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PHOTODESTRUCTION OF BIOCOMPOSITE POLYMER MATERIALS BASED ON POLYLACTIDE FILLED WITH THERMOPLASTIC COMPOUND WITH A PROOXIDANT ADDITIVE

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A B S T R A C T

The paper presents a new study aimed at creating polymer biocomposites based on polylactide filled with the thermoplastic compound "A-Len." It has been established that Alen in mixtures with polylactide affects the formation of a heterogeneous structure due to the presence of polyethylene in its composition. This indirectly reduces the elastic modulus by 34% (1050 MPa) compared to the initial value of polylactide – 1600 MPa. At the same time, for the polylactide phase in polymer compositions, recrystallization occurs with a denser ordering of the supramolecular structure, while for the polyethylene phase, there is a decrease in the segmental mobility of macromolecules and a hindrance to the crystallization process due to their different polarities with the formation of a phase boundary between the studied components. The mechanism of photodegradation of polymer compositions based on polylactide filled with Alen is carried out due to the presence of a pro-oxidant additive in the thermoplastic compound, which initiates the oxidation process, followed by the destruction of the low-molecular fraction of polyethylene and its subsequent fragmentation. Along with this, the photodegradation of the polylactide matrix proceeds according to the Norrish II mechanism, which consists of a radical-type oxidation process with the formation of C=C bonds. Thus, the developed biocomposite polymer materials are promising for the manufacture of packaging products for foodstuffs, characterized by optimal performance properties and accelerated kinetics of photochemical destruction.

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1. INTRODUCTION

The growing relevance of biodegradable polymers is due to the possibility of creating promising environmentally friendly materials to reduce environmental impact, with potential applications in the packaging, medical, and agricultural industries (Povernov et al., 2025). The leading position of synthetic thermoplastics and their sustainable development in the packaging industry are associated with an uncontrolled amount of polymer waste

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(Razzaq, 2025), most of which pollutes the environment by accumulating in landfills. In the vast majority of cases, polymers synthesized from petrochemical raw materials (Studenikina et al., 2025; Pekhtasheva et al., 2024; El-Taweel & Al-Hamdi, 2024) are modified with fillers of natural origin to impart biodegradability.

Starch (Brovina et al., 2023), cellulose (Yazlakova et al., 2025), chitin (Futoryanskaya & Kudyshkin, 2025), chitosan (Gul-E-Nayyab et al., 2024), and other natural polymers (Monina et al., 2024; Liu et al., 2024; Kuzmin et al., 2023) are used as modifying additives. Modification of synthetic polyolefins with naturally occurring polymers accelerates the fragmentation of the polymer matrix due to the rapid biodegradation of the filler. However, the formation of the above composites can be difficult due to insufficient adhesion of the synthetic matrix to the naturally occurring filler. An additional complicating factor is the maximum filler concentration (most often up to 30 wt%), which is associated with the technological complexity of obtaining dispersion-filled systems. Increasing the content of natural polymer in the synthetic polymer matrix above 30 wt% leads to the formation of a large number of agglomerates, which affects the appearance of defects during their production (Sirazetdinov et al., 2021; Shapovalov et al., 2024; Poddenezhny et al., 2023).

Chitin and chitosan are found in the shells of insects, crabs, and shrimp. They are mainly used in medicine. Chitin has low solubility, so it is mixed to produce packaging solutions in the form of barrier coatings for products. Chitin and chitosan are used in the production of various biodegradable packaging films, most often as an edible coating to extend the shelf life of fresh fruits and vegetables. They have good antimicrobial properties against various fungi, yeasts, and bacteria found in food products.

Starch is a natural polymer consisting of amylopectin (poly-α-1,4 D-glucopyranoside and α-1,6-D-glucopyranoside) and amylose (poly-α-1,4-D-glucopyranoside). Starch is produced from wheat, rice, potatoes, corn, peas, sorghum, rye, and cassava. Depending on the type of raw material from which the starch is obtained, the content of amylose and amylopectin varies. The mechanical properties of starch-based materials increase as the amylose content increases. Starch is a hydrophilic polymer, and its thermal properties vary depending on its water content. Biodegradation occurs through the hydrolysis of the acetal bond. Amylases cleave the α-1,4 bond, while glucosidases cleave the α-1,6 bond.

Cellulose is a linear polymer formed from repeating units of cellobiose. Cellulose is crystalline and insoluble in organic solvents. Due to its insolubility and low fluidity, it transforms into various forms.

In recent years, there has been a growing interest in the creation of biodegradable materials based on polymers synthesized from renewable raw materials, in particular polycaprolactone (PCL), polybutylene succinate (PBS), polybutylene adipate terephthalate (PBAT), polylactide (PLA), reducing dependence on polymers derived from petroleum (Michurov et al., 2024).

