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DEVELOPMENT OF AN INTUMESCENT SYSTEM BASED ON PHOSPHORUS-CONTAINING BIOMACROMOLECULES FOR THE FLAME-RETARDANT FINISHING OF CELLULOSIC TEXTILE MATERIALS

Introduction. Owing to the limitations of conventional flame retardants and increasingly stringent environmental regulations worldwide, the development of environmentally benign approaches to improving the flame resistance of textile materials has become an important research priority.

Problem Statement. Flame-retardant properties are conventionally imparted to textile fabrics through impregnation with flame-retardant formulations, many of which are based on halogen-containing compounds that pose significant environmental and health risks.

Purpose. This study aims to develop an intumescent formulation based on naturally occurring compounds for enhancing the thermal stability and flame resistance of cotton fabrics.

Materials and Methods. The developed intumescent formulation consists of phytic acid as the primary phosphorus-containing flame retardant, allantoin as the nitrogen-containing component, citric acid, and aluminum sulfate. The thermal stability of the treated fabrics is evaluated by thermogravimetric

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and differential thermal analyses, structural changes are characterized by Fourier-transform infrared (FTIR) spectroscopy, and flame-retardant performance is assessed using the vertical flame test.

Results. The presence of phytic acid, particularly in combination with aluminum sulfate acting as a smoke suppressant, promotes the onset of thermal decomposition at lower temperatures than in untreated cotton owing to the early decomposition of phytic acid prior to the degradation of the cellulose substrate. At the same time, the temperature corresponding to the final stage of cellulose degradation shifts to higher values, increasing from 499 °C for untreated cotton to 550 °C and 544 °C for the formulations containing phytic acid. The char residue increases by approximately 6%, indicating enhanced thermal stability of the treated fabric. Furthermore, the intumescent action of allantoin as the nitrogen-containing component improves the structural integrity and volumetric stability of the protective char layer. FTIR spectroscopy has confirmed the formation of chemical interactions between the flame-retardant formulation containing phytic acid and allantoin and the cellulose fibers.

Conclusions. The developed intumescent system based on naturally occurring phosphorus- and nitrogen-containing compounds has demonstrated high potential for improving the thermal stability and flame resistance of cellulosic textiles. The obtained results have provided a scientific basis for the development of environmentally friendly flame-retardant formulations for cotton and cotton-blended textile materials.

Keywords: phytic acid, allantoin, thermal stability of cotton fabric, coke-forming properties, fire-retardant finishing composition.

The primary objective of flame-retardant technologies for structural and textile materials is to reduce the heating rate of the protected surface while maintaining the mechanical integrity of the material for a specified period under fire exposure. Phosphorus-containing flame retardants, such as tetrakis(hydroxymethyl)phosphonium chloride (THPC) and N-methylol dimethylphosphonopropionamide (MDPA), commercially known as Pyrovatex CP and Pyrovatex CPN, are widely used for the flame-retardant finishing of cellulosic fabrics [1]. These compounds modify the cellulose pyrolysis pathway by suppressing the formation of levoglucosan and other flammable volatile products while promoting char formation. However, their major drawback is the release of formaldehyde during both the curing process and the subsequent use of treated textile materials. Because formaldehyde is recognized as a carcinogenic compound, increasing attention is being paid to the development of environmentally friendly flame-retardant systems [2].

Among the emerging approaches for improving the fire performance of textile materials, intumescent flame-retardant systems have attracted considerable interest. These systems promote the expansion and conversion of the surface layer ex-

posed to heat into a porous carbonaceous char. The resulting intumescent char acts as a physical barrier that protects the substrate from heat and flame for a certain period while simultaneously restricting the diffusion of atmospheric oxygen to the textile surface.

The effective performance of intumescent systems requires the presence of three principal components:

- ◆ an acid source, typically inorganic or organic acids and their derivatives, such as ammonium polyphosphate;
- ◆ a carbon source (char-forming agent), commonly pentaerythritol;
- ◆ a blowing agent (gas-generating agent), such as melamine or urea.

