing | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 |
| Weight of samples, g | 1 | 0,975 | 0,912 | 0,903 | 0,879 | 0,884 | 0,884 |
| | 2 | 0,915 | 0,860 | 0,857 | 0,856 | 0,855 | 0,855 |
| | 3 | 0,925 | 0,865 | 0,861 | 0,862 | 0,863 | 0,863 |
| | 4 | 0,945 | 0,876 | 0,882 | 0,888 | 0,896 | 0,896 |
| | 5 | 0,935 | 0,889 | 0,881 | 0,876 | 0,876 | 0,872 |
| | 6 | 0,980 | 0,940 | 0,930 | 0,928 | 0,926 | 0,926 |
| | 7 | 0,990 | 0,950 | 0,942 | 0,939 | 0,937 | 0,937 |

* – numbering of samples processed according to the regimes listed in Table 1.

*Table 6 – Results of tests of finished samples for resistance to washing*

| | Sample number* | Number of washing | | | | | ∑, % |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| % of samples weight loss | 1 | 6,153 | 6,289 | 6,458 | 6,689 | 6,689 | 6,706 |
| | 2 | 6,010 | 6,340 | 6,557 | 6,557 | 6,557 | 6,404 |
| | 3 | 6,490 | 6,920 | 6,811 | 6,703 | 6,920 | 6,669 |
| | 4 | 6,524 | 6,867 | 7,391 | 7,402 | 7,412 | 6,894 |
| | 5 | 4,920 | 5,775 | 6,310 | 6,310 | 6,738 | 5,354 |
| | 6 | 4,082 | 5,104 | 5,306 | 5,510 | 5,510 | 5,024 |
| | 7 | 4,040 | 4,850 | 5,150 | 5,354 | 5,253 | 4,638 |

* – numbering of samples processed according to the regimes listed in Table 2.

According to the analysis of the obtained results, it can be concluded that the addition of potassium iodide to the finishing composition significantly reduces the level of its wash-out during washing, which is positive.

In order to make sure that the proposed addition of potassium iodide significantly delays the antimicrobial drug in the structure of the fibrous polymer, it is necessary to conduct antimicrobial studies of washed samples of treated fabrics. The effectiveness of antimicrobial treatment of tissues prepared by a one-stage continuous method, which after preparation were washed according to the above-mentioned method, was determined by the agar method.

The data used to evaluate the effectiveness of the antimicrobial effect of the treated and then washed samples are presented in the Table 7.

*Table 7 – Results of antimicrobial tests of prepared samples after household washing*

| No. of the sample | Zone of delay, mm | | Total zone, mm | | Point assessment | |
|---|---|---|---|---|---|---|
| | Washing №5 | Washing №10 | Washing №5 | Washing №10 | Washing №5 | Washing №10 |
| 1 | 0 | 0 | 24 | 23 | 1 | 1 |
| 2 | 0 | 0 | 23 | 23 | 2 | 2 |
| 3 | 0 | 0 | 23 | 22 | 3 | 3 |
| 4 | 2 | 0 | 24 | 24 | 4 | 3 |
| 5 | 2 | 0 | 23 | 24 | 4 | 3 |
| 6 | 5 | 3 | 24 | 24 | 5 | 5 |
| 7 | 7 | 4 | 25 | 25 | 5 | 5 |

*Table 8 – Results of determination of antimicrobial activity of fabric samples after household washing*

| Processing composition | Activity, points | | | |
|---|---|---|---|---|
| | S. aureus | E. Coli | B. subtilis | Candida albicans |
| 1 | 1 | 1 | 1 | 1 |
| 2 | 2 | 1 | 1 | 1 |
| 3 | 4 | 2 | 4 | 2 |
| 4 | 4 | 3 | 3 | 4 |
| 5 | 4 | 3 | 4 | 3 |
| 6 | 5 | 4 | 5 | 4 |
| 7 | 5 | 4 | 5 | 4 |

During the final processing of textile materials with various finishes, the fabrics become denser and harder, which worsens the consumer properties of the fabrics. Therefore, to soften textile materials and give them elasticity, it is necessary to use special preparations – softeners. Therefore, the next stage of the work was to investigate how the addition of antimicrobial drugs affects the stiffness of the investigated tissues. The results are shown in Fig. 3.