Polycaprolactone is an aliphatic polyester synthesized from cyclic ε-caprolactone (CL) ester by ring polymerization catalyzed by metal alkoxides, metal carboxylates, or ionic initiators at elevated temperatures above 120 °C. Polycaprolactone can be processed by extrusion to produce films. It is characterized by an amorphous-crystalline structure with a predominant amorphous phase, which allows it to be used in blends with PLA, PBS, and PBA to level the deformation and strength properties of polymer compositions made from them. Melting point (Tm) 60-80 °C, glass transition temperature (Tg) -60 °C, thermal decomposition temperature above 170 °C. The degree of crystallinity varies widely. Products made from this material are marketed under the trade names Tone® by Union Carbide, Celgreen® by Daicel, and CAPA® by Solvay. Polycaprolactone is also produced by BASF SE, Sigma-Aldrich Corporation, Polysciences Inc. and several other companies.

Polybutylene succinate is a polymer belonging to polyalkenedicarboxylates, obtained by polycondensation of glycols (1,4-butanediol and ethylene glycol) with aliphatic dicarboxylic acids (adipic and succinic). PBS is characterized by mechanical properties comparable to polyethylene (PE) and polypropylene (PP). It is a stereoregular polymer with a high degree of crystallinity. PBS can be used to manufacture flexible packaging and rigid containers, products for the cosmetics industry, as well as in surgical medicine for the production of implants. In agriculture, PBS is used in slow-release products for pesticides and fertilizers. There are several major manufacturers in the polymer market for the production of polybutylene succinate, including Hexing Chemical (Anhui, China), Xinfu Pharmaceutical (Hangzhou, China), and IRe Chemical (South Korea). Since 2010, Hexing Chemical and Xinfu Pharmaceutical have been the largest producers of PBS (more than 30 000 tons/year), including the use of continuous production technology.

Polybutylene adipate terephthalate is a linear aromatic copolyester obtained by condensing 1,4-butanediol with a mixture of terephthalic and adipic acids. At a terephthalic acid concentration of more than 35%, PBAT is characterized by flexibility and rigidity. When the content exceeds 55%, the biodegradability rate of PBAT decreases. This material is flexible and soft, like PCL, so it is used in the production of films, polymer threads, bottles, and molded products. PBAT can be mixed with cellulose to improve hydrophobicity, mechanical and

thermal properties, as well as with starch and other biodegradable polymers.

Polybutylene adipate terephthalate is produced by BASF under the Ecoflex trademark and in a mixture with PLA under the name Ecovio. Novamont, Zhuhai Wango Chemical Co Ltd, JinHui Zhaolong, and Eastman Chemical produce biodegradable compounds called Origo Bi®, Wango®, and Ecoworld®, as well as starch-based compounds called Mater-Bi®, Ecowill®, and Eastar Bio®. In addition, PBAT is produced by suppliers in China and other countries, including Zhejiang Biodegradable Advanced Material Co. Ltd., Dongguan Xinhai Environmental Protection Material Co., Ltd. (China), as well as Green Chemical Co., Ltd. and WILLEAP (South Korea).

PBAT is marketed commercially as a fully biodegradable plastic, with BASF's Ecoflex showing 90% degradation after 80 days of testing. Due to its high flexibility and biodegradability, PBAT is also sold as an additive to stiffer biodegradable plastics to impart flexibility while maintaining the complete biodegradability of the finished products.

Polylactide is a synthetic polymer whose monomer, lactide, can exist in two optically active isomeric forms, L- and D-lactide, as well as in an optically inactive form, meso-lactide (see Figure 1).

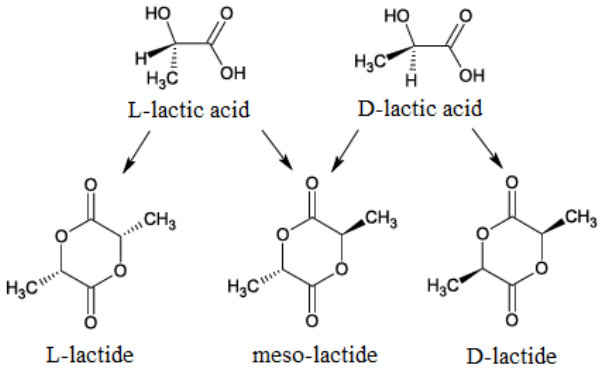


Figure 1. Appearance of thermoplastic rice compound string (a) and granulate based on it (b)

Polylactide is a strong and rigid polymer, comparable in performance to polyethylene terephthalate, and with appropriate plasticization, comparable to polyethylene and polyvinyl chloride (Tertyshnaya et al., 2024). Polylactide can be processed by extrusion to obtain flexible films, or by thermoforming to produce rigid containers (Poddenezhny et al., 2024). Although polylactide is a biodegradable polymer, it is important to note that its biodegradation kinetics occur under certain conditions (high temperature, pH, and humidity). In this regard, polylactide, like other polymers, is modified with additives of various origins (Bazhenov et al., 2024; Lytkina et al., 2023), but it is not always possible to achieve the desired properties due to their low technological compatibility (Mironov et al., 2024).

