IMPROVEMENT OF FLAME RETARDANT AND ANTIBACTERIAL PROPERTIES OF COTTON-POLYESTER BLEND FABRICS

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ABSTRACT

The fire retardant and antibacterial characteristics of cotton-polyester blend fabric have been improved. A composition has been developed for complex finishing of fabric using a phosphorus-containing substance on a biological basis, which, due to its high phosphorus content, can provide a fire-retardant function to textile material, as well as increase its antimicrobial properties. The thermal characteristics of treated textile materials have been studied and it has been established that the presence of phytic acid at the initial stage of destruction shifts the temperature towards lower values due to the activation of phytic acid degradation before the decomposition of the main substrate. The maximum temperature at which the final destruction of the cotton-polyester fabric occurs shifts to higher temperatures from 507°C for the untreated fabric to 565°C for the treated fabric, and the presence of dry residue increases by more than 2.5 times, which proves an increase in the heat resistance of the textile material. The length of the damaged area in the vertical combustion test was 6.5 cm, and the absence of drop formation of the polyester component was also noted, which eliminates the potential destructive effect due to the possible formation of additional fire areas. An increase in fabric antimicrobial activity is confirmed by a zone of inhibition of 2 – 4 mm around the sample using the diffusion method with gram-positive bacteria Staphylococcus pyogenes, as well as a pronounced growth inhibition of microorganisms around fabric samples examined by the method of inoculation of microflora from the environment. Treatment with the studied composition improves washing resistance and does not impair the mechanical properties of the textile material by increasing the degree of crosslinking of the polymer components used in the finishing composition.

KEYWORDS

Phytic acid; Polyhexamethylene guanidine phosphate; Thermal analysis; Antimicrobial finishing compositions; Fire-retardant finishing compositions; Cotton-polyester fabrics.

INTRODUCTION

The living conditions of a modern person dictate more and more new requirements for clothing, which should not only be comfortable and beautiful, but in the current difficult epidemiological situation, including the coronavirus pandemic, provide protection from the pathogenic effects of viruses and microorganisms. First of all, this concerns medical textiles, but the functionalization of home textiles, as well as fabrics for transport, military use, etc., is now acquiring no less importance. The search for effective sterilizing preparations against common pathogenic microorganisms, but at the same time non-toxic, is an important requirement of our time for the development of innovative technologies for imparting antimicrobial properties to textile materials.

No less popular in modern textile materials is resistance to fire. This requirement is caused by numerous fires provoked by global climate change, man-made disasters, hostilities, etc. Despite the rather high degree of fire protection of textiles with halogen- and formaldehyde-containing preparations, they must be abandoned due to the negative impact on the human body and the environment due to the release of hazardous halides, dioxins, benzofurans, and formaldehyde during combustion.

Due to the negative state of the environment in the world, there is a tendency to abandon the use of organic synthesis products. Substances originating from natural sources – biological or mineral – are increasingly used, in particular in textile finishing. Along with this, it is promising to search for and introduce into production multifunctional substances of natural origin, which, together with flame retardant properties, will impart antibacterial activity in order to ensure the functionality of finished products and the economic efficiency of their production.

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Currently, the attention of researchers is attracted by biologically based antimicrobial agents and fire retardants, which is the result of the society's desire to use environmentally friendly products and substances that are not generated from oil [1-3]. Scientists are developing and improving such preparations taking into account the fundamentals of "green technologies", namely, biologically active additives are being studied that can increase protection against fire and pathogenic microflora that threatens human life and health. Among natural plant products, extracts of neem, pomegranate, aloe vera, turmeric, cloves, etc. have antibacterial properties [4].

Biologically active substances can be added to synthetic fibres during the formation process [5], thus polyacrylonitrile, acetate and polypropylene fibres are functionalized and already on the market. However, this method of modification is fundamentally impossible for the processing of natural fibres. A more universal method of fibre modification is the formation of a polymer coating on the textile material, which makes it possible to immobilize various functional substances depending on the purpose of the textile and consumers [6]. For example, a composition with chitosan, a substance obtained from crustacean shells, has been developed to impart antimicrobial properties to nylon, cotton, and wool [7-9]. The disadvantages of chitosan are the need to use it in high concentrations, which worsens the hygienic properties of textile materials, increases their rigidity, as well as insufficient resistance of treatment to washing.