The flame-retardant efficiency of intumescent coatings is determined by several mechanisms:

- ◆ endothermic heat absorption, associated with the physical and chemical transformations occurring during the formation of the expanded char layer. The gaseous products released during this process, including ammonia, carbon dioxide, nitrogen, and water vapour, pass through the developing intumescent char, thereby cooling it and removing a significant portion of the incoming thermal energy;

- ◆ the thermal stability and insulating capacity of the intumescent char, which depend on its thermal conductivity, thermal resistance, thickness, microstructure, and formation kinetics;
- ◆ the barrier effect of the intumescent char, which reflects and absorbs part of the incident heat flux while simultaneously limiting the diffusion of volatile decomposition products into the flame and restricting the transport of atmospheric oxygen to the textile surface.

Given these considerations, increasing research attention is being directed toward flame-retardant systems based on bio-derived compounds. The flame-retardant performance of such systems is largely achieved through enhanced char formation during thermal decomposition. Renewable bio-based resources suitable for this purpose include lignin, chitosan, phytic acid, and other polyhydroxyl compounds that effectively promote char formation in the presence of acid catalysts. Among these, phytic acid, also known as myo-inositol hexakisphosphoric acid (or phytate in its salt form), is regarded as a promising “green” phosphorus-containing compound naturally abundant in plant tissues, including legumes, cereals, and oilseeds [3, 4]. Owing to its biocompatibility, environmental friendliness, low toxicity, and simple preparation, phytic acid finds broad application in antioxidant, antitumour, biosensing, cation-exchange, and nanomaterial technologies because of its unique inositol hexakisphosphate structure [5]. With a phosphorus content of approximately 28 wt%, phytic acid represents an attractive renewable precursor for the development of environmentally friendly flame-retardant formulations.

Previous studies have demonstrated the effectiveness of phytic acid as a bio-based flame retardant for various materials. For example, phytic acid has been applied to wool fabrics by immersion in aqueous solutions with concentrations ranging from 10 to 200 wt% under acidic conditions (pH 1.2), followed by thermal treatment at 90 °C for 1 h, resulting in enhanced flame-retardant performance [6]. It has also been used as a doping acid to significantly improve the fire performance of

flame-retardant composite paper [7]. Furthermore, the flame-retardant potential of various metal phytates as bio-based phosphorus-containing additives for polylactic acid composites has been evaluated [8].

Phytic acid contains six negatively charged phosphate groups and therefore exhibits a strong affinity for positively charged ions [9, 10]. Consequently, it readily binds to wool fibres through electrostatic interactions between the negatively charged phosphate groups and the positively charged amino groups present in the protein structure of wool. In addition, phytic acid effectively chelates metal ions while simultaneously acting as both an acid source and a carbon source in intumescent flame-retardant systems [11]. Phytic acid in combination with chitosan, as well as hybrid systems based on phytic acid and nitrogen-modified silanes, has been employed in layer-by-layer assembly to fabricate ultrathin flame-retardant coatings on cotton fabrics [12].

Particular interest has been attracted by the studies of the thermal behavior of phytic acid reported in [13]. These investigations have demonstrated that phytic acid undergoes carbonization and dehydration between 248 °C and 447 °C as a result of the decomposition of hydroxyl (—OH) groups present in the biomolecule. With a further increase in temperature, a second stage of thermal degradation occurs in the range of 447—863 °C, corresponding to the decomposition of phytate groups and the removal of elemental carbon formed during the earlier stages of degradation. At approximately 870 °C, the cumulative mass loss reaches 97%.

Phosphorus-containing flame retardants thermally decompose to form phosphorus-containing radical species ($\text{PO}\cdot$) which inhibit the combustion process by scavenging reactive radicals in the flame. In addition, these compounds promote the recombination of $\text{H}\cdot$ and $\text{HO}\cdot$ radicals in the gas phase, thereby interrupting the chain reactions responsible for flame propagation. Phosphorus-containing compounds also catalyze the dehydration and carbonization of substrates containing hydroxyl (—OH) groups, resulting in enhanced char formation and improved flame resistance [14].