Polylactide has high potential for use in a wide range of products, which is why the market for its production is growing. Currently, there are several major polylactide producers in the world, including NatureWorks (USA), Cargill Dow (USA), Hycail (Netherlands), and Mitsui Toatsu (Japan). Cargill Inc. in Minnetonka (USA) manufactures Eco-Pla, a product based on lactic acid, using simple fermentation, distillation, and polymerization processes to obtain patented polylactide. Sheets made from this material are comparable in impact strength to polystyrene. Production capacity is 6 000 tons per year, with plans to increase production to 150 000 tons per year and reduce the cost of the material from $250 to $2.2 per kg. NatureWorks LLC, wholly owned by Cargill, manufactures PLA under the NatureWorks PLA and Ingeo trademarks. Ingeo is a long-chain polylactide polymer formed by the opening of the lactide ring during polymerization. Ingeo PLA is formed into pellets, which are used in the manufacture of disposable tableware, electronic devices, etc. NatureWorks has a production capacity of 140 000 tons per year.

Another way to modify synthetic thermoplastics with additives that initiate the decomposition of the polymer matrix is to use pro-oxidant additives, which are transition metal stearates (Mn, Fe, Mg) that promote accelerated oxidative destruction (Shlush & Davidovich-Pinhas, 2022; Klaiber et al., 2024). The advantage of using transition metal stearates is associated with the possibility of modifying a wide range of thermoplastic polymers, including polylactide, by processing them on existing equipment designed for thermoplastics; their low toxicity and short oxidative degradation time of polymer materials at low mass content in the synthetic polymer, unlike natural fillers (Podzorova et al., 2022).

The ability of biopolymers to degrade not only photochemically but also biologically under the influence of microorganisms depends on parameters such as the chemical nature of the polymer, molecular weight, supramolecular structure, and the presence of functional groups with a polar structure. For example, nonpolar polyolefins, whose monomer units contain carbon and hydrogen atoms, unlike polylactide or polybutylene succinate, whose monomer units contain simple and complex esters, are not subject to biodegradation (Demina et al., 2024).

The biodegradation of synthetic polymers primarily depends on their chemical structure and the length of their macromolecular chains. Natural polymers, such as protein, cellulose, and starch, degrade in biological systems through hydrolysis accompanied by oxidation. Therefore, most known biopolymers contain hydrolyzable bonds along the polymer chain, such as ether and urethane functional groups, which can be destroyed by microorganisms and hydrolytic enzymes.

Since many proteolytic enzymes are catalysts for the hydrolysis of peptide bonds adjacent to substituents in proteins, synthetic polymers are introduced with substituents such as hydroxyl, carboxyl, methyl, and phenyl functional groups, which increase the biodegradability of polymers (Poddenezhny et al., 2024).

Another parameter affecting the degree of biodegradation of synthetic polymers is their hydrophobicity or hydrophilicity, since most degradation processes occur when exposed to water. Polymers with functional groups that undergo hydrolysis have a higher biodegradability, for example, polylactide or polycaprolactone, than polyethylene, which contains only hydrophobic monomer units in its structure. Synthetic water-soluble or hydrophilic polymers are also of interest in the creation of polymer materials with a controlled service life (Myalenko et al., 2023).

Another parameter affecting the kinetics of biodegradation is the length and flexibility of macromolecular chains. Unlike rigid-chain polymers, which are characterized by high stereoregularity and, as a result, high crystallinity, as well as dense packing of fragments, flexible-chain polymers, in turn, are characterized by flexibility and segmental mobility of macromolecular chains, which ensures their swelling in water and simultaneous migration of microorganisms into their structure, as a result of which the kinetics of biodegradation increases. For example, during biodegradation, semi-crystalline polymers undergo certain structural changes: initially, the amorphous phase is degraded, and the crystalline phase experiences modifications expressed either by partial recrystallization or by its increase (cross-linking) followed by fragmentation (Anokhina et al., 2024).

The molecular weight of synthetic and biopolymers also affects the kinetics of their biodegradation. Most of the observed differences can be attributed to the limited ability to determine changes in their properties during degradation, or, more often, to differences in the morphology of their structure, as well as hydrophilicity or hydrophobicity. Microorganisms produce both exoenzymes (polymer degradation begins at the terminal groups (inward)) and endoenzymes (polymer degradation occurs randomly along the chain). Hydrocarbon molecules are absorbed by microbial cells and converted into cellular metabolites inside the microbial cell. However, this process practically does not occur in the extracellular space, and polymer molecules are too large to penetrate the cell. This problem does not arise with natural polymers such as starch and cellulose, since their fermentation into low-molecular-weight components occurs in the extracellular space. Exposure to ultraviolet radiation can reduce the molecular weight of polymeric materials, causing products based on them to be more susceptible to destruction by bacterial microflora. For example, LDPE with an average molecular weight of Mw = 150 000 contains approximately 11 000 carbon atoms. Reducing the molecular weight and, as a result, the number of carbon atoms to the size required for biological degradation to occur requires the destruction of the PE matrix. Therefore, in practice, to reduce the molecular weight of polyethylene, its matrix is modified with organic additives that are subject to biodegradation by microorganisms (Alexandrova et al., 2023).

Thus, it is of scientific and practical interest to analyze the properties of triple compositions based on polylactide filled with the thermoplastic compound “A-Len” and to determine the mechanism of their degradation, which is currently insufficiently represented and requires further study.

The aim of this research is to study the influence of formulation and technological parameters of polymer biocomposite materials based on polylactide filled with the thermoplastic compound “A-Len” on the structural, thermophysical, and deformation-strength properties, as well as to determine the mechanism of destruction under the action of ultraviolet radiation.