Recently, the interest of inventors is directed to bioorganic phytic acid, known as inositol hexakisphosphate or phytate in the form of a salt, which is considered as a "green" molecule, contained in sufficient quantities in plant tissues [10]. As a biocompatible, environmentally friendly, nontoxic, and easily obtained organic acid, it is widely used in antioxidant, biosensor, cation exchange, nanomaterial, and other fields due to its special structure of inositol hexakisphosphate [11].

Phytic acid contains 28 wt.% phosphorus in terms of molecular weight and is a promising biomacromolecule for use as a fire retardant. In [12], phytic acid was used as a doping acid to significantly improve the flame-retardant characteristics of composite paper deposited with polyaniline. The compositions phytic acid /chitosan and phytic acid /nitrogen-modified silane hybrids were used by layer-by-layer assembly to produce thin fire-resistant films on cotton fabric [13]. The potential fire protection effect of various metal phytates was evaluated as a biosource of phosphorus additives for composites based on polylactic acid [14].

In general, the use of phytic acid allows it to be considered as one of the components of antimicrobial treatment. This is confirmed by the publication [15], which describes a method for treating cotton fabric coated with phytic acid with silicon and a nitrogen-containing compound, poly-[3-(5,5-cyanuric acid propyl-siloxane-tri-methylammoniumpropyl-siloxane-chloride)] by layer-by-layer assembly (Cotton-PEI/(PCQS/PA) 30-Cl). Treated cotton fabrics reduced the effects of E. coli and S. aureus by 100% within 1 minute of contact.

Cationic polymers such as quaternary ammonium compounds and guanidine-based polymers are known for their antimicrobial activity. They are widely used as active agents to fight cross-infections and contribute to the overall reduction of bacterial nosocomial infections. The effectiveness of antimicrobial treatment of cotton fabrics intended for use in everyday life and public buildings with coatings based on various types of polymers – guanidines or polymer nanocomposite materials with permanent antimicrobial properties without deterioration of their physicochemical and mechanical characteristics has been confirmed [16]. In addition, it is known [17] to use biodegradable polycarbonates functionalized with guanidine to provide in vivo antimicrobial activity against A. baumannii, E. coli, Klebsiella pneumoniae, S. aureus, and P. aeruginosa. In another study [18], polymer film coatings based on PVA/chitosan with the addition of polyhexamethylene guanidine were obtained, which are characterized by antibacterial properties.

An analysis of the results obtained by scientists indicates the relevance of the issue of simultaneously imparting flame retardant and antimicrobial properties to textile materials, as well as the existence of a whole range of unresolved issues, in particular, the search for environmentally friendly preparations and the development of resource-saving technologies for imparting appropriate special properties and characteristics to cotton textile materials.

The use of biomacromolecules in modern technologies as functional substances that can be used as fire retardants and as antimicrobials is a potential innovative environmentally friendly and non-toxic strategy that goes beyond the traditional chemical approach in creating "green" technologies.

The aim of this work is to develop a composition for the complex functional finishing of cotton-polyester textile material using a bio-based phosphorus-containing substance that can provide the flame-retardant function of the textile material due to phosphorus-nitrogen synergy, as well as increase its antimicrobial properties.

MATERIALS AND METHODS

Phytic acid and polyhexamethylene guanidine phosphate (PHMG-p) have been investigated as functional substances capable of providing a complex finish to fabrics and imparting both antimicrobial and flame retardant properties. Finishing was subjected to bleached and plain dyed blended cotton-polyester fabrics (PJSC Cherkasy Silk Plant).

Table 1. Characteristics of textile materials.

Fabric construction	Fabric composition	Surface weight [g/m^2]	Density [yarns per 10 cm]	
			warp	weft
2/1 twill	47% polyester, 53% cotton	220±11	300±6	160±6

The characteristics of the textile materials under study are presented in Table 1. The choice of the presented textile material is not accidental and is due to the fact that blended fabrics are widely used in everyday life to one degree or another.

In the case of imparting to textile materials any new properties that were not previously characteristic of them (bactericidal, reduced flammability, hydro-, oleophobicity, etc.) the principle of "transfer" of a substance with predetermined and specified properties to a polymeric textile material is used.

