Journal of Achievements in Materials and Manufacturing Engineering
International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Starch bioplastic film as an alternative food-packaging material

K. Jeyasubramanian *, R. Balachander

[a] Department of Mechanical Engineering, Mepco Schlenk Engineering College, Sivakasi, Tamil Nadu, India-626005

Corresponding e-mail address: kjeya@mepcoeng.ac.in

ABSTRACT

Purpose: To synthesize bioplastics on a small scale from starch available in potato and to study the characteristics of the same when pectin is blended with it.

Design/methodology/approach: The bioplastics are fabricated manually using starch extracted from potato and glycerol. Pectin was blended to this combination to synthesize another set of bioplastic films. The characterization of the obtained films were done by FTIR spectroscopy, SEM analysis, water solubility test, water absorption test and biodegradability test.

Findings: The synthesized films were found to be physically similar to the commercially available films. However on further study, it was found that the former could not provide adequate strength as compared to the latter though the former could still be used for light duty purposes. The advantage of the former over the latter was that it was found to be degradable.

Research limitations/implications: Environment-friendly manufacture of the films on a large scale is yet to be studied upon. Economic and eco-friendly methods to improve the tensile strength of the bioplastics to bring it at par with the commercial plastic films are to be found out.

Practical implications: The starch and starch-pectin blend films were found to be water soluble. However, they were also found to absorb water which could be implied as a disadvantage. The main objective of biodegradability was achieved.

Originality/value: Though researches are going on in the field of biodegradable films, the addition of pectin to starch to improve the characteristics of degradable films is an area where more research has to be done. This paper inculcates the study of adding pectin to starch and the resulting changes in the characteristics of the starch film.

Keywords: Bioplastics; Food-packaging; Films; Starch; Pectin

Reference to this paper should be given in the following way:

K. Jeyasubramanian, R. Balachander, Starch bioplastic film as an alternative food-packaging material, Journal of Achievements in Materials and Manufacturing Engineering 75/2 (2016) 78-84.

CLEANER PRODUCTION AND BIOTECHNOLOGY

1. Introduction

Plastics play a vital role in almost every aspect of our lives. They are used to manufacture everyday products such as food-packaging films, beverage containers, toys, and furniture etc. The widespread use of plastics demands suitable end of product-life management. The extensive global use of plastics has contributed immensely to environmental pollution; as plastics are not always properly discarded, reused or recycled and consequently persist within the environment for longer durations [1].

The manufacturing processes of plastic articles also create large quantities of chemical pollutants [2]. The prominence of plastic pollution is correlated with plastics being cheap and durable, which leads to high levels of plastics used by humans. The production of biodegradable alternatives with greater compatibility in the environment is necessary if the applications continue to grow.

Biodegradable plastics are best used in the making of products where biodegradability is of intrinsic value. Bioplastics are derived from renewable biomass sources such as vegetable fats and oils, starch, pectin or microbiota etc. [3]. These can be made from agricultural byproducts and also from used plastic bottles and other containers using microorganisms. Commonly used plastics, such as fossil fuel plastics (also called petro-based polymers), are derived from petroleum products. Production of these plastics tends to require more fossil fuels and produces more greenhouse gases than the production of bioplastics. Biodegradable bioplastics can break down in either anaerobic or aerobic environments compared to the petro-based polymers [4].

Bioplastics are normally composed of cellulose, starches, biopolymers, and a variety of other materials. Starch-based plastics currently represent the most widely used bioplastic, constituting about 50 percent of the total bioplastics market. They can be made at home and can be extensively used for food-packaging applications. Starch is able to absorb humidity, and is thus suitable for the production of drug capsules by the pharmaceutical sector. Plasticisers such as glycerol can also be added so that the starch can be processed thermoplastically. The characteristics of the resulting bioplastic can be tailored to specific needs by adjusting the amounts of these additives. Starch-based plastics are often blended with biodegradable polyesters which are used for industrial applications [5].

This report briefs about the fabrication of bioplastic films using potato starch and pectin as precursor with suitable additives like glycerol. The obtained bioplastic films were characterized by employing FTIR analysis, SEM analysis, water solubility test, water absorption test and biodegradability tests.