2. RESEARCH OBJECTS AND METHODS

Aliphatic polyester – polylactide (PLA) grade 524 manufactured in China – was used as the polymer matrix for the production of polymer compositions. As an additive initiating the destruction of the polymer matrix, a thermoplastic compound of the A-Len Tech BD00TY brand with an active (organic) substance content of 10 wt.% manufactured in India was used. Table 1 shows the characteristics of the initial components.

Table 1. Characteristics of the initial components.

Component	Melt flow index (MFI), g/10 min	Modulus of elasticity, MPa	Relative elongation at break, %	Density, g/cm^3
PLA	8.7	1600	4.2	1.24
Alen	2.3	600	3.2	0.97

The blending of components, plasticization, and subsequent production of polymer compositions were carried out on a flat-slot extruder manufactured by MashPlast (Russia), varying the Alen content from 5 to 20 wt% in blends with polylactide. The output was polymer compositions with a thickness of 60±3 μm. The temperature conditions for obtaining the initial PLA and Alen films, as well as polymer compositions based on them, are presented in Table 2. The compositions of the polymer compositions are presented in Table 3.

The operational properties were determined in accordance with ISO 527-3:2018 “Plastics. Determination of mechanical properties by tensile testing.” The tests were performed on a Z010 ZwickRoell tensile testing machine (Germany). Samples for testing

deformation and strength properties were obtained using a cutting device in accordance with type 1B (ENISO 527-3) and dimensions of 50×10 mm. The permissible load measurement error limit did not exceed 1%. The maximum deviation in sample width was ± 0.1 mm. The average value was determined from 10 measurements. The tests were conducted at a sample deformation rate of 50 mm/min. The elastic modulus (E_b) was determined as a strength property, and the relative elongation at break (ε_b) was determined as a deformation property.

Table 2. Temperature conditions to produce polymer compositions.

Polymer composition	Temperature regimes of flat-slot extruder zones, °C				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
PLA	165	168	170	173	175
Alen	120	125	130	135	140
PLA/Alen	165	168	170	173	175

Table 3. Name of the polymer composition.

Polymer composition	Concentration, wt%	
	PLA	Alen
PLA	100	-
Alen	-	100
PLA/Alen5	95	5
PLA/Alen10	90	10
PLA/Alen15	85	15
PLA/Alen20	80	20

The thermophysical properties of the samples were determined using differential scanning calorimetry on a DSC 204 F1 NETZSCH (Germany) in the temperature range from 20 to 200 °C at a scanning rate of 10 °C/min and a sample weight of 10±1 mg in an inert gas stream of argon. When studying the thermophysical properties, the melting enthalpy ΔH_m (J/g), melting temperature T_m (°C), and glass transition temperature T_g (°C) were determined. To determine the degree of crystallinity (α, %) of Alen and PLA, as well as polymer compositions based on them, the melting enthalpy of fully crystalline polyethylene ΔH_m = 293 J/g and polylactide – 93.7 J/g was used in accordance with ISO 11357-1:2016 "Plastics. Differential scanning calorimetry (DSC). General principles."

To identify the chemical composition and determine the mechanism of photodegradation, a FT-IR spectroscopy method with an NPVO attachment was used on an FSM-1201 (Russia) with a resolution of 1.0 cm^{-1} (spectral range of wave numbers 4000-375 cm^{-1}) at a temperature of 23±2 °C in accordance with GOST 57939-2017.

The structural and morphological properties of the samples, which had been pre-treated with gold sputtering, were studied using scanning electron microscopy (SEM) on a JCM-6000 PLUS microscope (JEOL, Akishima, Tokyo, Japan), with a secondary electron detector, at an accelerating voltage of 10 and 15 kV.

3. RESULTS AND DISCUSSION

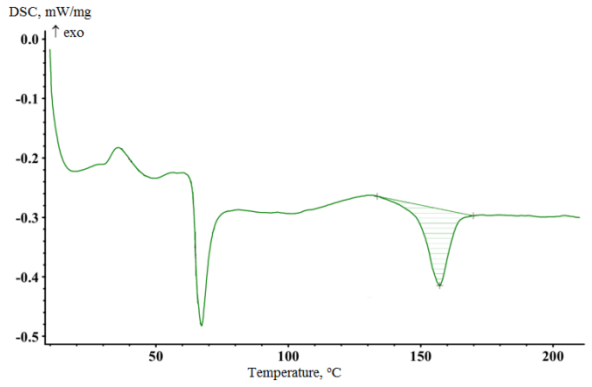
3.1. Thermophysical characteristics

The thermogram of polylactide (Figure 2a) shows two peaks: the first corresponds to the glass transition temperature and is 65 °C, while the second identifies the presence of a crystalline phase with a melting temperature of 157 °C. Figure 2b shows a characteristic endothermic melting peak at 125 °C, which corresponds to the melting temperature of polyethylene, which is part of the thermoplastic compound. The thermogram of the PLA/Alen polymer composition, in which the latter accounts for 20 wt% (Figure 2c), shows two endothermic peaks corresponding to the melting temperatures of polyethylene (118 °C) and polylactide (153 °C).

