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Operational properties of film materials for bio-packaging

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Abstract. The development of environmentally safe packaging materials has become one of the key requirements for 2026. Across various segments of the modern market, there has been a clear and steady increase in interest in biopolymer materials produced from renewable raw materials and capable of biodegradation. The aim of this work was to investigate the performance characteristics of films based on polyvinyl alcohol, maize starch, glycerine and sodium tetraborate, as well as to assess their potential for use as environmentally safe packaging materials. During the study, the films were produced by solution casting onto a glass substrate with heat treatment at temperatures of 393 K and 423 K. Samples of various thicknesses were produced: in the range of 0.0552-0.0616 mm, as well as thicker films – from 0.1953 to 0.2240 mm. The physical and mechanical properties of the materials were determined using a universal tensile testing machine. It was found that the experimental tensile strength values for the obtained film materials increased with an increase in the sodium tetraborate content – from 18.79 N to 66.2 N. The tensile strength reached 30.5 MPa at a sodium tetraborate content of 10% and a film stabilisation temperature of 423 K. The relative elongation at break gradually decreased at higher sample stabilisation temperatures. The increase in tensile strength for films containing 10% sodium tetraborate made this composition effective for producing films with improved strength. Film materials with a thickness of 0.0612-0.0734 mm exhibited the best performance characteristics in terms of the “material strength-film thickness” ratio. The results of the study of the performance characteristics of film materials formed on the basis of polyvinyl alcohol, water-soluble maize starch and glycerine with varying sodium tetraborate content allowed for the consideration of their potential use for food packaging and the encapsulation of fresh vegetables and fruit

Keywords: biodegradable materials; physico-mechanical properties; biopolymers; polyvinyl alcohol; tensile strength

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Introduction

Packaging has played a key role in ensuring the effective sale of goods, as it combines functional, logistical, marketing and informational aspects, whilst guaranteeing the physical, chemical, microbiological and barrier safety of goods. The rapid growth in packaging volumes, and consequently in the amount of plastic waste, has had a negative impact on the environment. In modern market segments, there has been a steady trend towards growing demand for biopolymer materials derived from renewable raw materials, which have found practical application particularly in food packaging. S. Kumar *et al.* (2022) highlighted the advantages of using biopolymers as materials for food packaging. The use of biodegradable materials, weight reduction and optimisation of packaging structure had a positive impact on companies' image and expanded opportunities for entering environmentally-oriented markets. Polyvinyl alcohol (PVA)-based film materials exhibited satisfactory gas barrier properties under conditions of low relative humidity and were used as a base for the production of environmentally safe packaging films. One of the main strategies for modifying PVA-based films involved the introduction of inorganic nanofillers (in particular, ZnO and TiO₂), which, according to research by Y. Xie *et al.* (2024), enhanced antimicrobial activity, provided UV protection and strengthened the mechanical structure of the film. Thanks to these properties, PVA films have been actively used to create modern packaging solutions in the pharmaceutical industry and as biocompatible coatings for medical devices. The method for producing PVA-based composite films proposed by C. Wang *et al.* (2024) enabled the production of strong materials with the potential to impart antimicrobial properties. A study by R. Hussain *et al.* (2023) established the antimicrobial activity of biodegradable PVA films in combination with ascorbic acid and glutaraldehyde.

PVA-based composite films demonstrated enhanced functional capabilities, making them promising for various technological applications. V. Krasinskyi *et al.* (2021) used montmorillonite as a filler in polyvinyl films, which enabled the formation of a homogeneous cross-linked structure, reduced the degree of crystallinity, and increased the thermal stability of the nanocomposites. X. Li *et al.* (2021) developed a packaging film based on polyvinyl alcohol containing Fe³⁺ ions, which optimised food storage conditions and was UV-resistant. This opened up the possibility of creating highly functional composite materials for packaging and smart quality control systems. To improve the barrier properties of PVA nanocomposite films, S.V. Nguyen & B.-K. Lee (2023) used cellulose nanocrystals in combination with titanium dioxide. In particular, this resulted in improved resistance to water vapour permeation, enhanced UV protection, and an effective extension of shelf life due to the high antioxidant and antimicrobial properties of the resulting nanocomposite.

