

Eco-friendly polymer materials for agricultural purposes

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Abstract. The paper deals with various polymer materials for agricultural purposes. To date, there are many technologies for growing crops that use polymer films: greenhouses, greenhouses, planting seeds in capsules. There are a lot of works on the study of biodegradable compositions based on biopolymers with synthetic polymers, as well as the analysis of the impact of destructive environmental factors on samples. Binary polylactide–low-density polyethylene blends of various compositions were prepared, and their biodegradability in soil and water absorption kinetics. The degree of water absorption is higher for the blends than for the pure polymers. The weight loss is higher upon incubation in laboratory soil compared to open soil. Changes in the specimen macrostructure after exposure to soil were demonstrated by optical microscopy.

1 Introduction

It is known for the cultivation of plants in the agricultural sector on an industrial scale, the most widely used technology that uses polymer coating films - mulching. In addition to mulching, the technology of growing crops in greenhouses and greenhouses has received wide industrial application. This technology provides for the use of film polymer material. It should be noted that almost all these technologies use synthetic polymers.

In this regard, much attention has recently been paid to biodegradable polymers because of their wide range of applications in the biomedical, packaging and agricultural industries.

The market offers a wide range of biopolymers. Sometimes, biopolymers (although it is against the European standard ENJ43432) are deemed including traditional polymers with special additives regulating the degree of decomposition, for example, hydro-decomposable and oxo-decomposable plastics [1]. Linear aliphatic polyesters polylactide (PLA) and poly-3-hydroxybutyrate (PHB) occupy a particular place among polymers prepared from natural raw materials [2–5]. Researchers in many countries are engaged in the development of composite materials based on PHB and PLA. The aim of many studies is to investigate the degradation of mixtures under the influence of natural factors to environmentally friendly products, such as carbon dioxide and water.

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In this paper, the compositions based on polylactide were studied, the second component was chosen thermoplastics-low density polyethylene (LDPE).

2 Experimental

Blends of LDPE (TM 15803-020 from Neftekhimsevilen, OJSC, Russia) with PLA (4032D from Nature works, USA) in a wide range of compositions were studied. The PLA content in the polymer matrix was 20, 30, 50, 70, 80 wt% and pure polymers PLA and LDPE. The film samples were compressed from granules in the manual hydraulic press PRG-10 at 180°C under a load of 7 kN, followed by rapid cooling. As a result, film round samples with a diameter of 8 cm and thickness of 100 ± 10 μm were obtained.

The degree of crystallinity and melting temperature of the samples were studied by differential scanning calorimeter Netzsch DSC 214 Polyma at the heating rate of 10K/min and sample weight of 5 ± 0.1 mg. The temperature scale was calibrated against an indium standard ($T_m = 156.6^\circ\text{C}$, $\Delta H = 28.44$ J/g). The kinetics of the absorption of distilled water by the blends was studied in 240-h experiments until the equilibrium water absorption was reached. When determining the maximal water absorption to the equilibrium state, the equilibrium was considered to be attained if the difference between the specimen weights determined at 24-h interval did not exceed 0.1%. For a complex study of the biodegradation of the materials, we performed a soil test on restored soil. The restored soil prepared according to GOST (State Standard) 9.060 (ASTM D570-98 (2010)) simulates the real soil, leveling off the difference between various types of soils and ensuring high reproducibility of the results. The testing procedure consisted in placing film specimens vertically in the soil and exposing for 12 months. Under real environmental conditions, the air temperature varies during a year in a wide range, from -30 to $+30^\circ\text{C}$, natural watering is irregular, and soil flora and fauna are present along with soil microorganisms. To check the results obtained in a laboratory, we performed a field test. The exposure times were 6, 12, 18, and 24 months [5].

3 Results and discussion

One of the environmental factors affecting polymers is water. Depending on the specific application, polymeric materials are exposed to either constant and continuous exposure to humidity or short-term exposure to this factor.

Polymers can be subdivided into hydrophobic and hydrophilic (sometimes intermediate polymers are distinguished). The practical criterion of such classification is the equilibrium amount of water dissolved in the amorphous fraction of the polymer at $T = 23 \pm 2^\circ\text{C}$. It is known that polylactide and LDPE are hydrophobic polymers; this is confirmed by the kinetic curves of water sorption: The degree of water absorption W is about 2% for polylactide and less than 1% for LDPE (Fig. 1). The blends exhibit somewhat higher W . The maximum, about 10%, is observed for the 50 : 50 blend. This is most probably associated with the occurrence of interfacial interactions and formation of an interfacial layer of decreased density, which is characteristic of specimens of the composition close to 50 : 50 (i.e., close to the phase inversion point). During the incubation of samples in soil, the effects of hydrolysis and degree of PLA crystallinity on the process of biodegradation were observed [6] (Fig. 1).

