Biodegradation Study of Some Food Packaging Biopolymers Based on PVA

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Abstract

Polymers are a common choice as protective materials since they combine flexibility, variable sizes and shapes, relatively light weight, stability, resistance to breaking, barrier properties and perceived high-quality image with cost-effectiveness. Currently, mainly non-biodegradable petroleum-based synthetic polymers are used as packaging materials for foods, because of their availability, low cost and functionality. However, biopolymers can be made from renewable resources without the environmental issues of petroleum-based polymers and with the additional advantage of being available from renewable sources or as by-products or waste-products from the food and agriculture industries.

The aim of this study was to test some food packaging biopolymers based on PVA. In this respect, some biopolymers for food packaging applications were subjected to biodegradation tests by covering the tested samples with soil. The samples were incubated in known temperature and humidity conditions.

The experiment lasted 45 days, after that the samples were washed, weighed and the biodegradation degree was calculated. The obtained results shows that PVA is a promising material for food packaging usage, as it is made from renewable resources and it is environmentally friendly.

Keywords: *biodegradability, environmentally friendly, food packaging*

INTRODUCTION

A great variety of synthetic polymers based on petroleum are produced worldwide, reaching around 300 million tonnes by 2015 (Halden, 2010) and many of these polymers are introduced into the ecosystem as industrial waste. Plastics are resistant to microbial attack, since during the short period in which microorganisms have been present in nature, they have not been able to create new enzimatic structures capable to disintegrate synthetic polymers.

The dependence on petroleum resources can be mitigated by developing polymers using biological resources, namely renewable resources (Reddy et al., 2013). So there is an increased interest in the production and use of biodegradable polymers made from renewable resources, both economically and in terms of waste management and carbon emissions (Wu, 2012).

Biodegradability is the property of a material (including polymeric) to alter its chemical and morphological structure under the action of various species of microorganisms. The attack of microorganisms on plastic materials occurs through a complex mechanism that takes place in three phases on the basis of the alteration of the substrate. Thus, primary biodegradation is characterised by the fact that it only produces changes in the functional groups of a polymer without affecting the skeleton. Partial biodegradation degrades a polymer substance by splitting volume, along with a reduced destruction of the cradle. Complete biodegradation involves the complete destruction of the macromolecular support, simultaneously with the formation of reaction by-products.

Starch is an abundant and renewable natural polymer (Tanase et al., 2015), which consists of linear amylose and branched amylopectin (Russo et al., 2009; Joye and McClements, 2014). Natural starch can be found in the form of granules and can be used as a polymer filler. The main limitation of starch is its hydrophilic nature, which limits its use in high humidity environments (Mensitieri et al., 2011; Akter et al., 2012; Priya et al., 2014).

Polyvinyl alcohol (PVA) is a synthetic biodegradable polymer soluble in water, with excellent properties such as flexibility, low permeability, high water absorption capacity and high tensile strength, being common to many industrial or agricultural applications (Taghizadeh et al., 2012; Priya et al., 2014). PVA is among the few synthetic biodegradable polymers that is frequently changed due to its properties. Various PVA-based polymer mixtures have been made in order to improve certain properties, thereof depending on the added polymer: PLA (Abdal-hay et al., 2015; Cadena et al., 2015), starch (Julinova et al., 2010; Guimarães et al., 2015) or chitosan (Liu G. et al., 2015; Pereira et al., 2015). The aim of this study was to test the biodegradability of some food packaging biopolymers based on PVA and starch.

MATERIALS AND METHODS

1. Materials

In order to obtain the polymeric materials, the following raw materials were used:

- PVA type ELVANOL 75-15 (DU PONT) - it was used as thermoplastic matrix.
- Starch type AMYZET 100 (AMYLUM Romania) - it was used as biodegradation agent.

Tab. 1. PVA/starch blends

Code sample	Composition			Characteristics
	PVA, wt. %	Starch, wt. %	Glycerol, wt. %	
PVA/Starch 0	66.67	0	33.33	- thickness of 1 mm; - obtained by melt mixing procedure, at 170±5 °C.
PVA/Starch 10	60	10	30	- thickness of 1 mm; - obtained by melt mixing procedure, at 170±5 °C.
PVA/Starch 20	53.34	20	26.66	- thickness of 1 mm; - obtained by melt mixing procedure, at 170±5 °C.
PVA/Starch 30	46.67	30	23.33	- thickness of 1 mm; - obtained by melt mixing procedure, at 170±5 °C.

Fig. 1. The glass recipients filled with soil

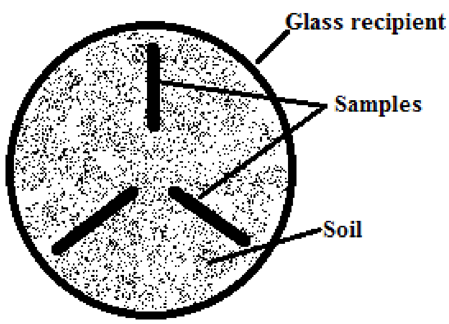

Fig. 2. The arrangement of the tested specimens in soil

- Glycerol (SIGMA-ALDRICH) - it was used as plasticizer.