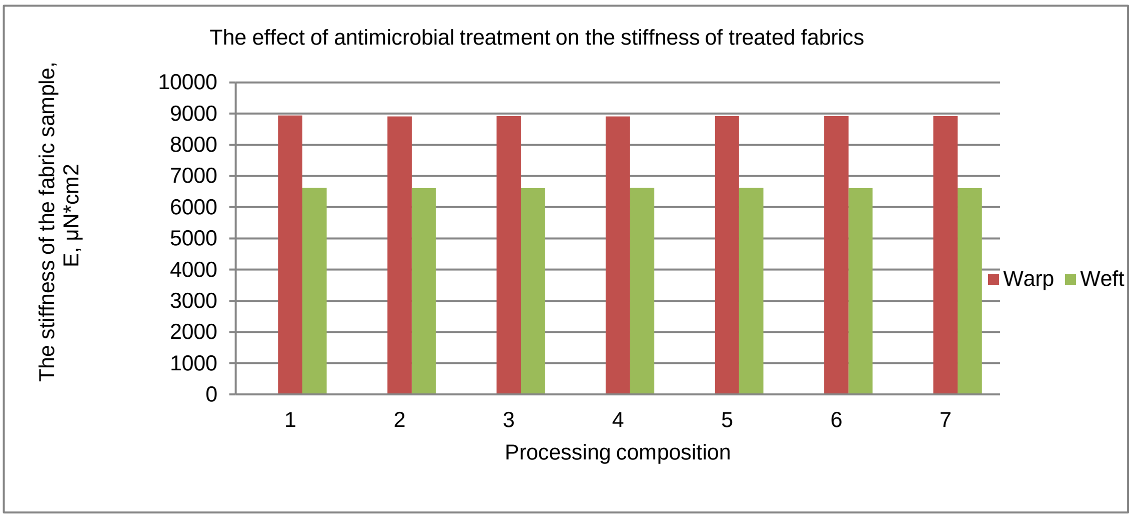



*Fig. 3. The effect of antimicrobial treatment on the stiffness of treated fabrics*

It was found that the influence of antimicrobial agents on the stiffness of textile materials is extremely insignificant.

It is known that hygroscopicity is the property of fabric to change its moisture depending on the humidity and temperature of the environment. Bed linen fabrics should have this property in the first place: they should easily absorb the moisture released by the human body and evaporate it into the environment, thus maintaining the human body in a hygienic state. The hygroscopicity of fabrics is characterized by the normal moisture content of the fibres that make up the fabric, that is, the moisture content of the fibers under normal conditions.

Moisture binds to materials in different ways. According to the intensity of the bond energy, these methods are divided into 3 groups: chemical, physicochemical, and physicomechanical.

Chemically bound moisture, which is not removed during the drying process, is best retained by the material. Adsorption moisture is a physical and chemical method of moisture connection with the material. Adsorption processes are greatly influenced by the chemical structure of the absorbent material. The sorption properties of high-polymer compounds that make up fibres depend on the presence of hydrophilic groups in the polymer molecule that actively interact with water molecules (hydroxyl –OH, carboxyl –COOH, carboamide –CONH, etc.), as well as on the packing density and molecular fibres weight.

Depending on the number of hydrophilic groups that have the ability to attract and retain water around them, textile fibres have greater or lesser hygroscopicity, therefore, at the same relative humidity and air temperature, different textile materials have different moisture capacities.

When absorbing moisture, the fibres swell, which increases the volume of the fibre more in diameter and less in length. This phenomenon is explained by the fact that the structural elements of the fibre – macromolecules, micro fibrils, fibrils are located along the axis of the fibre or at a small angle to it. Chemically bound moisture plays the main role in the processes of moisture-heat treatment of fabrics, because it is a plasticizer of the substance of fibres, weakens intermolecular bonds and facilitates the transition of fibres to a highly elastic state.

Therefore, it was appropriate to investigate the effect of antimicrobial drugs on the hygroscopicity and capillarity of the investigated tissues. The results of the research are given in Fig. 4-5.