Encapsulating fresh products in film packaging made from active packaging materials has become a cost-effective way to prevent the impact of external conditions and to maintain high food quality. As noted by S. Yildirim *et al.* (2017), the primary objective of active packaging is to ensure microbiological and chemical safety, extend the shelf life of food products, and, in some cases, preserve or improve their sensory characteristics, such as taste, aroma or appearance. Interest in PVA stems from a combination of its properties that are important for food packaging: high flexibility, excellent film-forming ability, pronounced biodegradability, chemical stability, significant hydrophilicity and biocompatibility. An additional advantage was that PVA was considered an edible material, which expanded its potential applications in the food industry. Assessing the impact of various additives on the physicochemical and functional properties of PVA films became crucial, as this enabled the development of optimal materials suitable for use as active food packaging. R. Dermondes Souza *et al.* (2024) noted the use of PVA-based films containing sodium nitrite as active packaging for meat products. It was established that the properties of such films contributed to more effective preservation of chilled meat, in particular by inhibiting microbiological processes and reducing oxidative changes due to the high gas barrier properties of PVA. This modification of the material provided the potential to extend the shelf life of pork by reducing microbiological spoilage of the product. Furthermore, in the work by A. Jayakumar *et al.* (2023), a smart composite film based on polyvinyl alcohol was developed for the safe packaging of food products. In this system, chitosan combined with zinc oxide nanoparticles acted as antimicrobial agents, whilst sweet purple potato extract was used as a sensitive indicator of changes in product quality.

X. Dang *et al.* (2025) identified encapsulation as the ideal method for storing fresh fruit and vegetables, where products can slow down the loss of quality and nutrients, thereby maximising shelf life. The developed eco-friendly, multifunctional food packaging for food products based on PVA exhibited good water vapour barrier properties, resistance to ultraviolet radiation, and antimicrobial activity. The data obtained by the author regarding the film demonstrated thermal stability and antioxidant activity. Encapsulation in the films obtained prevented product spoilage, extended shelf life, and significantly expanded the possibilities for their use in safe packaging, such as edible coatings, as investigated by B.R. Moreira *et al.* (2020). The combination of PVA with biopolymers such as starch and chitosan improved the materials' biodegradability and enabled waste disposal via industrial composting (anaerobic) or decomposition in soil (aerobic process). Combining polyvinyl alcohol with natural polymers, particularly polysaccharides, has not only improved the performance

properties of film materials but also significantly enhanced their biodegradability.

Film materials containing polyvinyl alcohol in combination with maize starch are capable of degradation under the action of enzymatic processes as well as under natural soil and compost conditions. The results of the analysis of biodegradation studies of composite materials based on polyvinyl alcohol and starch indicated that, under the influence of microorganisms present in biohumus, there was intensive and relatively rapid destruction of the biopolymer matrix. Biodegradable polymers from renewable sources have become a promising solution not only as effective packaging but also as an environmentally friendly solution to the waste problem. The widespread adoption of biodegradable packaging is associated with various challenges, such as cost-effectiveness, technological limitations, labelling and waste management. The aim of this study was to investigate the performance properties of film materials based on polyvinyl alcohol, water-soluble maize starch and glycerine at various concentrations of sodium tetraborate, and the potential for their use as eco-friendly packaging.