Four formulations were carried out, coded: PVA/Starch 0, PVA/Starch 10, PVA/Starch 20 and PVA/Starch 30 containing starch from 0 to 30 wt. %. The ratio 2:1 between PVA and plasticizer was respected. Sheets were obtained by melt mixing procedure (Table 1).

2. Method - Determination of the biodegradability degree using the soil burial test

The tested samples were cut into a rectangular shape (1.5x6 cm) and burried in a natural soil characterised by a known water retention capacity and a specified water content. This method was adapted from SR EN ISO 846/2000. An active soil was used with water content of (60 ± 5)% of water retention capacity of the soil. The pH value of the soil aqueous extract (1 g soil in 20 ml water) should be between 4.0 and 7.0, and it was determined to be 6.7. In order to determine the weight variation, the sample batches used were preserved in a desiccator at ambient temperature until the weight of each sample reached a constant value (about 48 hours).

The microbiological activity of the soil was determined by using microbiological analysis (yeasts, moulds and total aerobic mesophiles count determination). After these tests, it was determined that the soil was microbiologically active.

The glass recipients were filled with soil, which had a water content of (60 ± 5)% of the soil retaining water capacity (Figure 1).

Polymeric samples were buried vertically in soil in 6 replicates (Figure 2) for each polymeric blend and for each stage of removing the mixtures from soil. The soil from the glass recipients must not be compacted, and the thickness of the covering layer of the samples should not be bigger than 12.5 cm. To ensure oxygen flow, the glass recipients were sealed. Samples incubation was performed at a temperature of 25°C for 45 days.

At the end of the testing period (45 days), the polymeric materials studied were extracted from the soil, washed with distilled water in order to remove soil, and dried on filter paper. The samples were stored in the desiccator for 48 hours until they reached a constant weight.

Samples were weighed, and the weight variation (biodegradation degree) was determined using the following equation (1):

$$\Delta M_{biol.} = \frac{\Delta M_i - \Delta M_f}{\Delta M_i} \times 100 \qquad (1)$$

Where: $\Delta M_{biol.}$ represents the variation of sample's weight (biodegradation degree), ΔM_i represents the average of sample's initial weight and ΔM_f represents the average of the sample's final weight (at the end of the incubation period).

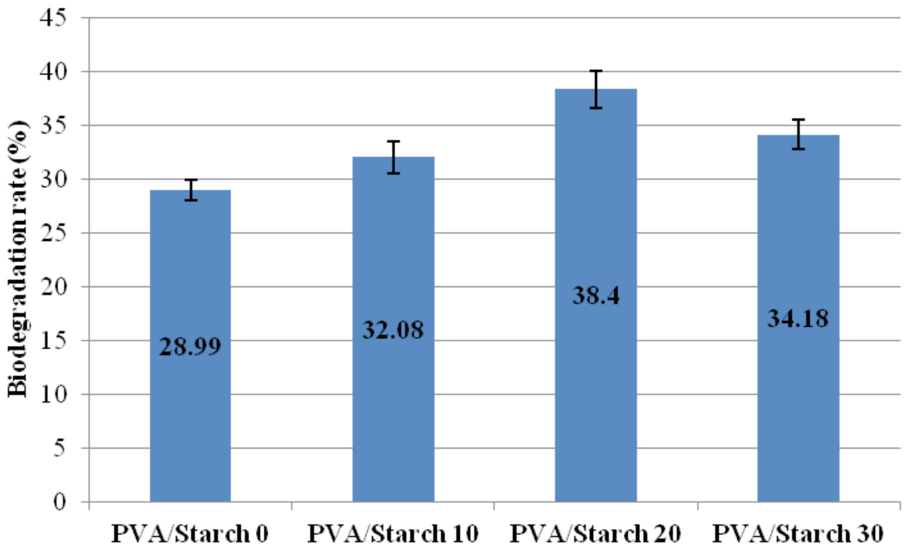

Fig. 3. Graphic representation of the weight loss values of the PVA based polymeric blends buried in soil. Vertical bars represent the standard deviation (s) of the mean values obtained for the tested samples

The statistical analysis was performed using Microsoft Office Excel 2007.

RESULTS AND DISCUSSION

At the end of the incubation period the samples were extracted from soil, washed with distilled water and stored into a desiccator until they reached a constant value of their weight. Afterwards, the weight loss was evaluated (Figure 3) and a microscopic analysis of the samples was performed.

When evaluating the weight loss of the PVA/Starch based samples, a clear evolution of their biodegradation was noticed (Fig. 3).