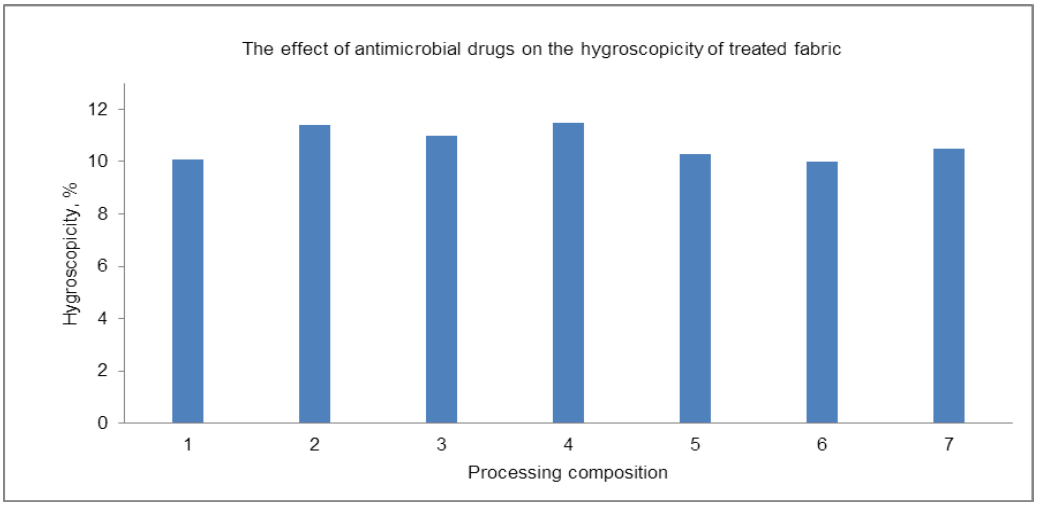



*Fig. 4. The effect of antimicrobial drugs on the treated fabric hygroscopicity*

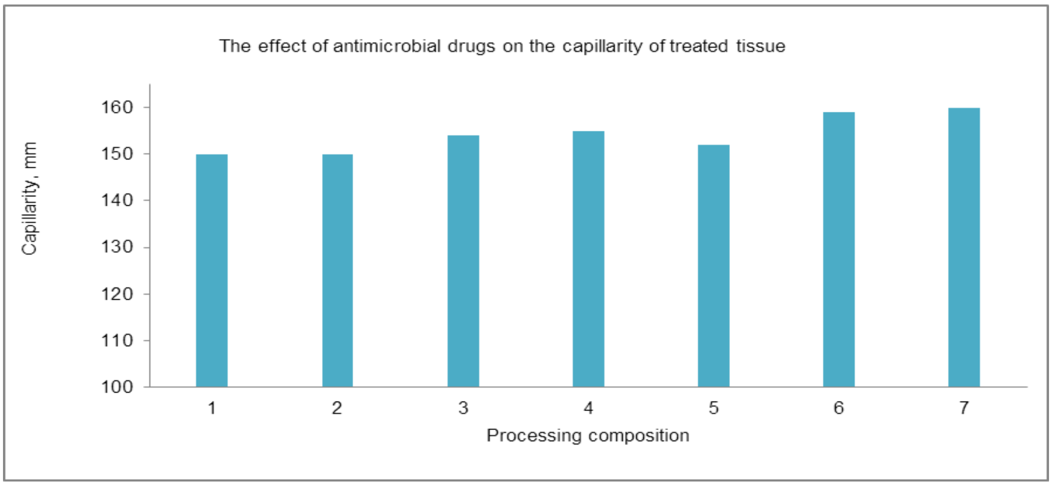



*Fig. 5. The influence of antimicrobial drugs on the treated tissue capillarity*

It has been established that preparations containing decamethoxine and potassium iodide increase tissue capillarity and practically do not affect hygroscopicity.

After analyzing the obtained results, it can be concluded that adding potassium iodide to the finishing composition actually increases the resistance of the finishing to washing and at the same time maintains a prolonged antimicrobial effect. Also, the main mechanical and physical parameters of the fabrics, which potentially depend on the fabric preparation process, do not change or improve slightly.

**Conclusions.**

1. As a result of the work performed, a technology of antimicrobial treatment of prolonged action can be proposed, which consists in the treatment of textile materials with a coating containing an antimicrobial composition of modified starch and a cationic surface-active substance – decamethoxine and potassium iodide, which is used to fix decamethoxine in the composition of the finishing covering.

2. Treated textile materials have an antimicrobial effect that lasts for multiple washings. Addition of decamethoxine and potassium iodide to the finishing practically does not affect the stiffness and hygroscopicity of fabrics and to a small extent increases their capillarity.