Materials and Methods

Polyviol G 04/140 (Germany) polyvinyl alcohol was used as the polymeric base for the production of film materials. Water-soluble corn starch (DSTU 3976-2000, 2001) was added to the pre-prepared aqueous PVA solution as a biodegradable component. The gelation process was carried out by heating the composition to a temperature of 363 K whilst stirring until a homogeneous gel-like system was formed. After the mixture had cooled partially, glycerine of the FS 42-2202-84 grade (Ukraine) was introduced into its composition, which was used as a plasticising additive. The addition of glycerine improved the flexibility and elasticity of the films. Furthermore, glycerine facilitated a more uniform distribution of polymer chains within the composite structure. To impart antimicrobial properties to the films, sodium tetraborate ($\text{Na}_2\text{B}_4\text{O}_7$) was incorporated into the composition. Thanks to this composition, the resulting film materials could be effectively used in the packaging of food products, hygiene items and medicines. The films were formed by casting the solution onto a glass substrate, after which the samples were dried at a temperature of 293 K on a flat surface to ensure uniform film thickness. This process corresponded to the solution casting method. After the drying process was completed, the films were subjected to heat treatment at temperatures of 393 K and 423 K for 30 minutes to stabilise their structure. Three samples of each film composition were produced. The film thickness was measured using an IZV-2 (USSR) thickness gauge at five different points on each sample, and the average value was calculated. Tests of tensile strength and relative elongation at break were carried

out on a universal tensile testing machine manufactured by VEB Werkstoff-Prufmaschinen (Germany). The film samples measured 100×15 mm, with a distance of 50 mm between the grips. Measurements of tensile strength and relative elongation at break were carried out in accordance with DSTU EN ISO 8067:2018 (2020). The tensile stress was defined as the tensile force per unit area of the film's cross-section at the moment of its failure. The tensile stress σ (MPa) was calculated using the formula:

$$\sigma = \frac{P}{S}, \quad (1)$$

where P – the applied tensile force, S – the cross-sectional area of the film specimen.

The relative elongation at break was calculated in accordance with DSTU EN ISO 8067:2018 (2020) using the formula:

$$\varepsilon = \frac{\Delta l}{l_0} \cdot 100\%, \quad (2)$$

where l_0 – initial film length, l film length at the moment of rupture, $\Delta l = l - l_0$.

The film spectra were obtained using a PerkinElmer Spectrum Two Fourier-transform infrared (FTIR) spectrometer from PerkinElmer (UK), equipped with a single-element UATR attachment with a diamond crystal. The infrared (IR) analysis of the films was carried out in the range of 4,000-400 cm^{-1} .

Results and Discussion

Polyvinyl alcohol, as a non-toxic, water-soluble polymer, formed the basis for the film materials developed. As the semi-crystalline structure of PVA contains a significant number of hydroxyl groups capable of forming intermolecular hydrogen bonds, this has enabled the effective combination of synthetic polyvinyl alcohol with a biopolymer – maize starch. In this process, glycerol, acting as a plasticiser, facilitated the formation of a uniform polymer matrix. One of the key performance properties of PVA-based films was gas impermeability under conditions of low relative humidity. At the same time, its high hygroscopicity proved to be a significant drawback, as it led to increased water permeability. To overcome this drawback, a cross-linking method was employed. Sodium tetraborate hydrolysed in water to form orthoboric acid, which proved to be an effective cross-linking agent. Film samples containing 5% and 10% borax (relative to the content of other components) were produced using the solution casting method. The composition of the formulations is given in Table 1.

Heat treatment of the films at temperatures of 393 K (samples 2, 5, 8) and 423 K (samples 3, 6, 9) contributed to the strengthening and stabilisation of the structure. It is worth noting that raising the heating temperature above 433 K led to yellowing of

the films. This effect was particularly evident when the composition contained a higher proportion of thermally unstable maize starch. The film samples were produced with thicknesses ranging from 0.0552 to 0.0734 mm (samples 1-6) and from 0.1953 to 0.2240 mm (samples 7-9). The measured average film thicknesses are given in Table 1. The film samples combining polyvinyl alcohol with starch, glycerine

and borax had a uniform thickness, were practically transparent, colourless and homogeneous. The films were soft to the touch and stretchable. During storage under room conditions, good resistance to moisture absorption from the air was observed. For testing the strength of the films under load, strips measuring 100 mm in length and 15 mm in width were prepared (Fig. 1).