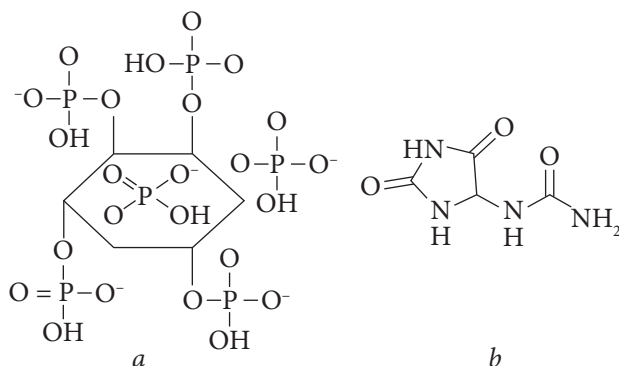


Fig. 1. Structural formulas of composition components: *a* — phytic acid; *b* — allantoin

The aim of the present study is to develop an environmentally friendly intumescent formulation based on naturally occurring compounds for imparting flame-retardant properties and improving the thermal stability of cotton textile materials.

The experimental investigation is performed using printed cotton fabric. The characteristics of the textile material under study are presented in Table 1.

To form a carbonized layer, the cotton textile material is treated with an intumescent composition consisting of an aqueous solution of phytic (300 g/l) and citric acids (100 g/l); a nitrogen-containing component — allantoin (50 g/l). Phytic acid (PhA) is used as a phosphorus-containing component. To ensure phosphorus-nitrogen synergism, a nitrogen-containing component is used — 2,5-dioxoimidazolidin-4-yl urea (allantoin), which simultaneously acts as a foaming agent. Citric acid (CA) is added to form bonds with the OH group of fabric cellulose and as an additional source of carbon. Aluminum sulfate $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ is introduced to eliminate residual combustion, reduce the length

of the charred zone and reduce smoke formation during combustion. The structural formulas of phytic acid and allantoin are shown in Fig. 1.

The fabric is treated with a finishing composition by double immersion, 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 min. The wash fastness of textile finishing has been determined by treating the samples in a soap-soda solution at a temperature of 40 °C and a module of 1:50 for 30 min.

The structural characteristics of the treated textile materials have been studied by FTIR spectroscopy using a Tensor 37 FTIR spectrometer (Bruker, Germany) in the spectral region of 600—4000 cm^{-1} .

The rate of change in the mass and the magnitude of thermal effects when exposed to elevated temperatures on textile materials has been studied by thermogravimetric and differential thermal analysis after examining the samples on the ThermoScan-2 derivatograph. Aluminum oxide has been used as a reference. The weight of the samples is 0.1 g. The samples are heated using quartz crucibles in air from 10 °C to 700 °C at a constant heating rate of 10 °C/min. The thermal behavior of the treated fabrics has been compared with the original sample.

The flame-resistant properties of the fabric have been investigated using the vertical flammability test method. The effect of treatment on the physico-mechanical and hygienic properties of the textile material has been evaluated based on tensile strength (RT-250M testing machine), hygroscopicity, and air permeability (VPTM-2 type instrument).

When heated, the textile material forms a voluminous foamed carbonized layer that acts as a physical barrier, slowing heat and mass transfer between the gas and condensed phases. Considering that intumescent systems consist of an acid source, carbon-rich component, and blowing agent, this study employed phosphorus-rich phytic acid. Additionally, phytic acid contains an intrinsic carbon source, which enhances the formation of a foamed layer on the textile surface and enables the production of reactive flame retardants through interac-

Table 1. The Textile Material Properties

Fabric construction	Fabric composition	Surface weight, g/m^2	Density, yarns per 10 cm	
			Warp	Weft
2/2 broken twill	100% cotton	162 ± 10	320 ± 7	240 ± 7

tions with amino and hydroxyl groups to improve wash durability [15]. Given the positive effect of phosphorus-nitrogen synergy on flame-retardant textile finishing, allantoin (2,5-dioximidazolidin-4-yl urea) is incorporated into the impregnation solution as a nitrogen-containing foaming component. Under flame exposure, phosphorus and nitrogen compounds react with high-energy H and OH radicals in both gas and condensed phases. When combined with phosphorus synergists, these intumescent agents enhance char stability through the formation of phosphorus-nitrogen bonds.