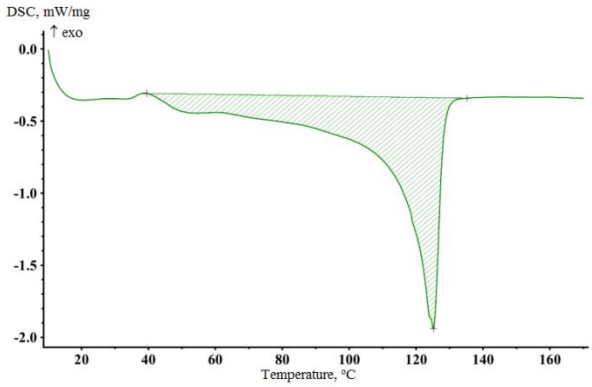
When Alen is introduced into polylactide in an amount of 20 wt, an increase in the melting enthalpy and crystallinity of the polylactide phase is observed (Table 4). This is due to the recrystallization process, which results in a more dense ordering of its supramolecular structure caused by the presence of the crystalline phase of polyethylene in the polymer composition. The shift of the endothermic melting peak of polyethylene to a lower temperature range of 118 °C indicates the formation of more defective small crystals, which is due to a decrease in the segmental mobility of polyethylene macromolecules and a hindrance to the crystallization process.

After 150 hours of exposure to UV radiation, the thermophysical properties of films based on the initial components of polylactide and Alen, as well as PLA/Alen polymer compositions (Figure 3), change.

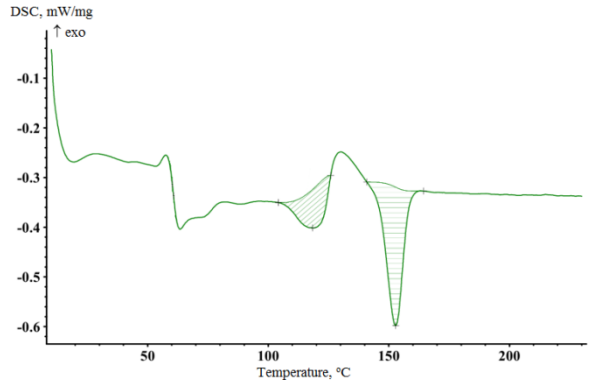
For the polylactide-based film, compared to the original, a cold crystallization peak appears at 105 °C on the thermogram, and the melting enthalpy increases more than 3.5 times. At the same time, the melting temperature decreases by 5.2 °C.



a)



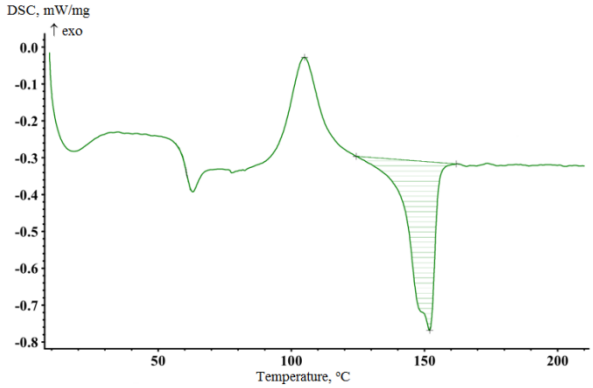
b)



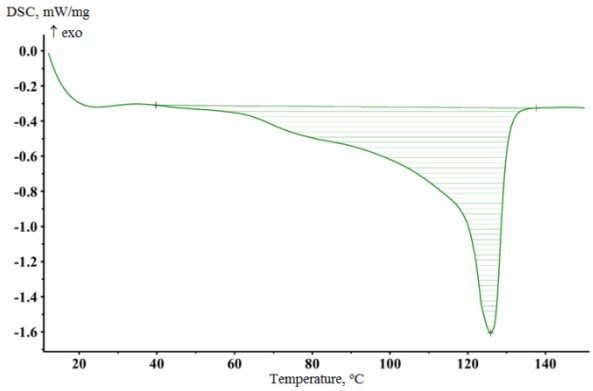
c)

Figure 2. Thermograms of melting of PLA (a), Alen (b) and PLA/Alen20 (c)

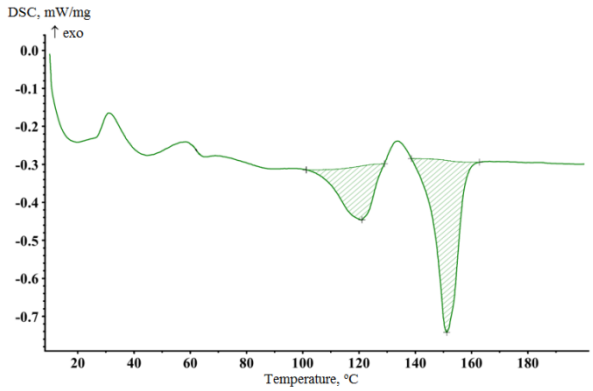
The increase in melting enthalpy under UV radiation is due to the partial destruction of the amorphous phase of polylactide, as a result of which the crystalline phase undergoes a change in its supramolecular structure—more dense and larger crystals are formed. There is another explanation: the presence of a metastable crystalline structure of polylactide under UV radiation probably contributes to the continuation of crystallization due to the rupture of stressed passage chains, which increases its degree of crystallinity.