Table 1. Composition and average thickness of films

Sample No	Stabilisation temperature, K	Composition of film samples, wt.%				Film thickness, mm
		PVA	Starch	Glycerol	Sodium tetraborate	
1	293	45	10	40	5	0.0635
2	393	45	10	40	5	0.0616
3	423	45	10	40	5	0.0552
4	293	40	10	40	10	0.0734
5	393	40	10	40	10	0.0657
6	423	40	10	40	10	0.0612
7	293	40	10	40	10	0.2240
8	393	40	10	40	10	0.2150
9	423	40	10	40	10	0.1953

Source: compiled by the authors



Figure 1. Film samples for determining physico-mechanical properties

Source: compiled by the authors

Uniform strips 15 mm wide were cut from the film materials. Three samples of each film composition were prepared for the study. The tensile strength and elongation at break were determined using a universal testing machine (dynamometer). The measurements were carried out with a crosshead speed of 0.5 mm/s. Figure 2 shows the average values of the experimentally determined tensile strength of bioplastic films

based on polyvinyl alcohol, corn starch, glycerine and sodium tetraborate. The results of the tensile strength measurements showed that the tensile strength of the films increased with increasing sodium tetraborate concentration. Heat treatment of the films also increased their strength. The highest tensile strength values – 18.79 N, 28.1 N and 66.2 N – were obtained for samples stabilised at 423 K.

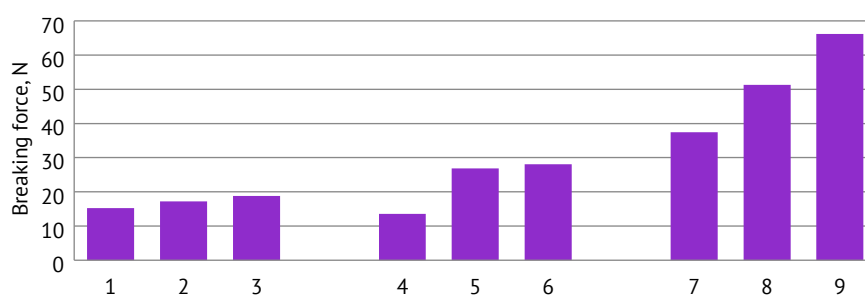


Figure 2. Tensile strength of bioplastic films based on polyvinyl alcohol, maize starch, glycerine and sodium tetraborate

Note: the numbers 1 to 9 are sample numbers

Source: developed by the authors

As the thickness of the samples increased, the tensile strength also increased: the tensile strength of films with a thickness of 0.1953-0.2240 mm was 2-3.5 times greater than the corresponding values for samples with a thickness of 0.0552-0.0734 mm. The main strength characteristic of the film materials was the tensile stress at break, as this parameter took into account the dimensions of the sample, in particular

its thickness. Tensile stress is defined as the tensile load per unit cross-sectional area of the film material at the moment of failure. The calculation of tensile stress, or tensile strength, as one of the key performance characteristics, was performed using formula (1). The highest tensile strength values – 22.7 MPa, 30.5 MPa and 22.6 MPa – were obtained for samples stabilised at 423 K (Fig. 3).