The results of thermal stability evaluation for the investigated fabric samples using thermogravimetric analysis are presented in Table 2.

Analysis of the obtained data (Table 2) has revealed that the untreated cotton fabric sample exhibits three distinct degradation stages, the first of which occurs at the temperature of 323 °C, and the next two with peak temperatures $T_{\max 1}$ at 363 °C and $T_{\max 2}$ 499 °C. The results of the conducted studies correlate with data published in [16, 17], which has confirmed that cotton decomposes in air in three stages. The first stage of destruction occurs between 300 °C and 400 °C and involves two competitive pathways that trigger the formation of both aliphatic char and gaseous species. The second stage occurs at temperatures from 400 °C to 800 °C, during which the aliphatic char is partially converted into an aromatic, more stable analogue or is oxidized, forming CO and CO₂. As the temperature rises to 800 °C, the carbon formed in the previous stages continues to oxidize.

Metal ions can also effectively catalyze the formation of a stable cross-linked char layer, preventing the release of smoke and further pyrolysis of polymers. The research [18] shows that, in fact, gC₃N₄ and PAZn containing nitrogen, phosphorus and zinc can be an effective combination that improves the flame resistance of the matrix.

Treatment of the fabric with an intumescent formulation containing aluminum sulfate shifts the cellulose degradation temperatures to lower values (120 °C and 230 °C) compared with those observed with phytic and citric acid treatment alone

(230 °C and 321 °C, respectively). Mass loss in this case varies from 51% of residue for untreated fabric to 56% for acid-treated samples and 64% for treated with the acid-allantoin-aluminum sulfate composite. These shifts, as assessed in [19, 20], are obvious in the presence of metal ions in the compositions. This behavior has been observed for cotton fabrics treated with biomacromolecules when the flame-retardant coating is activated to form a stable char that can act as a thermal barrier, as opposed to the formation of flammable gaseous products that can further stimulate the destruction of the cellulosic substrate [21].

The incorporation of Al₂(SO₄)₃ · 18H₂O into the intumescent system reduces the degradation temperature to 230°C, which is explained by the loss of water when the temperature increases in the range from 230 °C to 420 °C, and at a temperature of 420 °C a completely anhydrous form of aluminum sulphate is formed. With a further increase in temperature, aluminum sulphate also decomposes above a temperature of 580 °C into the γ-modification of aluminum oxide and sulfuric anhydride. The onset of thermal decomposition of aluminum sulphate with the release of sulfur oxide helps limit the residual combustion of the fabrics under study.

The maximum temperature at which the final decomposition of cellulose occurs, on the contrary, shifts to a higher temperature range — from

Table 2. Thermal Stability of Cotton Textile Materials

Treatment	T_{in} , °C	$T_{\max 1}$, °C	ε_{m1} , %	$T_{\max 2}$, °C	ε_{m2} , %	ε_m , %
Untreated	323	363	51	499	2.82	<1
PhA + CA	230	321	56	550	25.2	6.8
PhA+CA+allantoin+ +Al ₂ (SO ₄) ₃ · 18H ₂ O	120	230	64	544	24.5	6

Note: T_{in} is the initial temperature of degradation; $T_{\max 1}$, $T_{\max 2}$ is the maximum temperatures at which the second and third stages of cellulose degradation occur, respectively; ε_{m1} , ε_{m2} are the mass fractions of residue at $T_{\max 1}$ and $T_{\max 2}$, respectively; ε_m is the mass fraction of residue at the end of degradation