a)



b)



c)

Figure 3. Thermophysical properties of PLA (a), Alen (b), PLA/Alen20 (c) after 150 hours exposure to UV radiation

For the Alen-based film (Figure 3b), the melting enthalpy decreases by 12%. The difference in melting temperature before and after UV irradiation does not exceed 1 °C. The specific energy of the endothermic process of the PLA/Alen20 polymer composition (Fig. 3c) also increases compared to the initial one (Table 4). Thus, for polyethylene, the melting enthalpy increases two times, and for polylactide, it increases 1.7 times. At the same time, the melting temperature for the polyethylene phase increases by 3 °C, and for the polylactide phase, it decreases by 1.6 °C.

Table 4. Thermophysical properties of polymer compositions.

Exposure	Sample	T_m, °C	ΔH_m, J/g	D, %
0 hours	PLA	157	8.7	9.3
	Alen	125	176	60.0
	PLA/Alen20	153/118	14.5/5.9	15.5/2.0
150 hours	PLA	152	30	32
	Alen	125	155	52.9
	PLA/Alen20	151/121	23.9/12.0	25.5/4.1

3.2. Characteristics of the IR spectrum

The presence of intense absorption bands in the IR spectrum of polylactide (Figure 4a) in the 1180-1077 cm-1 region indicates the presence of a pendulum oscillation of the methyl CH_3 group, which allows the identification of high-molecular-weight polylactide obtained by ring-opening polymerization.

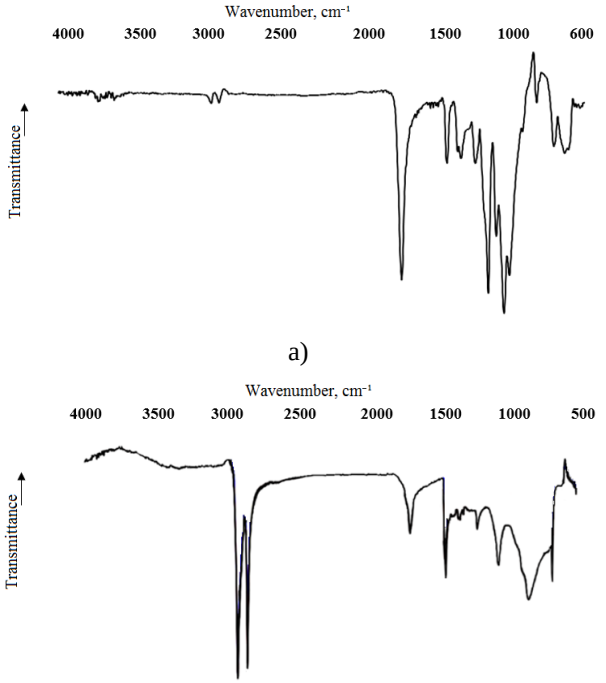


Figure 4. IR spectra of PLA (a) and Alen (b)

Thus, polylactide is an optically active poly(D,L-lactide). The IR spectrum of Alen (Figure 4b) shows absorption bands in the 2914 and 2847 cm^{-1} regions, indicating the presence of asymmetric and symmetric CH2 groups in Alen, as well as an absorption band in the 1462 cm-1 region, characteristic of a scissor CH_2 group. The IR spectrum also shows a distinct absorption band in the 1740 cm^{-1} region, which is not characteristic of polyethylene but allows to identify the presence of a second component in Alen containing a functional carbonyl C=O group.

According to (Kupinsky et al., 2024), the presence of polyethylene and a carbonyl C=O group represents an additive – a superconcentrate containing active transition metal elements (Mn, Fe, Mg) that initiate the decomposition of the polymer matrix through a process of oxidative destruction. Thus, Alen is a polyethylene composition with a pro-oxidant additive in the form of transition metal stearates.

Apparently, the mechanism of photodegradation of PLA/Alen polymer composites is due to the presence of a pro-oxidant additive in the thermoplastic compound "A-Len," followed by the destruction of the low-molecular-weight fraction of polyethylene with its subsequent fragmentation, and for the polylactide matrix, photodegradation proceeds according to the Norrish II mechanism (Mikheev et al., 2024), which consists of a radical-type oxidation process with the formation of a C=C bond, appearing as an absorption band on the IR spectrum in the 1654 cm^{-1} region (Figure 5), on which a change in the intensity of the characteristic absorption bands of the PLA/Alen polymer composition is also noticeable, which also confirms the photodegradation process.