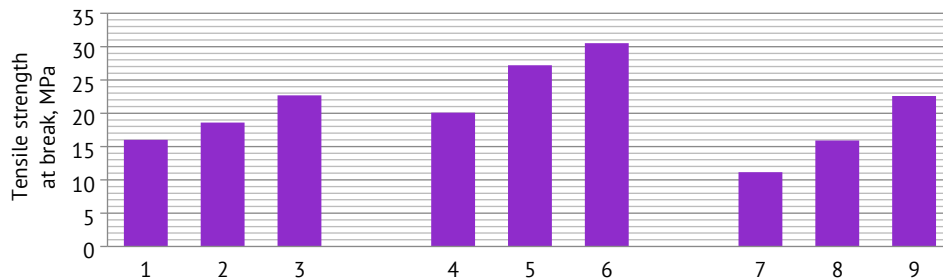


Figure 3. Tensile strength at break of films based on polyvinyl alcohol, maize starch, glycerine and sodium tetraborate
Note: the numbers 1 to 9 are sample numbers
Source: developed by the authors

PVA/starch films exhibited tensile strength under load. The relative elongation at break for the films under investigation was calculated using formula (2). Figure 4 shows the variation in relative elongation at break for the films under investigation with different compositions. The best tensile strength was demonstrated by film samples containing 10% sodium tetraborate. It is worth noting that, compared to tensile strength, the change in

relative elongation at break showed a slightly different trend. It was found that at higher concentrations of borax, the relative elongation at break was greater. At the same time, a higher stabilisation temperature of the samples led to a decrease in elongation at break. This could be attributed to a reduction in the water content of the film material and the cross-linking and strengthening of the polymer matrix, which led to a decrease in elasticity.

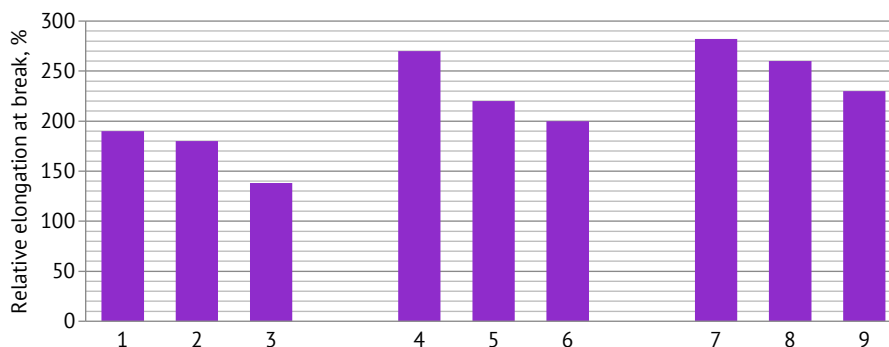


Figure 4. Change in relative elongation at break for films based on polyvinyl alcohol, maize starch, glycerine and sodium tetraborate
Note: the numbers 1 to 9 are sample numbers
Source: developed by the authors

Studies of tensile strength and elongation, as well as calculated values of tensile stress at break for the resulting film materials containing polyvinyl alcohol, maize starch, glycerine and borax, demonstrated their potential for use as packaging materials, particularly for food products and for encapsulating fresh vegetables and fruit. To produce films with improved strength, a 10% sodium tetraborate content proved promising, as this composition resulted in an increase in the tensile strength of the films. In terms of the

“material strength – film thickness” ratio, film materials with a thickness of 0.0612-0.0734 mm exhibited the best performance characteristics. The results of the study of film materials using infrared spectroscopy indicated that the main characteristic bands in samples 4, 5 and 6 predominantly corresponded to the spectrum of polyvinyl alcohol. At the same time, no significant changes in the position or shape of these bands were detected in the samples that had undergone heat treatment (samples 5 and 6). In the

spectra of films stabilised at 393 K and 423 K (samples 5 and 6, respectively), a noticeable decrease in the intensity of absorption bands associated with the hydroxyl groups of water was observed, particularly in the regions around $2,300\text{ cm}^{-1}$ and $1,670\text{--}1,630\text{ cm}^{-1}$. In addition, for sample 6, the appearance of a shoulder at $1,701\text{ cm}^{-1}$ was recorded, which corresponded to the valence vibrations of the ester-type carbonyl group ($\text{C}=\text{O}$), indicating the possible formation of new chemical bonds in the material's structure as a result of heat treatment. In the spectrum of the untreated