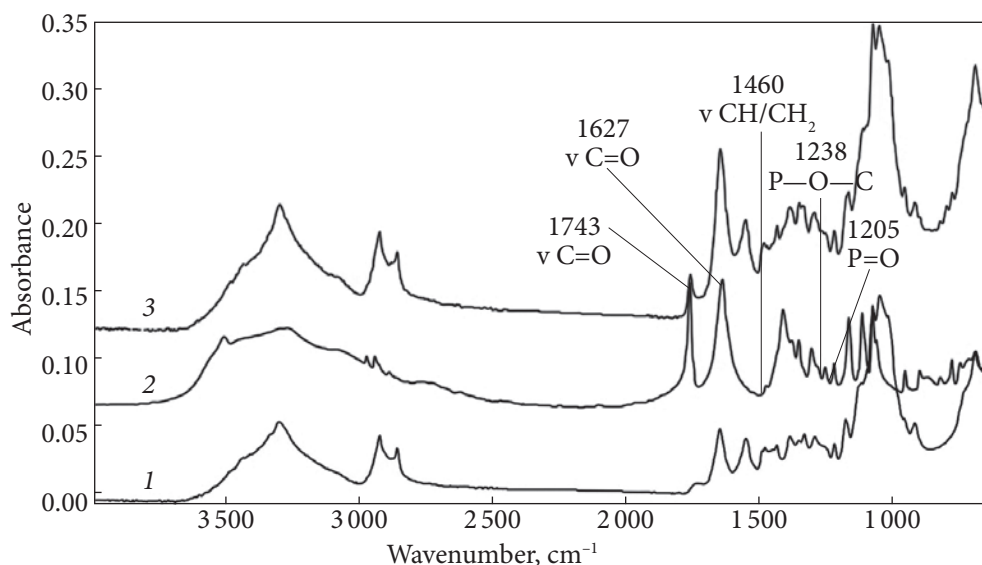


Fig. 2. FTIR spectra of samples: 1 — untreated cotton fabric; 2 — original PhA; 3 — PhA treated cotton fabric

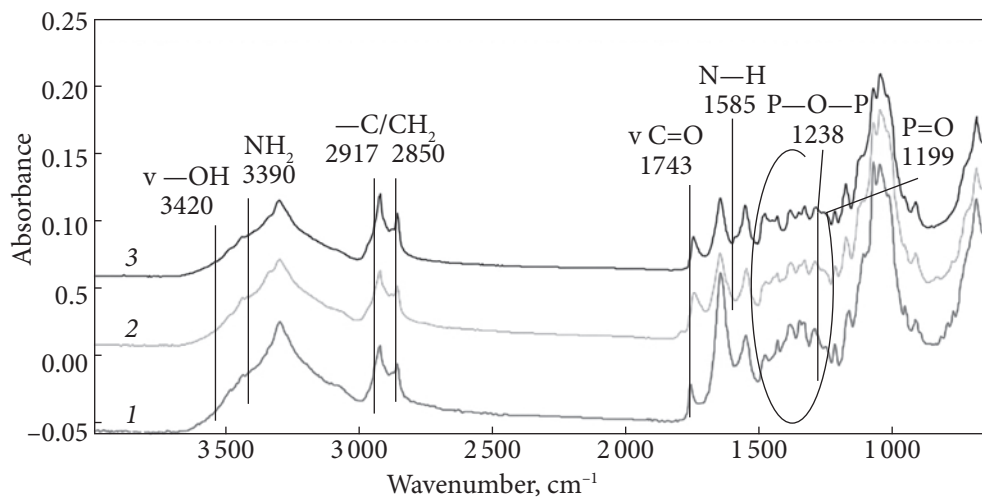


Fig. 3. FTIR spectra of cotton fabric samples: 1 — PhA treated; 2 — PhA + allantoin treated; 3 — PhA + allantoin treated after washing

499 °C for untreated fabric to 550 °C and 544 °C for fabrics containing phytic acid. Mass fraction of final residue increases to 6%. A shift in temperature to a higher region confirms the increase in flame resistance of cellulosic textile materials treated with intumescent system.