3. This technology is easy to use in production, quite promising, and can be implemented on basic equipment for the final processing of fabrics.

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***Олена Іщенко[1], Ольга Сумська[2], Катерина Смикало[3], Юлія Фещук[4], Дарія Кучинська[5]***

[1]доктор технічних наук, доцент, доцент кафедри хімічних технологій та ресурсозбереження
Київський національний університет технологій та дизайну (Київ, Україна)
**E-mail:** e_ishchenko5@gmail.com. **ORCID**: https://orcid.org/0000-0002-9510-6005
**ResearcherID**: GYV-0809-2022. **Scopus Author ID:** 57200013816

[2]кандидат технічних наук, доцент, доцент кафедри харчових технологій
Херсонський державний аграрно-економічний університет (Кропивницький, Україна)
**E-mail**: sumskaetdt@gmail.com. **ORCID**: https://orcid.org/0000-0003-1606-6103
**ResearcherID:** 91.215.68.126. **Scopus Author ID:** 57204470556

[3]здобувач вищої освіти
Херсонській національний технічний університет (Хмельницький, Україна),
доктор філософії, викладач студії моди (Луцьк, Україна)
**E-mail:** smykalo.kateryna@vnu.edu.ua. **ORCID:** https://orcid.org/0000-0002-9670-6563
**ResearcherID:** E-7755-2017. **Scopus Author ID:** 57809016000

[4]лаборант кафедри харчових технологій
Херсонський державний аграрно-економічний університет (Кропивницький, Україна)
**E-mail:** yulka131417@gmail.com. **ORCID:** https://orcid.org/0000-0003-0510-6325. **Researcher ID:** JOK-4531-2023

[5]аспірант кафедри хімічних технологій та ресурсозбереження
Київський національний університет технологій та дизайну (Київ, Україна)
**E-mail:** dkuchinska@gmail.com. **ORCID:** https://orcid.org/0009-0007-5928-6639

# АНТИМІКРОБНА ОБРОБКА ТЕКСТИЛЬНИХ МАТЕРІАЛІВ

*Використання текстильних матеріалів з антимікробною обробкою є одним із способів ефективного захисту людини від впливу різних збудників. Стаття присвячена актуальному питанню розробки інноваційних текстильних матеріалів з пролонгованою антимікробною обробкою. Встановити можливість та особливості одержання інноваційних текстильних матеріалів з пролонгованою антимікробною обробкою. Для підготовки цієї статті було розглянуто публікації стосовно препаратів та технологій одержання антисептичних текстильних матеріалів, які були у відкритому доступі. Незважаючи на те, що дослідження за цією тематикою проводилися, але для отримання пролонгованого ефекту необхідно приділити особливу увагу проблемі фіксації протимікробного препарату.*

*Визначено склад композиції, особливості обробки текстильного матеріалу; досліджено вплив полімерного носія, фіксатора на стійкість заключної обробки з антимікробним ефектом. Для отримання пролонгованого антимікробного ефекту було вирішено проблему фіксації антимікробного препарату на текстильному матеріалі за допомогою розробленої композиції препарату. Запропоновано опоряджувальна суміш, яка містить – карбоксиметильований крохмаль, декаметоксин як бактерицидний препарат і засіб для їх закріплення на текстильному матеріалі – йодистий калій. Досліджено вплив компонентів на сорбційні властивості бавовняною тканиною та виявлено збільшення цього показнику на оброблених тканинах. Це пояснюється утворенням іонного зв'язку між карбоксиметильними групами та декаметоксином. Встановлено технологічні особливості нанесення пролонгованої антимікробної обробки текстильного матеріалу, одностадійним безперервним способом апретування.*

*Показано вплив полімерного носія та фіксатора на стійкість заключної антимікробної обробки. Наведено результати антимікробних досліджень підготовлених зразків, оброблених технологічними методами. Встановлено, що тканина, виготовлена за запропонованими технологічними режимами, має антимікробну дію, стійка до багаторазових прань. Розроблена технологія є перспективною і може бути реалізована на обладнанні опоряджувальних фабрик.*

***Ключові слова**: антимікробний захист; декаметоксин; модифіковані полісахариди; застосування; четвертинна амонійна сіль; текстиль; антимікробний засіб.*

*Рис.: 5. Табл.: 8. Бібл.: 23.*

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