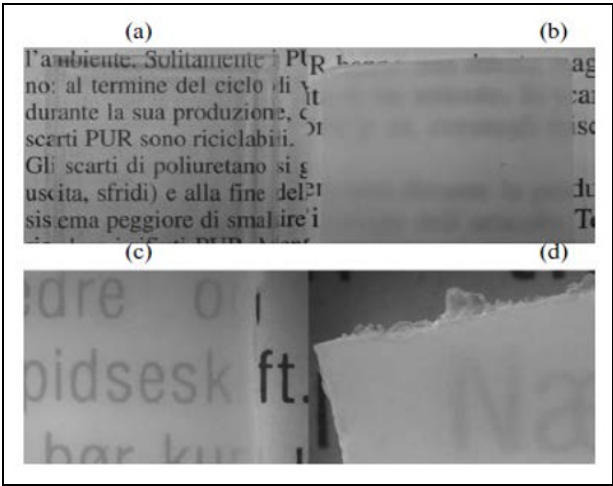


Fig. 1. Effect of hydrolysis for PLA samples: (a) amorphous PLA before the test, (b) crystalline PLA before the test, (c) amorphous PLA after 24 h of hydrolysis, (d) amorphous PLA after 24 h of hydrolysis.

After incubation of specimens in restored soil for 12 months, the largest weight loss, 18%, is observed for the 50 PLA–50 LDPE blend. For the other compositions, Δm is 5–10% (Fig. 2). These results may be associated with the above-noted structural feature of the 50 PLA–50 LDPE blend. The lowest weight loss, 0.2%, is observed for LDPE.

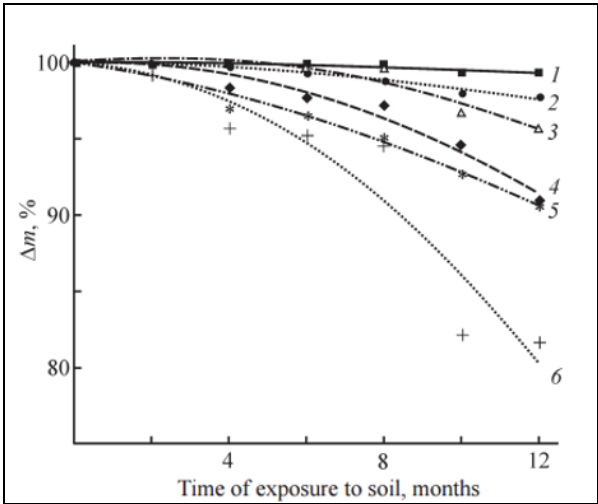


Fig. 2. Kinetics of the weight loss in the course of 12-month exposure to laboratory soil for specimens containing (1) 100, (2) 20, (3) 70, (4) 80, (5) 30, and (6) 50 wt % PLA in the matrix.

After exposing the materials under natural environmental conditions, numerous mechanical damages are observed. They are caused by temperature fluctuations passing through zero centigrade and by the action of micro- and macroorganisms. It is important that some PLA–LDPE blends, e.g., those with 30, 50, and 100 wt % polylactide content, undergo biofouling under field conditions more intensely compared to the materials subjected to laboratory tests. This fact can be attributed to higher concentration of microorganisms in soil on the test site (e.g., the amount of only bacteria reaches 10 bln per

gram of soil). In laboratory soil, the concentration of microorganisms can decrease with time (Fig. 3).

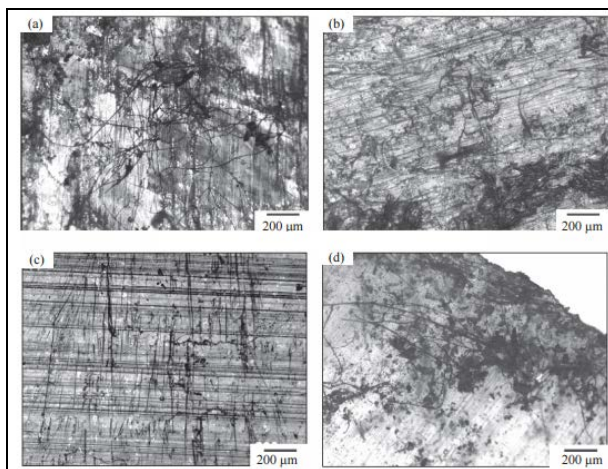


Fig. 3. Photomicrographs of specimens of PLA–LDPE blends after exposure to soil under field conditions for 24 months. PLA content of the matrix, wt %: (a) 30, (b) 50, (c) 70, and (d) 100.

Signs of the development of mycelial fungi are clearly seen in Fig. 3. The most intense development of microorganisms was observed in specimens containing 100, 70, 50, and 30 wt % polylactide in the matrix. However, the weight loss rate for PLA–LDPE specimens exposed under field conditions is considerably lower than that for the similar specimens in laboratory tests.

4 Conclusion

A wide range of innovative technologies existing in modern agricultural production (mulching, covering technologies, etc.) requires the development of new polymer materials for agricultural purposes, characterized by the desired properties that ensure high efficiency of agricultural production. The development of new biodegradable polymer materials that can preserve their performance properties and at the same time improve the environmental situation is a promising direction.

References

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