The nature of chemical bonds formed between components of the developed formulation and

cellulose of the textile material has been investigated using FTIR spectroscopy. Figure 2 presents the FTIR spectra of the untreated fabric, pure phytic acid, and phytic acid-treated fabric.

The spectral analysis revealed the following distinctive features. The frequencies of the main absorption bands in curve 1 (Fig. 2) show the characteristic spectrum of cellulose with hydrogen-bon-

ded —OH groups in the 3100—3550 cm^{-1} region. In the spectrum, the region around 3600 cm^{-1} reveals stretching vibration bands of —OH groups (primary, secondary, tertiary). This broad band has two maxima: 3329 cm^{-1} (primary OH) and 3285 cm^{-1} (secondary OH). The C—O stretching vibrations of different groups (C—OH — primary, OH — secondary, C—O—C — cyclic, C—O—C — intercylic) are observed in the 900—1200 cm^{-1} region as a band with several maxima corresponding to these bonds: 1003 cm^{-1} , 1034 cm^{-1} , 1051 cm^{-1} , 1143 cm^{-1} , and 1179 cm^{-1} . The spectrum also contains bands of stretching and bending vibrations of C—H bonds in different groups. The bands with maxima at 2890 cm^{-1} and 2850 cm^{-1} correspond to stretching vibrations of —CH/CH₂— groups, while in the 1300—1500 cm^{-1} region, bending vibrations of —CH groups of both cyclic and backbone types are observed.

The main absorption bands for phytic acid have been confirmed by the corresponding stretching vibrations: ν O—Na 505 — 495 cm^{-1} , ν P—O 970 cm^{-1} , ν P=O 1205 cm^{-1} , δ CH/CH₂ 1460 cm^{-1} , and ν C=O 1743 cm^{-1} (Fig. 2, curve 2).

After treatment with phytic acid (Fig. 2, curve 3), a series of new bands appeared in the fabric sample at 1238 cm^{-1} , 1205 cm^{-1} , and 970 cm^{-1} , which correspond to the characteristic absorption bands of P=O, P—O—C, and P—O bonds, respectively.

Figure 3 shows the FTIR spectra of cotton fabric samples treated with the finishing composition. To confirm the fixation of the intumescent system components with cellulose fibers, the spectra of the treated fabric after washing are presented (Fig. 3, curve 3).

FTIR spectroscopy investigation of cotton textile samples treated with a phytic acid-containing composition revealed the appearance of new absorption bands at 1238 cm^{-1} , 1205 cm^{-1} , and 970 cm^{-1} , corresponding to characteristic vibrations of P=O, P—O—C, and P—O bonds, respectively (Fig. 3, curve 2). The addition of allantoin resulted in an additional shoulder and N—H bond vibration with a band at 1580 cm^{-1} , while a new —NH band appeared at 3390 cm^{-1} in the 3200—3400 cm^{-1} region.



Fig. 4. Fabric samples after vertical flame test: *a* — PhA treated; *b* — PhA + allantoin treated; *c* — PhA + allantoin + aluminum sulfate treated

These bands remained after washing (Fig. 3, curve 3). The characteristic peaks of P=O, P—O—C, and P—O bonds at 1238 cm^{-1} , 1205 cm^{-1} , and 970 cm^{-1} , respectively, are also preserved after washing. The FTIR spectroscopy analysis results demonstrate that phytic acid molecules chemically incorporate into cotton fibers, providing the textile material with enhanced flame-retardant properties.

Vertical flame testing of the treated cotton fabrics (Table 3) has shown that the char length after 15 s of flame exposure is 57 mm, whereas the samples treated with formulations containing the nitrogen-containing additive allantoin have exhibited a reduced char length of 55 mm. The char length of the treated textile material after washing is 12 cm; however, the developed intumescent composition provides resistance to one washing cycle, as confirmed by FTIR spectra (Fig. 3, curve 3) after treatment of the textile material in a soap-soda solution.