2. Materials and methods

2.1. Extraction of starch

100 g potato was taken and its skin was peeled off using peeler and the potato was grated. The potato mass was then put into a mortar and 100 ml distilled water was added. It was then grounded carefully into a paste. The mixture was then poured onto a filter to remove the water content. The solid mass left behind was then put into the mortar and 100 ml distilled water was added again and the process of grinding and straining was repeated for 3 times for obtaining more quantity of starch. The mixture was left to settle in the beaker for 5 minutes. The supernatant liquid from the beaker was decanted, leaving behind the white starch which had settled at the bottom. 100 ml distilled water was added to the starch and was stirred gently. The process was repeated for 3-4 times, and the water was then decanted. The starch obtained was white in colour. 10 g of starch was obtained from 100 g of potato and the efficiency of this manual method was 10% [6,7,9]. The photographic image of the obtained starch powder is given in Figure 1.

Fig. 1. Starch extracted

2.2. Starch film

20 ml distilled water was taken in a beaker and 1.5 g potato starch, 3 ml hydrochloric acid (0.1 M) and 0.5 ml glycerol (1%) were added. The mixture was heated on a hot plate at 100°C with continuous manual stirring for 15 minutes. 3 ml sodium hydroxide solution was then added to neutralise the mixture. It was then poured onto a plastic plate and was glided around with the glass rod so that an even covering was obtained. The mixture was left to dry out for 4 days. The cast film was later peeled off [6,10]. The photographic image of the starch film is shown in Figure 2.

Fig. 2. Starch film

2.3. Fabrication of starch film blended with pectin

1 g of pectin was added to 20 ml distilled water with stirring at 50°C. Gelatinized starch solution [13] was prepared by adding 0.6 g starch to 10 ml distilled water and this mixture was heated on the hot plate at 100°C for about three minutes. The starch solution was then cooled in a water bath for about 20 minutes and then added to the pectin solution with stirring. 1% glycerol solution was prepared and 0.5 ml glycerol was added to the mixture. The mixture was then stirred for approximately one hour before casting. The solution was then cast on a plastic plate and left to dry for 4 days [11,12]. The photographic image of the peeled off film is shown in Figure 3.

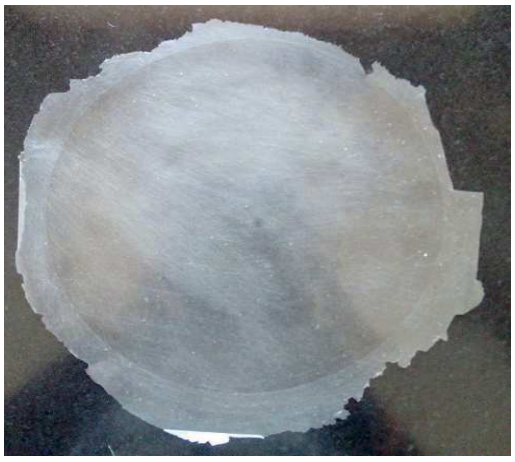

Fig. 3. Pectin starch blend film

3. Testing and analysis

3.1. Tests for starch

10 g of potassium iodide crystals were added to 100 ml distilled water and were swirled until it dissolved. 5 g iodine crystals were added to the solution and stirred until all iodine got dissolved. The solution was prevented from exposure to light to avoid the degradation of chemicals. 0.2 g of starch extracted from potato was taken in a petri dish and 5 ml distilled water was added to it. One drop of iodine solution was added on the petri dish and the occurrence of blue-black colour confirmed starch content.

When infrared radiation passes through a material, some intensity passes through without interacting with the molecules, while the remainder interacts with molecules and is absorbed. The proportion of absorbed intensity over the total intensity that enters the material is in direct relation to the concentration of absorbing molecules. This is the principle of Fourier Transform Infrared (FT-IR) Spectroscopy Analysis. Starch powder extracted was subjected to FT-IR analysis (Make - Bruker, Germany) and evaluated [8].

3.2. Water solubility test

Water solubility is defined by the content of dry matter solubilized after 24 hrs of immersion in water. The initial dry matter content of each film was determined by drying to constant weight in an oven at 105°C. Two discs of film (1 cm diameter) were cut, weighed, and immersed in 100 ml of water. After 24 hrs of immersion at 20°C with occasional agitation, the pieces of film were taken out and dried to constant weight in an oven at 105°C; to determine the weight of dry matter which was not solubilized in water. The solubility was calculated using the equation:

$$SW\ (\%) = [(Wo - W)/W]\ X100\% \quad (1)$$

where SW is solubility in water; and W_0 and W are the dry sample weights before and after the test, respectively [6,15].