sample 4, characteristic bands at $1,148$ and $1,078\text{ cm}^{-1}$ were clearly evident. After annealing, these bands disappeared, indicating structural transformations in the polymer matrix. At the same time, for sample 6, an increase in the intensity of the absorption band associated with $\text{C}-\text{O}$ group vibrations was observed in the $1,120\text{--}1,080\text{ cm}^{-1}$ range. Furthermore, the shift of the most intense $\text{C}-\text{O}$ group absorption peak from $1,023$ to $1,034\text{ cm}^{-1}$ indicated a decrease in the degree of crystallinity of the starch amylose under the influence of elevated temperature (Fig. 5).

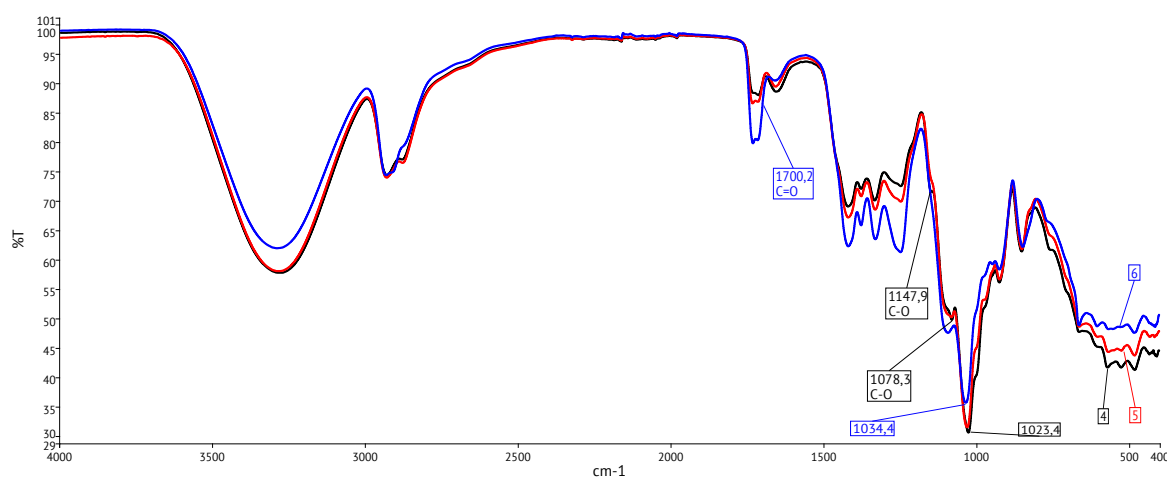


Figure 5. Spectra of films based on polyvinyl alcohol and starch ($4,000\text{--}400\text{ cm}^{-1}$ range)

Source: developed by the authors

Thus, sodium tetraborate emerged as one of the key components ensuring the formation of a stable and robust structure in the film materials under investigation; it was incorporated into the composition to impart antimicrobial properties to the potential packaging materials. In an aqueous environment, sodium tetraborate underwent hydrolysis to form orthoboric acid, which initiated cross-linking processes between the polyvinyl alcohol macromolecules. The implementation of this mechanism contributed to the strengthening of intermolecular interactions between the system's components, particularly between the polyvinyl alcohol and starch chains, which had a positive effect on the structural integrity and performance characteristics of the films. The presence of cross-linking processes was confirmed by the appearance in the spectrum of sample 6 of a characteristic band corresponding to ester groups at $1,701\text{ cm}^{-1}$, as well as an increase in the intensity of the absorption band in the $1,120\text{--}1,080\text{ cm}^{-1}$ range. These spectral changes indicated the formation of new chemical bonds in the structure of the composite film materials. As a result, a film material was formed that was characterised by increased mechanical strength and greater structural stability.