Figure 4 shows the results of open flame exposure on the treated textile material. As can be seen from the figure, a carbonized layer forms on all samples.

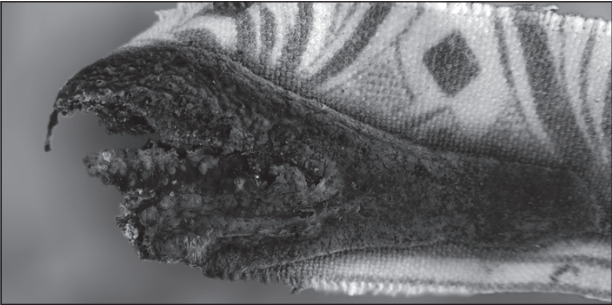


Fig. 5. Foaming effect of the studied finishing composition on cotton fabric (carbonized layer)

However, the fabric treated solely with phytic acid burned through upon flame exposure, but ceased flame propagation and self-extinguished upon removal from the fire. The inclusion of allantoin and aluminum sulfate in the finishing composition induced intumescent behaviour during combustion, leading to formation of a carbonized surface layer on the textile material, accompanied by self-extinguishing and non-propagating flame characteristics. No afterglow has been observed following flame removal.

Thus, the phytic acid-based formulation effectively promotes condensed-phase flame retardant mechanisms similar to conventional flame retardants such as ammonium polyphosphate. Simultaneously, phytic acid may participate in gas-phase reactions. The intumescent charring effect intensifies for cotton fabrics when phytic acid combines with ammonium ions from allantoin. Incorporation of nitrogen-containing components in the finishing formulation enhances the volume of in-

tumescent char, which functions as a physical barrier protecting the textile surface.

Allantoin addition further improves the wash durability of phytic acid-based flame-retardant treatment through formation of chemical bonds with cellulose fibers, as evidenced by FTIR analysis. The resulting carbonized surface coating on the cotton textile material containing phytic acid as the main flame retardant and allantoin as the intumescent agent after exposure to flame is shown in Fig. 5.

Thus, under the action of high temperatures and as a result of flame exposure on the surface of the textile material treated with the intumescent composition, the formation of a voluminous carbonized layer up to 1.5 mm high is observed (Fig. 5). The presumed mechanism of the foamed layer formation appears as follows. At elevated temperatures, polyphosphoric acid is released and melts from the phosphorus-containing component, covering the textile fibers with a protective film, preventing them from burning and smouldering. The decomposition of the nitrogen-containing agent is accompanied by the formation of gaseous ammonia, which impedes oxygen access and inhibits carbon oxidation in the gas phase. The phosphorus-nitrogen synergy is explained by the formation of phosphorus-nitrogen bonds during thermal decomposition, and the resulting carbonized layer acts as a physical barrier to flame propagation over the surface of the textile material, as well as preventing ambient oxygen from reaching the inner layers of the textile material. The use of allantoin in the finishing composition ensures an increase in the volume of the foamed carbonized layer, which acts

Table 3. Quality Indicators of Cotton Fabric with the Flame-Retardant Finishing

Treatment	Height of the charred area, cm	After-flame time, s	After-glow time, s	Height of charred area after 1 washing cycle, cm	Tensile strength, N		Hygroscopicity, %	Air permeability, $\text{dm}^3/\text{m}^2 \cdot \text{s}$
					Warp	Weft		
Untreated fabric	—	—	—	—	608	312	8.33	238
PhA	57	0	0	14	578	297	7.48	222
PhA + CA + allantoin + aluminum sulfate	55	0	0	12	576	299	7.45	220

as a physical barrier to protect the surface of textile materials. The addition of allantoin also improves the wash resistance of the phytic acid-based flame-retardant finish due to the formation of chemical bonds with the cellulose fiber, as proven by FTIR analysis. The quality indicators of the cotton fabrics treated with the studied flame-retardant compositions containing phytic acid are presented in Table 3.