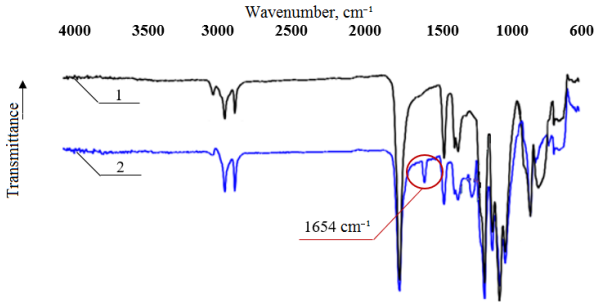


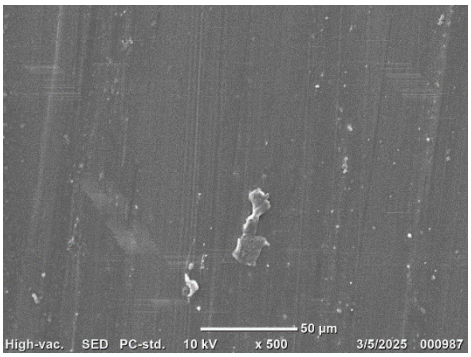
Figure 5. IR spectra of the polymer composition PLA/Alen20: 1 – initial, 2 – after 150 hours of UV radiation

3.3. Scanning electron microscopy

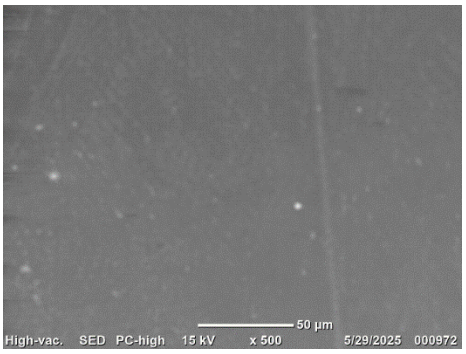
The surface of the extruded polylactide film (Figure 6) is characterized by a minimal number of defects, presumably related to the manufacturing process.

The surface of the Alen film (Figure 7a) shows scratches, presumably formed during extrusion, and noticeable spherulites (Figure 7b) (average size in the image ~7 μm). After 150 hours of UV radiation, wide through cracks formed on the film surface (Figure 7c), the number of defects increased, and the spherulite structure became less noticeable (Figure 7d), which is the result of photodestruction.

After 150 hours of UV irradiation, the surface remained unchanged, indicating no visible signs of photodegradation throughout the experiment.



a)



b)

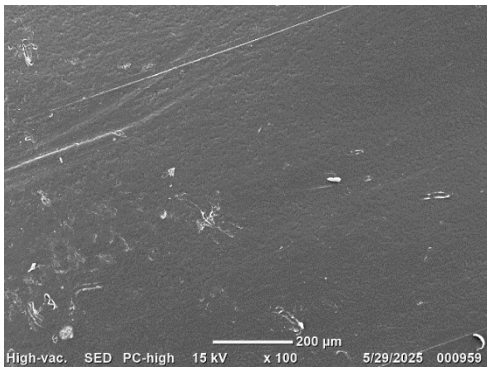
Figure 6. Morphology of the surface of the PLA film: initial (a), after 150 hours of UV radiation (b)

The surface morphology of the PLA/Alen polymer composition is shown in Figure 8. When the above composition is obtained by extrusion, a structurally heterogeneous film is formed (Figure 8a). At higher magnification (Figure 8b), domains are visible, which is associated with the phase separation of polylactide and Alen. After 150 hours of exposure in a UV chamber, microcracks form on the surface (Figures 8c and 8d), indicating photodegradation. Most likely, this occurs in the thermoplastic compound "A-Len" phase.

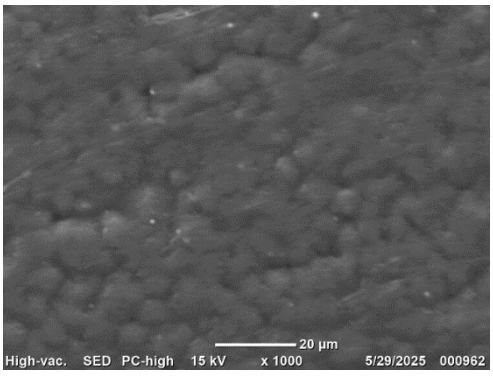
4. MECHANICAL CHARACTERISTICS

For the initial polylactide and Alen films, the elastic modulus is 1600 and 600 MPa, respectively. When the Alen content in blends with polylactide is increased to 20 wt%, the elastic modulus decreases by 34% and is 1050 MPa, which is due to the formation of a heterogeneous structure due to low intermolecular interaction resulting from the different polarities of the initial components. At the same time, the relative elongation at break for the polylactide film is 4.2%, and for the Alen film, it is 3.2%.

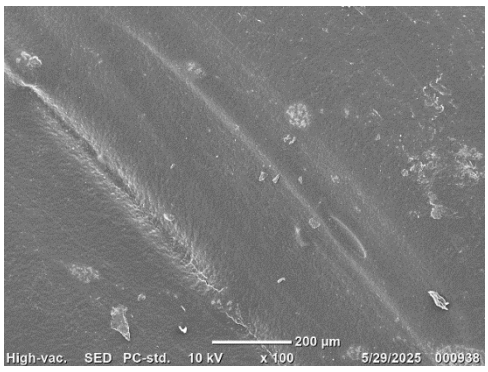
After 150 hours of UV exposure, the elastic modulus for the PLA film decreases by 50% and is 800 MPa. For the Alen-based film, it was not possible to determine the elastic modulus due to the presence of a large number of through holes, which also act as stress concentrators.