The textile material was treated with an aqueous solution of phytic acid (PhA) with the addition of citric acid (CA), which improves the solubility of PhA in water and increases the carbon residue during the combustion of the fabric. The tricarboxylic acid addition also provides cross-linking with the –OH groups of the cellulose component of the fabric.

The composition of the impregnating bath contained as a binder acrylic polymer Neoprint NPO – 60 g/l; PhA – 300 g/l; CA – 200 g/l; PHMG-p (6% aqueous solution) up to 1000 g. The acrylic dispersion is introduced to increase the stabilization of functional components and is able to provide a set of necessary fabric properties. After impregnation with the finishing composition, the textile materials were pressed on a laboratory padder to a residual moisture content of 90%, dried to a constant weight in an oven at a temperature of 80 °C, followed by heat setting at a temperature of 120 °C for 5 minutes.

The behaviour of the studied textile material under the influence of high temperatures was evaluated by the method of thermogravimetric and differential thermal analysis after examining the samples on the Thermoscan-2 derivatograph. Studies were carried out with treated and untreated fabric samples in the temperature range up to 700 °C, using quartz crucibles. Aluminium oxide was used as a reference. The weight of the samples was 0.1 g. The samples were heated in air from 10°C to 700 °C at a constant heating rate of 10 °C/min.

RESULTS AND DISCUSSION

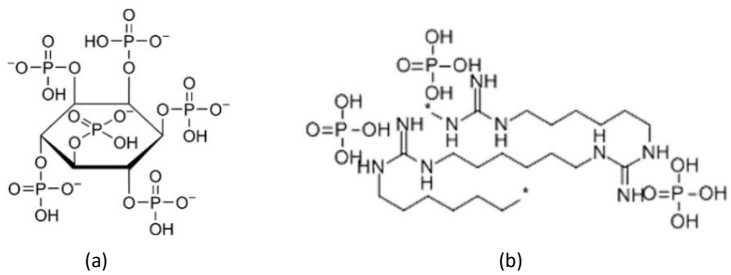
The heat resistance results of the textile materials under study are compared with untreated textile samples in Table 2.

Mass loss at temperatures from $T_{0\%}$ to $T_{5\%}$ for the original cotton-polyester fabric occurs mainly due to the dehydration of cotton fibres and reaches 5%. According to the literature data, thermal degradation of polyester fabric occurs at 410°C. However, the presence of cotton fibres in the fabric affects the decomposition of the untreated sample. The main stage of destruction occurs at 314°C, which is actually close to the decomposition temperature of the cotton component of the fabric, since the thermal decomposition of cotton begins at a lower temperature than polyester. The final destruction temperature for the initial sample occurs at T_f = 507°C. In the case of a cotton-polyester blend fabric, the cotton acts as the initial ignition source, and the mass loss is mainly due to the complete decomposition of the cotton and the partial decomposition of the polyester in the second temperature range.

Table 2. Heat resistance of textile materials.

Treatment	Mass loss temperature					Mass fraction of residue, ε_m [%]
	$T_{0\%}$ [°C]	$T_{5\%}$ [°C]	$T_{10\%}$ [°C]	$T_{20\%}$ [°C]	T_f [°C]	
Untreated fabric	122	232	292	314	507	1.7
PhA+CA	194	208	234	290	546	4.82
PhA+CA+PHMG-p	205	219	241	298	565	5.07

Note: $T_{5\%}$ (°C), $T_{10\%}$ (°C), $T_{20\%}$ (°C) – correspond to the temperatures at which fabric samples lose weight by 5%, 10%, 20%, respectively; $T_{0\%}$ – the beginning of destruction; T_f – the final temperature of mass loss (end of destruction).



(a) (b)

Figure 1. Structural formulas of macromolecules: (a) phytic acid; (b) polyhexamethylene guanidine phosphate.