The results obtained correlated with the work of S. Zhang *et al.* (2023), where the task of increasing the

mechanical strength of polyvinyl alcohol-based films was solved by chemical cross-linking with boric acid, which made it possible to significantly improve the mechanical properties of the material without compromising its optical transparency. Furthermore, in the work by A.K. Sonker & V. Verma (2017), it was determined that the addition of an organic acid to the polyvinyl alcohol polymer matrix led to the strengthening of the films and a reduction in water absorption. The introduction of sodium tetraborate into the polymer matrix could be considered more promising, as it not only improved the strength of the film materials but also imparted antimicrobial properties. The stabilisation of the film materials at temperatures of 393 K and 423 K contributed to the strengthening of the material – a functional characteristic such as tensile strength increased. The results of this study were consistent with those of L. Li *et al.* (2024), who reported that the presence of water in polyvinyl alcohol films reduced the material's mechanical properties, particularly tensile strength, but increased its ductility. The thermal method of film strengthening became more expensive compared to cross-linking as the boric acid content increased. Similar results are reported in the study by V. Sytar *et al.* (2020). The authors found that the maximum resistance of the film composition to dissolution in water is

achieved both by heating to 443 K for 30 minutes and by adding boric acid (30% relative to the dry weight of PVA). Thus, the introduction of sodium tetraborate into the composition of polyvinyl alcohol, maize starch and glycerine proved to be an effective solution, contributing to an increase in the material's chemical stability and an improvement in its performance properties, in particular an increase in strength and the assurance of material stability during prolonged use. The films under investigation may also find application in agriculture, particularly for the bio-packaging of plant protection products. J. Song *et al.* (2024) developed a new strategy combining mechanical activation with esterification and blending with polyvinyl alcohol (PVA), to produce biodegradable and cold-water-soluble starch (St)/PVA films with excellent mechanical properties, solubility and oxygen barrier properties. The resulting films effectively improve the emulsification and dispersibility of fat-soluble pesticides, thereby enhancing their efficacy when packaged in St/PVS films.

Since disposal has become a crucial stage in the "life cycle" of packaging, the inclusion of biopolymers in the polymer composition enables the biodegradation of the materials under investigation and significantly accelerates the biodegradation processes of the films, as established by N.N. Nasir & S.A. Othman (2021) due to the presence of starch. Furthermore, the authors noted that optimising the concentrations of starch and glycerol allows the properties of the films to be maximised for various applications, ensuring a balance of strength, flexibility and hydrophilicity. M.C. Alvarado (2024) investigated the use of composite films based on polyvinyl alcohol and nanocellulose for packaging materials, demonstrating that the addition of nanocellulose improves the mechanical properties and barrier characteristics of the films. In the work by A.A. Oun *et al.* (2022), the combination of PVA with various biopolymers and functional materials was analysed, highlighting the potential for using such composites as packaging materials. Research by O. Fedoryshyn *et al.* (2024) on experimental and industrial film materials containing maize and potato starch demonstrated increased microbial activity on their surfaces in soil and biodegradability. Research by V. Lebedev *et al.* (2022) investigated the hybrid modification of environmentally friendly polylactic acid polymers with humic substances and identified an intermolecular bond between polylactic acid and humic substances. Furthermore, the researchers noted that the modification mechanism promoted increased crystallisation and the formation of complex bonds, which improved the mechanical properties of the materials. In the work by O. Krykhovets & V. Slobodanyk (2023), the wetting of polyvinyl alcohol-based film surfaces by test liquids was investigated. Thanks to their good printability, polyvinyl alcohol-based films can be printed to a high standard for applying the information required for packaging. The authors S. Sheikh *et al.* (2021) demonstrated

the economic viability of using biodegradable compositions containing polyvinyl alcohol as active packaging. The combination of enhanced mechanical properties, high transparency, biodegradability and antimicrobial activity has made the studied film materials promising for the production of environmentally safe packaging.