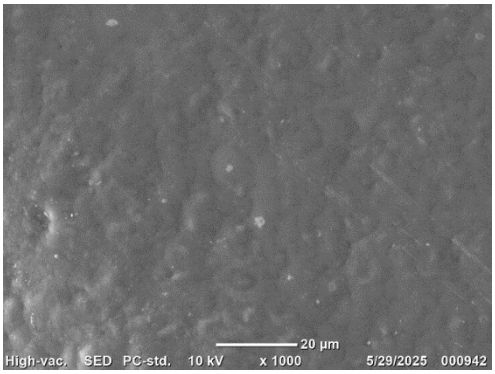
a)



b)



c)



d)

Figure 7. Surface morphology of the Alen film: initial (a and b), after 150 hours of UV radiation (c and d)

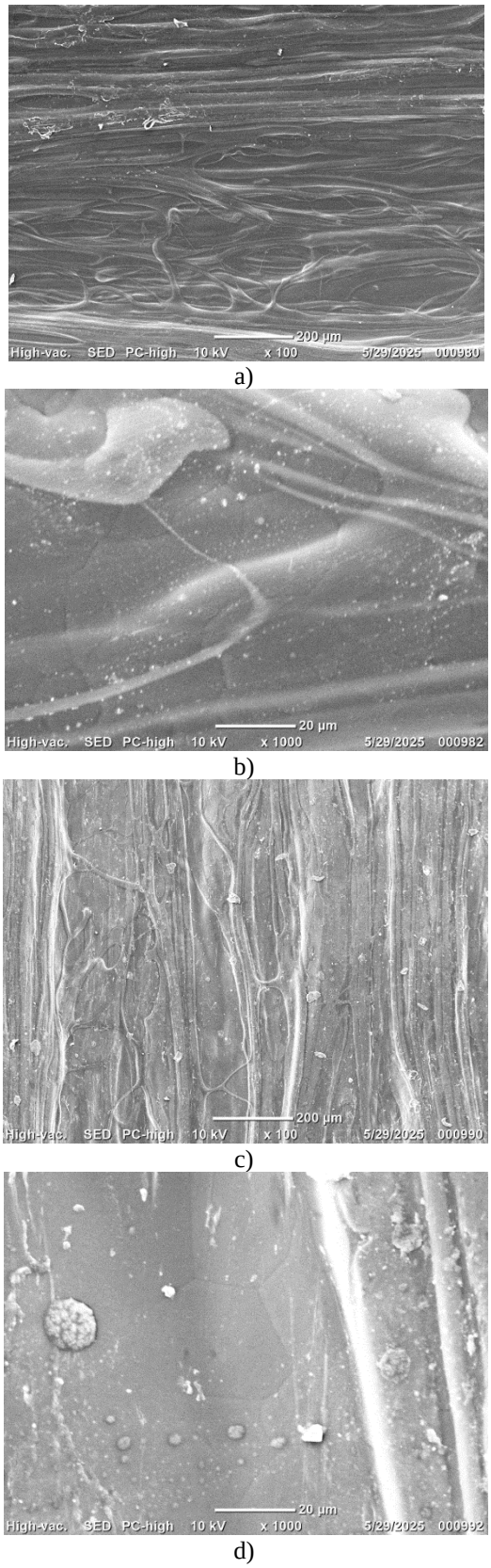


Figure 8. Surface morphology of the polymer composition PLA/Alen20: initial (a and b), after 150 hours of UV radiation (c and d)

For the PLA/Alen20-based polymer composition, the elastic modulus decreases by 82% from the initial value, mainly breaking down at the PLA/PE phase boundary. Analyzing the mechanical characteristics, it can be concluded that polymer compositions based on polylactide and the thermoplastic compound "A-Len" can be recommended for use as packaging materials.

Thus, the production of biocomposite materials based on polylactide filled with the thermoplastic compound "A-Len" is a promising technology that can be used to produce polymer packaging materials with specified operational properties and accelerated photochemical degradation kinetics.

5. CONCLUSION

The study was conducted to determine the photochemical degradation of polymer compositions based on polylactide filled with the thermoplastic compound "A-Len." During the extrusion of polymer compositions, the polylactide phase in the mixture with Alen undergoes a change in its supramolecular structure, manifested in an increase in the degree of crystallinity. This is caused by the presence of the polyethylene phase. For this phase, in turn, the segmental mobility of macromolecules decreases, which affects the formation of more defective and smaller crystals and, as a result, reduces the degree of crystallinity. The identified structural features of polymer compositions affect the reduction of their operational properties due to the different polarity of the initial components.

The effect of UV radiation on Alen and PLA/Alen leads to the appearance of structural defects, as well as a decrease in deformation and strength properties. The most likely explanation for photodegradation is the presence of a pro-oxidant additive in Alen. In this case, the low-molecular fraction of polyethylene is primarily destroyed, followed by fragmentation of the polyethylene matrix, while for polylactide, photochemical destruction occurs via the Norrish II mechanism, consisting of radical-type oxidative destruction with the formation of C=C bonds. The established patterns can be used in the development of biocomposite materials with accelerated kinetics of photochemical destruction.

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