3.3. Water absorption test

Film discs (1 cm diameter) were cut and dipped in 1% glycerol solution (v/v) and then taken out and dried.

The film was air dried for the removal of water from the surface for about 24 hrs and the weight of the film was measured. The percentage of water absorption was calculated using the following equation:

$$AW\ (\%) = [(W_f - W_0)/W_0]\ X100\% \quad (2)$$

where AW is absorption in water; and W_0 and W_f are the sample weights before and after the test, respectively [14,15].

3.4. Biodegradability test

Pieces of bioplastic film obtained was placed in a container having 400 g of wet soil collected near plant roots and kept at observation for 7 days in an open environment. The difference in weights before and after the test indicated the biodegradable property of the film. SEM analysis technique allows examining of changes in the morphology of materials at the micro scale. In order to perceive such monitoring and the changes in the structure of films, images from the scanning electron microscope were used (Make - Hitachi, Japan) [18]. The % of biodegradability was calculated using the equation:

$$Biodegradability\ (\%) = [(W_0 - W)/W]\ X100\% \quad (3)$$

where W_0 and W are the sample weights before and after the test, respectively [17,19].

4. Result and discussion

4.1. FTIR analysis

The FT-IR spectrum of starch was analyzed in the region 500cm^{-1} - 4000 cm^{-1} which exhibited complex vibrational modes due to the skeletal vibrations of the pyranose ring in the glucose unit. Significant changes were observed in the infrared absorption band around 1149.9 cm^{-1}, 1079.16 cm^{-1}, 994.59 cm^{-1}, consistent with changes in the glycosidic linkages in starch molecules. The peaks at 1149.97 cm^{-1}, 1079.16 cm^{-1}, 994.59 cm^{-1} were assigned as the C-O bond stretching. The bands at 1079.16 cm^{-1}, 994.59 cm^{-1} were attributed to the ordered and amorphous structures of starch, respectively [8]. All these vibrations support the fact that the starch powder extracted from potato resembled the starch powder available commercially. The FTIR spectrum of starch is represented in Figure 4.