Therefore, after 45 days of soil burial, the tested samples had a biodegradation degree of 28.99% (s=0.033) for PVA/Starch 0, 32.08% (s=0.047) for PVA/Starch 10, 34.18% (s=0.040) for PVA/Starch 30 and 38% (s=0.045) for PVA/Starch 20. PVA/Starch 30 sample, presented a lower biodegradation degree than PVA/Starch 20, mostly due to some concomitant phenomena of water absorption / degradation.

It can also be noticed that the biodegradation degree depends on the quantity of starch from the sample. When starch content increases, the biodegradation rate also increaseas. The results are in accordance with Julinova et al. (2010), who stated that blends containing starch exhibited an increased biodegradation rate of PVA.

The obtained standard deviation values show the population values distribution around the mean values. The data obtained in our work shows that the standard deviation is close to 0, which indicates that the data points tend to be very close to the expected value (≤0.05); therefore, the obtained values are not statistically significant.

A microscopical analysis of the tested samples was carried out (Fig. 4). When the samples were analysed, little holes were noticed in the material that was exposed to the soil. These results led us to the conclusion that PVA/Starch based polymers can be easily biodegraded in soil. Similar results were also obtained by Riyajan et al. (2015), when they analysed the biodegradation process of some composites based on PVA and cassava starch.

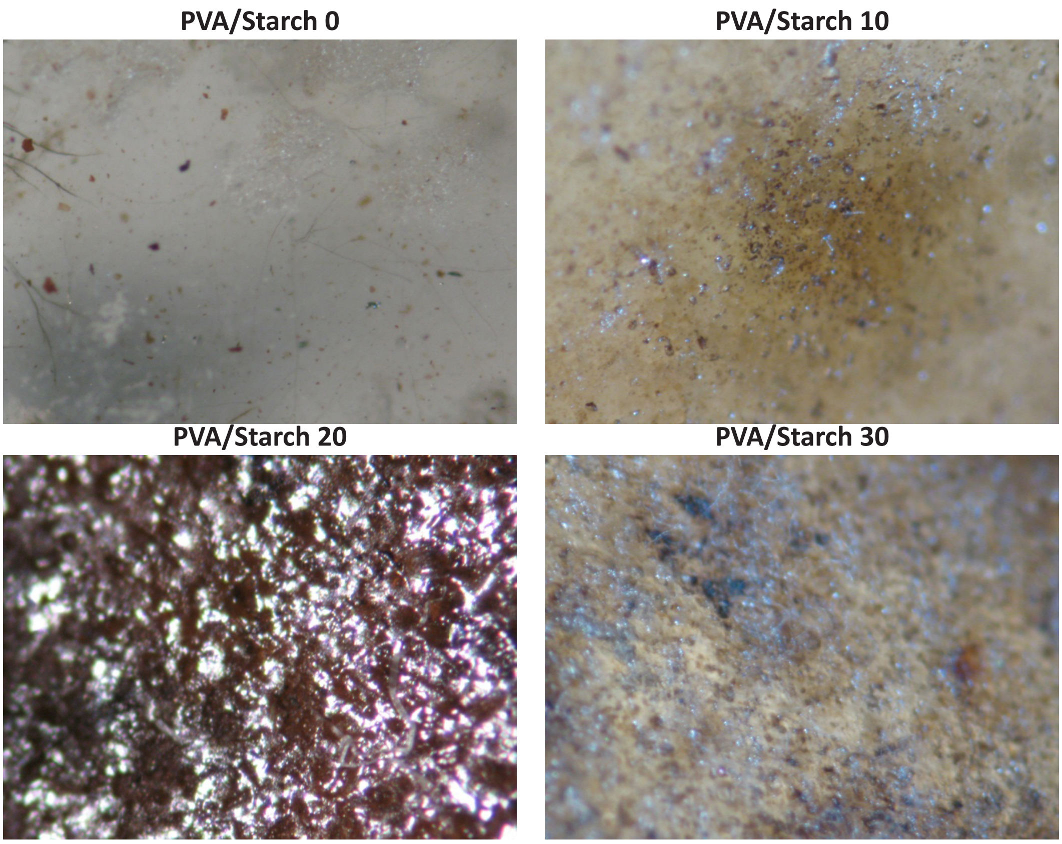

Fig. 4. The microscopic aspect of the studied polymeric materials after soil biodegradation (5x)

CONCLUSION

After the soil burial test, the studied samples were biodegraded between 28% and 37%. The biodegradation rate was noticed to increase with the increasing quantity of strach in the polymeric matrix of PVA. It is well known that soil can initiate the process of depolymerisation of many biopolymers such as starch, cellulose or hemicellulose (Sukhlaaied and Riyajan, 2014). In addition, the water in the soil contain enzymes that may cause degradation of the polymer (Riyajan et al., 2013).

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