The initial stage of destruction of the cotton-polyester fabric sample treated with PhA occurs with the formation of a protective barrier at a temperature equal to 194°C – 208°C, which is due to the decomposition temperature of PhA. The value of the mass loss of the fabric sample treated with PhA is significantly shifted towards lower temperatures at the first stage. Thus, with a mass loss of 10%, the temperature decreased from $T_{10\%}$ = 292°C for untreated fabric to 234°C, which is explained by the catalytic effect of PhA, which contributes to the carbonization of cotton. The same trend persists with a loss of fabric mass of 20%. The decomposition temperature of $T_{20\%}$ is still 24°C lower than that of the untreated fabric. This property belongs to the phosphate groups of the PhA biomacromolecule, which, decomposing at a temperature of about 200°C and releasing phosphoric acid, promotes fabric dehydration, which leads to the formation of a residue that is thermally stable up to 500°C – 600°C [19,20]. The significant advantages of this biomacromolecule include not only the formation of acid, but also the fact that it is, by its nature, a carbon source that promotes the formation of a carbonized layer on the surface of textile materials [21]. The structural formula of PhA is shown in Fig. 1.

Phosphorus-containing compounds, which include the biomacromolecule of PhA, are thermally decomposed to $PO^{\bullet}$, which can block combustion, although $H^{\bullet}$ and $HO^{\bullet}$ are formed when the matrix combustion is extinguished. On the other hand, phosphorus-containing compounds can catalyse dehydration and carbonization reactions containing –OH groups [22].

The temperature of the end of destruction of the studied textile material treated with PhA T_f = 546°C shifts relative to the untreated sample, the end temperature of which is 507°C and moves to a higher temperature region. This confirms the improvement in the fire resistance of the textile compared to the untreated fabric. At temperatures above 500°C, the process of thermal oxidation occurs, that is the formation of a carbonized residue, the value of which on the fabric depends mainly on the organic and inorganic substances deposited on the surface. The condensed phase mechanism based on the use of PhA is further enhanced by the inclusion of PHMG-p containing nitrogen.

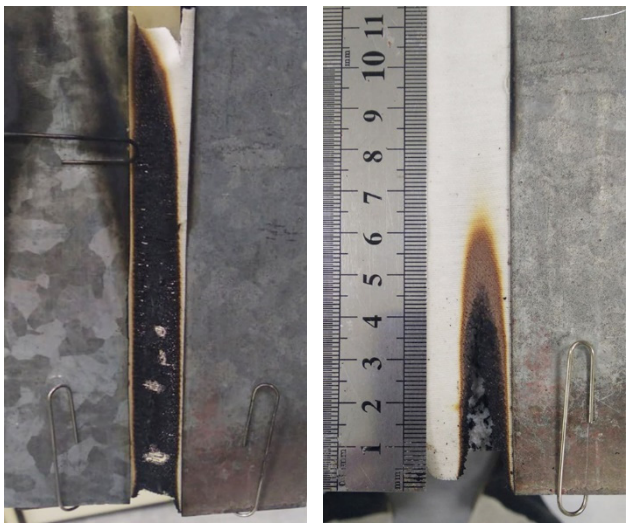
When the system is functionalized with nitrogen-containing compounds, mechanisms of gas-phase and intumescent action are observed through the release of NH_3 during combustion. During the decomposition of the nitrogen-containing agent, a gas barrier of ammonia is formed above the surface of the substrate, which impedes the access of oxygen and inhibits the oxidation of carbon in the gas phase. Phosphorylation of cellulose is catalysed by nitrogen-containing molecules through the intermediates PN, CO_2, NH_3. It was shown in [23] that the formed carbon layer and the formed dense framework in this case may contain POP, POC, PNC bonds. As a result of the study, it was found that the mass fraction of residues of the treated textile material is 4.82% and 5.07% in the case of the addition of PHMG-p. The coke residue of the initial cotton-polyester fabric at a temperature of 700°C was 1.7%.

The results of thermal analysis were confirmed by fire resistance tests of the studied fabric samples in terms of afterburning time and charring height. The charring height after exposure to a flame for 15 seconds was 6.5 cm for the fabric sample treated with the composition containing PHMG-p (Fig. 2). At the same time, this sample is characterized by the intumescent nature of the fabric behaviour during combustion.

There was no residual burning of the fabric after removal from the fire. The absence of drop formation of the polyester component of the fabric was also noted.

The studied samples of cotton-polyester fabric showed the presence of a significant charred residue after burning compared to untreated ones, and the absence of drop formation of the synthetic component was also noted, in contrast to the untreated fabric. The formation of an isolated dense protective layer is important for improving the flame-retardant properties of textile materials, as it prevents its subsequent heating and blocks the free access of atmospheric oxygen, contributing to the further formation of a carbonized layer.