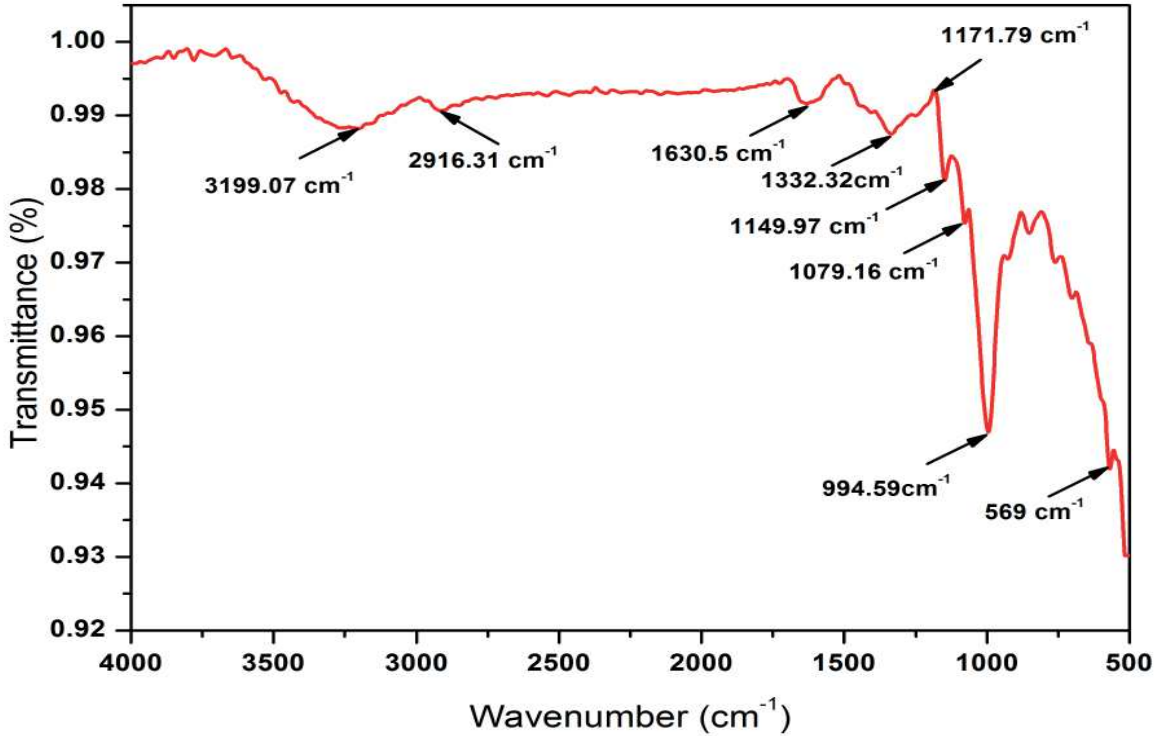

Fig. 4. FTIR Spectrum of starch

4.2. Water solubility test

The thickness of the starch film and the blend film was measured using screw gauge and was found to be 0.17 mm and 0.15 mm respectively [6]. The solubility of the films in water is an important property and may protect food with high water activity. Potential applications may require water insolubility to enhance product integrity and water resistance. In other cases, the film water solubility before product consumption may be useful in the encapsulation of food. The solubility of the potato starch film and the blend film was found to be 5.66% and 7.21% respectively. The water solubility of the potato starch films may have been attributed to the interactions between amylose, amylopectin molecules and intramolecular bonds, which influence the capacity of the film to absorb water [6,15].

4.3. Water absorption test

One of the major drawbacks about the utilization of starch-based material is its water absorption tendency and any improvement in water resistance is therefore highly important. Water uptake increased with increasing immersion time and starch content. This observation is due to the hydrophilic character of natural starch, which is responsible for the water absorption in the composites. Therefore, higher starch content led to a higher amount of water being absorbed. The gelatinized starch favoured degradation of the blends when immersed in water; this was likely due to the rupture of the grains during starch gelatinization. When water is absorbed onto the hydrophilic group, mainly through hydrogen bonding or weak electrostatic interactions, the film can be easily dissipated with water molecules. Therefore, it is relevant to relate the effect of the hydroxyl group in the water absorption mechanism. The water absorption (%) of starch and blend films was found to be 2.85% and 4.1% respectively [15,16].

4.4. Biodegradability test

SEM analysis exhibited the microbial activity of degradation on the bioplastic sample (Figs. 5 and 6). The surface structure of the material had lost its smoothness, and cracks were evident. The sample showed a significant change in the structure. SEM images confirmed the biodegradation process that happened over the bioplastic film with the presence of cracks and loss of filmy nature. After the termination of the testing process in real conditions, the bioplastic sample showed visual modifications, and broke into pieces when touched upon [18]. The biodegradability (%) of the starch film and blend film was found to be 15% and 10% respectively.