Conclusions

Film materials combining polyvinyl alcohol, maize starch, glycerol and sodium tetraborate were found to be transparent, of uniform thickness, soft and elastic. It was established that the physical and mechanical properties of the biopolymer films varied depending on the composition of polyvinyl alcohol, corn starch, glycerine and sodium tetraborate, and the temperature at which they were stabilised. The tensile strength of films containing 10% sodium tetraborate increased by 125% compared to those containing 5% sodium tetraborate at a temperature of 293 K and by 151% after heat treatment. The introduction of 10% sodium tetraborate enabled the effective production of films with increased strength. The highest tensile strengths – 18.79 N, 28.1 N and 66.2 N – were recorded for samples stabilised at 423 K. Heat treatment of the film materials at temperatures of 393 K and 423 K contributed to the strengthening of the material, in particular improving functional characteristics such as tensile strength. Furthermore, the results of IR spectroscopy of the films indicated structural transformations in the polymer matrix. The formation of new chemical bonds in the material structure as a result of heat treatment was evidenced by the appearance of a band corresponding to the valence vibrations of the ester-type carbonyl group. With film thicknesses ranging from 0.0552 to 0.2240 mm, which met the requirements for packaging films, the biofilms obtained exhibited high performance properties. The ability of the studied materials to undergo relative elongation within the range of 130%–280%, combined with the high gas barrier properties of polyvinyl alcohol, made it possible to predict the potential use of transparent PVA/starch films for encapsulating food products, particularly vegetables and fruit. The presence of a biopolymer in the film composition will allow packaging waste to be disposed of by composting or burial in soil, thereby helping to improve its composition. The study of the conditions and rates of biodegradation of polyvinyl alcohol-starch films is the subject of further research.

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Conflict of Interest

None.

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Експлуатаційні властивості плівкових матеріалів для біопакування

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Анотація. Розробка екологічно безпечних матеріалів для пакування стало однією з ключових вимог 2026 року. У різних сегментах сучасного ринку чітко спостерігалось стабільне зростання інтересу до біополімерних матеріалів, що виготовлялися з відновлюваних джерел сировини і були потенційно здатні до біорозкладу. Метою роботи стало дослідження експлуатаційних характеристик плівок на основі полівінілового спирту, кукурудзяного крохмалю, гліцерину і натрій тетраборату, а також оцінка можливості їх застосування як екологічно безпечного пакувального матеріалу. У процесі проведення дослідження плівки отримували методом лиття з розчину на скляну основу з термічною обробкою за температурах 393 К та 423 К. Було виготовлено зразки різної товщини: у діапазоні 0,0552-0,0616 мм, а також плівки більшої товщини – від 0,1953 до 0,2240 мм. Фізико-механічні характеристики матеріалів було визначено за допомогою універсальної розривної машини. Було з'ясовано, що експериментальні значення розривного зусилля для одержаних плівкових матеріалів зростали із збільшенням вмісту натрій тетраборату – від 18,79 Н до 66,2 Н. Напруження при розриві досягало 30,5 МПа при вмісті натрій тетраборату 10 % і температурі стабілізації плівок 423 К. Відносне видовження при розриві поступово знижувалося при вищій температурі стабілізації зразків. Зростання межі міцності при розтязі для плівок із вмістом 10 % натрій тетраборату зробили цей склад ефективним для одержання плівок покращеної міцності. Плівкові матеріали товщиною 0,0612-0,0734 мм показали найкращі експлуатаційні характеристики за співвідношенням «міцність матеріалу – товщина плівки». Результати дослідження експлуатаційних характеристик плівкових матеріалів, сформованих на основі полівінілового спирту, водорозчинного кукурудзяного крохмалю та гліцерину за різного вмісту натрій тетраборату дозволили розглядати можливість їх використання для пакування продуктів харчування, капсулювання свіжих овочів і фруктів

Ключові слова: біорозкладні матеріали; фізико-механічні властивості; біополімери; полівініловий спирт; межа міцності