The versatility of polyhexamethylene guanidines is confirmed by the fact that they are also effective and environmentally friendly antimicrobial agents [24, 25]. Thus, the presence of PHMG-p in the finishing composition will not only enhance the fire retardant and antimicrobial properties of textile materials, but also additional film formation on the surface of textile



(a) (b)

Figure 2. The nature of carbonization of cotton-polyester fabric samples treated with the studied compositions: (a) PhA+CA; (b) PhA+CA+PHMG-p.

fibres, which will increase the resistance of the finishing to physical and chemical influences. Also, the macromolecular nature of PHMG-p due to film formation is able to provide a prolonged antimicrobial effect as a result of the formation of a biocidal film on the surface, which provides long-term (several months) protection of the treated surface from microorganisms.

Polyguanidines by their nature are polycationic amines capable of destroying bacterial cells due to electrostatic attraction [26, 27] and, according to the literature, they are classified as low-hazard substances when applied to the skin.

For example, [28, 18] presents studies of biodegradable polycarbonates functionalized with guanidine to provide in vivo antimicrobial activity against A. baumannii, E. coli, Klebsiella pneumoniae, S. aureus and P. aeruginosa. The mechanism of action is described as a significant electrostatic attraction between a cationic polymer and a negatively charged bacterial cell, facilitating its rapid destruction under the influence of guanidine biocides [29].

Identification of the effectiveness of antibacterial sensitivity of textile materials treated with finishing compositions was carried out on LB medium of the following composition (g/l): peptone – 10.0; yeast extract – 5.0; NaCl – 5.0; agar-agar – 14.0; at pH – 7.0±0.2. As a test culture, we used one of the representatives of the wound microflora – the gram-positive bacterium Staphylococcus pyogenes from the Ukrainian collection of microorganisms, which was cultivated at 37°C for 24 hours. After cultivation, part of the culture was added to physiological solution and aliquots from the resulting suspension were transferred to fresh LB medium, then fabric samples treated with the compositions were added. After keeping in a desiccator for 24 hours, the resistance of the treated fabric samples to the action of microorganisms was determined.

The results of the study showed that around samples of cotton-polyester blend fabric treated with phytic and citric acids, there is a zone of growth inhibition of Staphylococcus pyogenes microorganisms within 1 – 4 mm.

In the photos of Fig. 3 shows the zone of growth inhibition of treated fabric samples with and without heat setting. Analysis of the results shows that the growth inhibition zone of Staphylococcus pyogenes microorganisms is within 2 – 4 mm (Fig. 3). The inhibition of the growth of Staphylococcus pyogenes bacteria culture, confirming the antimicrobial properties of the textile samples treated with the studied composition, was evaluated by degree during their incubation.

Given that textile materials are used in everyday life, transport and other public places, determining the effectiveness of antimicrobial treatment to inhibit

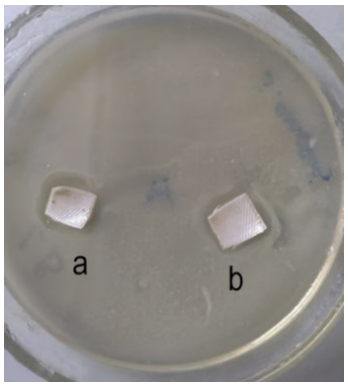


Figure 3. Staphylococcus pyogenes growth inhibition zone around the fabric samples treated with PhA+CA+PHMG-p: a) with heat setting; b) without heat setting.