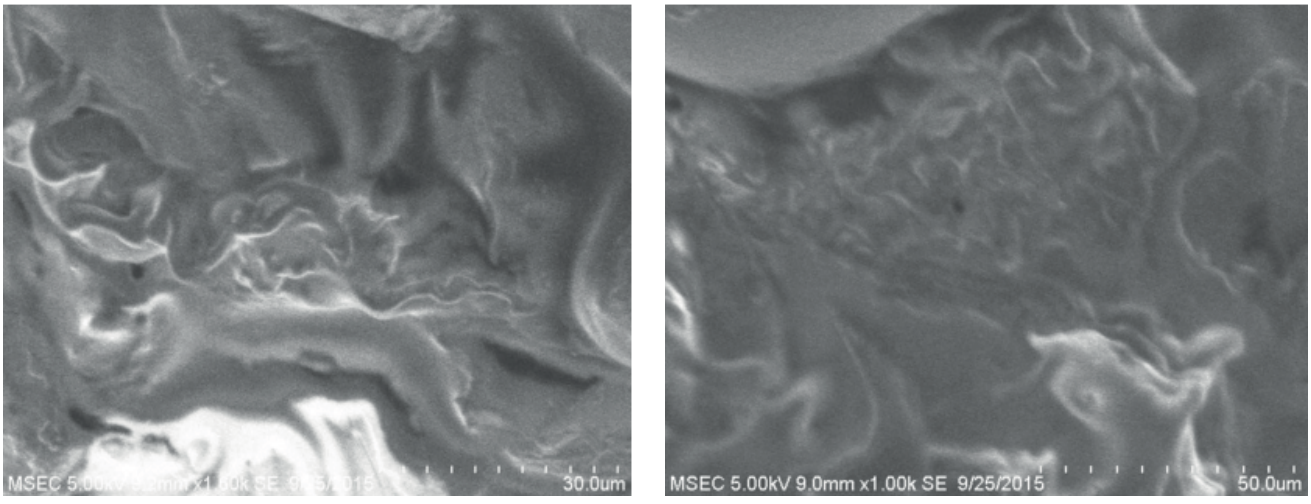

Fig. 5. SEM Images of film before biodegradation

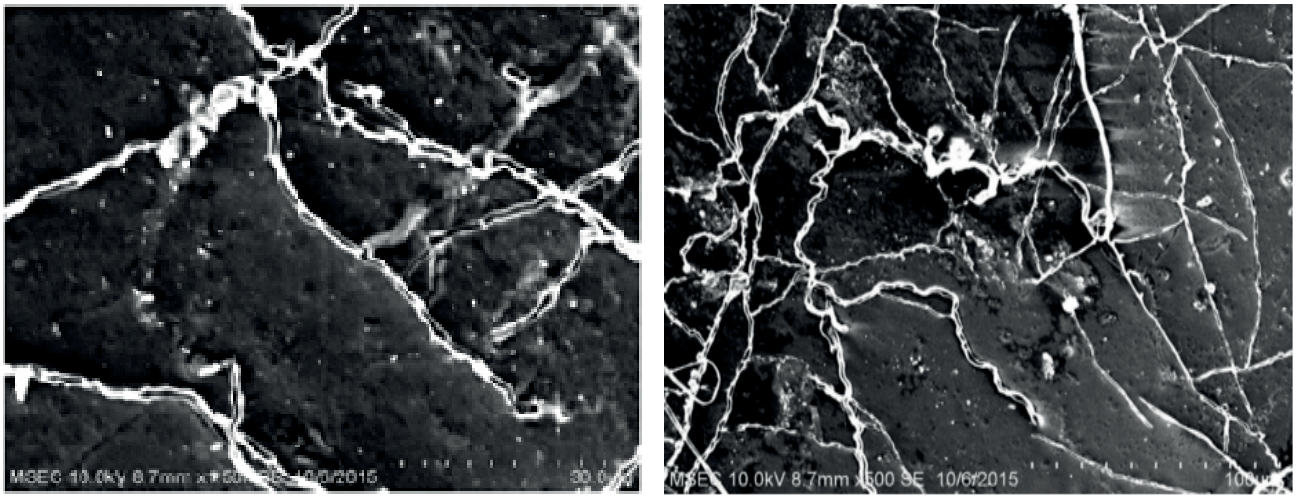

Fig. 6. SEM images of film after biodegradation

5. Conclusions

Conventional plastics possess multitude of drawbacks: the large amount of energy that is required to produce the plastic, the wastes formed as a result of plastic production, and the use of materials that do not biodegrade readily. In order to transform the production of plastics towards a more sustainable path, research is being conducted to determine the types of renewable bioplastic resources that could be converted into plastic form. It was demonstrated that by employing a simple and economic methodology, it was possible to extract representative starch quantities from potato. The optimized concentration for preparation of the bioplastic film using the various constituents were found and studied. Numerous tests were conducted to evaluate the properties of the bioplastic film prepared. It included film thickness test, wherein the thickness of the bioplastic film was measured; water solubility test which ensured that the bioplastic was soluble in water and it hinted on the possibility that even if the film was disposed on water streams after usage, it would degrade with time; biodegradability test was carried out by subjecting specimens of bioplastic to be buried in soil which resulted in weight loss of the specimen and a further image analysis of the specimen indicated the degradation process. The bioplastic so prepared could be used for food-packaging applications as they are readily degradable in soil after use and also act as an effective alternative for the already available commercial plastic food-packaging films.

Acknowledgement

The authors extend their sincere thanks to the Department of Mechanical Engineering, Mepco Schlenk Engineering College, Sivakasi for providing all sort of supports to carry out this research work successfully.

References

[1] H.K. Webb, J. Arnott, R.J. Crawford, E.P. Ivanova, Plastic Degradation and Its Environmental Implications with Special Reference to Poly (Ethylene Terephthalate), Polymers 5 (2013) 1-18.