Treatment of cotton fabric with the intumescent composition slightly reduces tensile strength, despite the acidic nature of phytic acid. The hygroscopicity of the fabric after treatment with intumescent compositions decreases by an average of 5% as compared with untreated cotton fabric. The air permeability indicators of treated fabric samples decrease by an average of 3%. The obtained data indicate an insignificant influence of the finishing treatment on the hygienic properties of the processed textile material.

Textile materials with intumescent properties play an important role in preventing fire spread,

enhancing human protection and safety, and serving as alternatives to traditional flame-retardant compositions. The developed intumescent composition based on phytic acid, allantoin, and aluminum sulfate carbonizes cellulose fibers, forming a protective charred layer on the textile material surface that impedes heat transfer between the unburned primary layer and the environment. The damaged fabric measures 55–57 mm, with the formed layer reaching up to 1.5 mm in height; the fabric exhibits self-extinguishing properties. Hygienic and physico-mechanical properties of the fabric demonstrate that the treatment caused no significant damage. The results of FTIR spectroscopy confirm the presence of chemically bonded components of the intumescent composition with the cellulose of the textile material, which ensures increased resistance of the finish to washing.

Advancements in intumescent technologies stimulate progress in developing environmentally friendly methods for flame-retardant modification of cotton fabrics.

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РОЗРОБКА ІНТУМЕСЦЕНТНОЇ СИСТЕМИ НА ОСНОВІ ФОСФОРОВІСНИХ БІОМАКРОМОЛЕКУЛ ДЛЯ ВОГНЕЗАХИСНОГО ОПОРЯДЖЕННЯ ЦЕЛЮЛОЗНИХ ТЕКСТИЛЬНИХ МАТЕРІАЛІВ

Вступ. З огляду на недоліки сучасних антипіренів і регламенти багатьох країн постала необхідність у розробці екологічно безпечних методів підвищення вогнестійкості текстильних матеріалів.

Проблематика. Надання тканинам вогнезахисних властивостей досягається просочуванням їх антипіренами, переважно галогеновмісними препаратами, які становлять загрозу довкіллю.

Мета. Розробка інтумесцентної композиції для підвищення термічної стійкості бавовняних тканин з використанням речовин природного походження.

Матеріали й методи. Інтумесцентний склад містить фітинову кислоту як основний антипірен, алантоїн як азотвмісний компонент, лимонну кислоту та сульфат алюмінію. Термостійкість тканини оцінювали методами термогравіметричного та диференційного термічного аналізів, структурні характеристики — методом ІЧ-спектроскопії, вогнезахисні властивості — методом вертикального горіння.

Результати. Присутність фітинової кислоти та її комбінації з сульфатом алюмінію як димоподавлювача на початковій стадії термічного розкладу призводить до зменшення температури деструкції тканини до більш низьких значень порівняно з необробленим зразком через активацію розкладання фітинової кислоти до початку деструкції основного субстрату. Максимальна температура, при якій відбувається остаточна деструкція целюлози, навпаки, зміщується до більш високих температур — з 499 °C для необробленої бавовни до 550 °C і 544 °C для складів із фітиновою кислотою. Масова частка карбонізованого залишку збільшується на 6 %. Зменшення температури деструкції у більш високу область підтверджує підвищення термостійкості тканини. Інтумесцентна дія алантоїну як азотвмісного компонента покращує структурну стабільність та об'ємні характеристики коксового шару. Наявність хімічної взаємодії вогнезахисної композиції, що містить фітинову кислоту та алантоїн, з целюлозним волокном доведено результатом ІЧ-Фур'є-спектроскопії.

Висновки. Отримані результати мають практичне значення для розробки вогнезахисних опоряджувальних складів для бавовняних та змішаних текстильних матеріалів.

Ключові слова: фітинова кислота, алантоїн, термостабільність бавовняної тканини, коксоутворюючі властивості, вогнезахисний опоряджувальний склад.