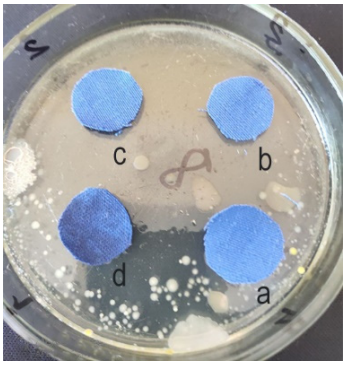


Figure 4. Inhibition of bacterial contamination of microflora inoculated from the air: a) untreated sample; b) sample treated with PhA+CA+PHMG-p+heat setting; c) treated sample after 1 washing cycle; d) treated sample after 5 washing cycles.

bacterial pollution of air microflora is of great importance. This method is one of the simplest and fastest methods for studying air microflora and is used for comparative analysis of bacterial environmental pollution. For inoculation of microorganisms from the microflora of the environment, Petri dishes with solidified agar were left in an open space in a room for 15 min. Fabric samples in the form of a round disk were placed in a Petri dish on the surface of air-inoculated agar, covered, placed in a thermostat for incubation for 72 hours at a temperature of 38°C. The antimicrobial properties of textile materials were determined by analysing the diffusion of a fabric disk. The results of the study are presented in Fig. 4.

As can be seen from the photo in Fig. 4, the initial fabric (Fig. 4a) is characterized by high bacterial contamination, the absence of an inhibition zone around it, and the development of various microflora inoculated from the air. Composite treatment (Fig. 4b) shows a significant zone of growth inhibition of pathogenic microflora, that is observed even after the first washing (Fig. 4c). After the fifth washing (Fig. 4d), the quality of the antimicrobial treatment decreases, but still, at a distance of 1 – 2 mm around the sample, the maximum amount of microflora is suppressed.

Table 3. Structural characteristics of the formed polymer films.

Composition of polymer film	Sol fraction, *S* [%]	Degree of polymer crosslinking, *j* [%]	Crosslinking coefficient	Fraction of active polymer chains, *Vc* [mol/cm^3]
Without additives	3.20	4.74	9.48	0.75
PhA+CA	2.89	2.89	5.78	0.77
PhA+CA+PHMG-p	0.42	14.50	29.0	0.92
PhA+CA+PHMG-p+ heat setting	0.39	15.07	30.14	0.93

The zone of inhibition formed around textile samples treated with PHMG-p and biological PhA confirms the effectiveness of the antimicrobial treatment against a variety of airborne bacteria.

Taking into account that textile materials during operation are subjected to various physical and chemical influences, in particular washings, an acrylic polymer was additionally introduced into the finishing composition as a film former capable of immobilizing various substances on the surface of textile fibres. To confirm the effectiveness of the introduction of the film former, the structural characteristics of the films formed from the acrylic polymer Neoprint NPO, as well as films from Neoprint NPO with the addition of acids and PHMG-p, were studied. Studies were carried out using the limited swelling properties of cross-linked polymer systems in solvents. Structural characteristics were evaluated by the amount of the acetone-insoluble fraction of the studied polymer films during the extraction of samples in a solvent.

To determine the structural characteristics, polymer films were formed on a glass substrate from individual Neoprint NPO and the polymer filled with functional components to impart a flame retardant and antimicrobial finish. Extraction of polymer films was carried out with acetone for 18 hours and benzene for 16 hours in a Soxhlet apparatus according to the standard procedure. The mass of the swollen sample was determined, as well as the dry residue from it. The amount of benzene extract corresponds to the content of the sol fraction S (%) and is determined by the relation:

$$S = \frac{m_a - m_b}{m_a} \cdot 100\%, \qquad (1)$$

where m_a is the mass of the sample after extraction with acetone, g; m_b is the mass of the sample after extraction with benzene, g.

The presence of the sol fraction after extraction in the Soxhlet apparatus indicates the content of the macromolecules remaining outside the network in the crosslinked sample of the composite polymer film. The sol fraction is washed out of the polymer film by the solvent, since it is not bound into a three-dimensional network of the polymer formation.

The degree of polymer crosslinking (crosslinking coefficient), showing the number of monomer chains, along which the crosslink was formed, in terms of the average macromolecule, was determined by the relation:

$$j = \frac{1}{S+\sqrt{S}}, \qquad (2)$$

The fraction of active polymer chains was found by formula:

$$V_c = (1 - S)^2(1 - 2jS)(1 + jS), \qquad (3)$$

The calculation results are presented in Table 3.

When PhA and CA are added to the acrylic polymer, the cross-link density of the polymer compared to an unfilled film is reduced by 39%, while the fraction of active chains is 0.77 compared to an unfilled film, the fraction of active chains of which is 0.75. The addition of PHMG-p to the polymer composition makes it possible to increase the degree of film crosslinking by almost 3 times and reach 14.50%. An increase in the degree of crosslinking of the polymer film is associated with the ability of PHMG-p to film formation, which leads to an increase in the number of interlinkages of polymer macromolecules. After heat setting, the degree of crosslinking of the composite polymer film somewhat increases.