[2] L. Adane, D. Muleta, Survey on the Usage of Plastic Bags, Their Disposal and Adverse Impacts on Environment: A Case Study in Jimma City, Southwestern Ethiopia, Journal of Toxicology and Environmental Health Sciences 3/8 (2011) 234-248.

[3] S. Kumaravel, R. Hema, R. Lakshmi, Production of Polyhydroxybutyrate (Bioplastic) and Its Biodegradation by Pseudomonas Lemoignei and Aspergillus Niger, E-Journal of Chemistry 7/S1 (2010) 536-542.

[4] J. Sarasa, J.M. Gracia, C. Javierre, Study of the Biodisintegration of a Bioplastic Material Waste, Bioresource Technology 100 (2009) 3764-3768.

[5] J. Vartiainen, M. Vähä-Nissi, A. Harlin, Biopolymer Films and Coatings in Packaging Applications-A

Review of Recent Developments, Materials Sciences and Applications 5 (2014) 708-718.
[6] E. Da Rosa Zavareze, V. Zanella Pinto, B. Klein, S.L. Mello El Halal, M. Cardoso Elias, C. Prentice-Hernández, A.R. Guerra Dias, Development of Oxidised and Heat-Moisture Treated Potato Starch Film, Food Chemistry 132 (2012) 344-350.
[7] Q. Liu, E. Weber, V. Currie, R. Yada, Physicochemical properties of starches during potato growth, Carbohydrate Polymers 51 (2003) 213-221.
[8] R.R. Ali, A.W. Wan Rahmana, R.M. Kasmanib, N. Ibrahimb, S.N.H. Mustaphaa, H. Hasbullah, Tapioca Starch Biocomposite for Disposable Packaging Ware, Chemical Engineering Transactions 32 (2013) 1711-1716.
[9] M.A. Omotoso, G.O. Ayorinde, O.A. Akinsanoye, Preparation of Biodegradable Plastic Films from Tuber and Root Starches, IOSR Journal of Applied Chemistry (IOSR-JAC) 8/4 (2015) 10-20.
[10] E. Budina, Bioplastics, United States Patent, 2013. Patent No. US 2013/0186303 A1.
[11] P.D. Hoagland, Biodegradable Laminated Films Fabricated from Pectin and Chitosan, United States Patent, 1999, Patent No. 5.919.574.
[12] P.J. Pérez Espitia, W.X. Du, R. de J. Avena-Bustillos, N. de F. Ferreira Soares, T.H. Mchugh, Edible Films from Pectin: Physical-Mechanical and Antimicrobial Properties - A Review, Food Hydrocolloids (2013) 1-10.
[13] W.S. Ratnayake, D.S. Jackson, Gelatinization and Solubility of Corn Starch during Heating in Excess Water: New Insights, Journal of Agricultural and Food Chemistry 54/10 (2006) 3712-3716.
[14] Ch.H. Tsou, M.Ch. Suen, W.H. Yao, J.T. Yeh, C.S. Wu, C.Y. Tsou, S.H. Chiu, et. al, Preparation and Characterization of Bioplastic-Based Green Renewable Composites from Tapioca with Acetyl Tributyl Citrate as a Plasticizer, Materials 7 2014 5617-5632.
[15] S. Galus, A. Turska, A. Lenart, Sorption and Wetting Properties of Pectin Edible Films, Czech Journal of Food Sciences 30 (2012) 446-455.
[16] N.A. Azahari, N. Othman, H. Ismail, Biodegradation Studies of Polyvinyl Alcohol/Corn Starch Blend Films in Solid and Solution Media, Journal of Physical Science 22/2 (2011) 15-31.
[17] N. Czaja-Jagielska, K. Melski, Biodegradation of Starch-Based Films in Conditions of Nonindustrial Composting, Polish Journal of Environmental Studies 22/4 (2013) 1039-1044.
[18] K. Leja, G. Lewandowicz, Polymer Biodegradation and Biodegradable Polymers - A Review, Polish Journal of Environmental Studies 19/2 (2010) 255-266.
[19] D. Adamcová, M. Vaverková, Biodegradation of Degradable/Biodegradable Plastic Material in Controlled Composting Environment, Polish Journal of Environmental Studies 23/5 (2014) 1465-1474.