Tensile tests were performed to compare the mechanical properties of treated and untreated cotton-polyester textile materials. The research results are shown in Fig. 5. Qualitative indicators of functional finishes are included in the Table 4.

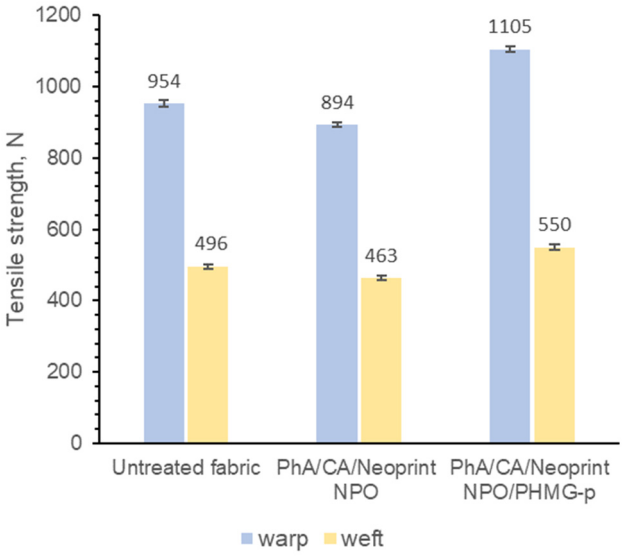


Figure 5. Tensile strength of untreated and treated cotton-polyester fabrics.

Table 4. Qualitative indicators of the functional finish of cotton-polyester fabric.

Treatment	Height of the charred area [cm]	Afterflame time [s]	Afterglow time [s]	Height of charred area after washing [cm]	Washing fastness
Untreated fabric	–	–	–	–	–
PhA – 300 g/l; CA – 200 g/l; Neoprint NPO – 60 g/l	12.5	–	–	15	resistant to 1 washing cycle
PhA – 300 g/l; CA – 200 g/l; Neoprint NPO – 60 g/l; PHMG-p – up to 1000 g	6.5	0	0	12.4	resistant to 5 washing cycles

Textile materials treated with a composition with PhA have a slightly reduced tensile strength, which can be explained by the acidic nature of the biomacromolecule used. The composition, which includes PHMG-p, restores tensile strength by increasing the degree of crosslinking of the polymers in the composition.

The decrease in resistance of the functional treatment to washing can be explained by the fact that the washing process takes place at high pH values (~10.5) arising from the presence of detergent, as well as by ion exchange with alkali metal cations, such as sodium, released from detergent agents and hard water. At the same time, given that PhA has six phosphoric acid groups, it can be used to obtain reactive fire retardants by interacting with amino groups and hydroxyl groups to improve washing fastness [30].

Table data confirm that the developed finishing composition makes it possible to obtain textile materials with enhanced antimicrobial and flame retardant properties. Thus, the result of the work is the developed composition for obtaining a complex antimicrobial and fire-retardant textile material that has barrier functions against pathogenic microorganisms and an open flame.

CONCLUSIONS

The composition containing phytic acid and polyhexamethylene guanidine phosphate, due to the high content of phosphorus and nitrogen, gives the cotton-polyester fabric flame retardant and antimicrobial properties. The damaged length of the fabric decreased to 6.5 cm in the vertical burn test. TGA showed a shift in the temperature of the final destruction of the fabric to higher temperatures, which indicates an increase in the thermal stability of the fabric and contributes to the formation of charred parts that can prevent the transfer of heat and fuel in the condensed phase. An increase in the antimicrobial activity of the fabric is confirmed by a zone of inhibition of 2 – 4 mm around the sample according to the diffusion method using gram-positive bacteria Staphylococcus pyogenes, and is also characterized by a pronounced retardation of the growth of microorganisms around fabric samples studied by the method of inoculation microflora from the environment. Treatment with the studied composition improves the resistance to washing by increasing the degree of crosslinking of the polymer components used in the finishing composition, and also does not impair the mechanical properties of the textile material.

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