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Production of bioplastic from potato peel waste and investigation of its biodegradability

Ezgi Bezirhan Arıkan [a,*] ***and H. Duygu Bilgen*** [a]

[a] *Faculty of Engineering, Department of Environmental Engineering, Mersin University, Mersin, 33343, Turkey*

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ABSTRACT

Recently, environmental problems caused by petroleum-based plastics have been increasing. Therefore, researchers have begun to investigate new materials that may be alternatives to plastics. Bioplastics are considered as green materials alternatives to plastics and they are produced from renewable resources such as corn and potatoes, or microorganisms under certain conditions. In addition, most researchers are concerned with renewable resources for non-food using, such as bioplastic production. For this reason, researchers have been focusing on the utilization of the wastes as bioplastic products. In this study, the bioplastic was produced from potato peel as the food industry waste. Also, some properties of the produced bioplastic such as water absorption capacity and biodegradability were analyzed. Furthermore, water absorption capacity and biodegradability of a commercial bioplastic were also determined in order for the comparison with the one produced from potato peel waste in different conditions. It was found that the produced potato peel bioplastic (PPB) had higher water absorption capacity than commercial bioplastic (CB). Therefore, PPB may not be used in the food service industry but can be used as packing material. Biodegradability tests showed that PPB biodegraded at about 71% in moist soil and 100% in vermicompost within four weeks. On the other hand, it was determined that CB was not degraded in the soil or in the compost in four weeks. Therefore, as a food industry waste, potato peel can be used in biodegradable bioplastic production. In this way, petroleum-based plastic pollution may be decreased both in Turkey and the world.

1. Introduction

Plastics are more useful than metals, papers, and other materials because of their properties such as lightness, cheapness and durability. Therefore, they have been being used in almost every industrial field. Worldwide, more than 300 million tons of plastic were consumed in 2015 [1]. The whole world, even the oceans, is full of plastic wastes. In addition, the plastic industry has some disadvantages related to economic and environmental problems [2].

The first disadvantage related to the environment is the shrinking of the landfill capacity because of the increasing of the plastic waste amount in the landfill areas [3]. Increasing of the plastic waste leads to a crisis in the landfill due to the rising costs and strong legislation. On the other hand, oceans are also full of plastic wastes. The damaging of the marine ecosystem is the second disadvantage. The third disadvantage is that the waste management options are inadequate. Recycling proportion of plastics is very low. On the other hand, toxic emissions such as carbon dioxide and methane are generated because of plastic incineration. These greenhouse gases (GHGs) affect the worldwide climate change negatively [4]. Plastic's non-degradability or durability is the fourth disadvantage. It was known that plastics are not biodegradable and it can remain in the environment for hundreds of years [5]. In addition, it is expected that fossil fuel will become more expensive and the supply will become more volatile [3].The economic problem is the increasing fossil fuel prices. These environmental/economic disadvantages and social concerns have led to the development of the green

* Corresponding author. Tel.:*+90 324 361 00 01*; Fax: *+90 324 361 00 32.*
E-mail addresses: *ezgibezirhan@gmail.com (E.B. Arıkan), hduygubilgen@gmail.com (H.D. Bilgen)*
ORCID: 0000-0003-4203-165X *(E.B. Arıkan)*, 0000-0002-9510-8131 *(H.D. Bilgen)*
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materials, such as bioplastics, in recent years [6]. Today, bioplastics are considered as a promising alternative to plastics [7] since they may diminish the dependency on fossil fuels and the certain environmental problems.

Although there are several definitions, generally, 'Bioplastics' are defined as plastics made from renewable resources such as potato, sugar, corn etc. [8, 9] and produced by a range of microorganisms [10]. Photodegradable, compostable, bio-based and biodegradable bioplastics are types of bioplastics. Photodegradable bioplastics are light sensitive group due to the additives, and UV can disintegrate their polymeric structure. However, they cannot be disintegrated where there is lack of sunlight [5]. Bio-based bioplastics are derived from renewable resources containing starch, protein, and cellulose [11]. The most known bio-based plastic is Polylactic Acid (PLA). Compostable bioplastics are defined as biologically decomposed during a composting process [9] and according to American Society for Testing and Materials (ASTM) D6400 standard, the plant should not be damaged after the composting process. Biodegradable bioplastics are completely biologically degraded by microorganisms. The term "biodegradable" refers to materials that can disintegrate or break down naturally in carbon dioxide and water as a result of being exposed to a microbial environment and humidity [5].

In many countries, bioplastic are mostly used as cutlery, diapers, packing materials etc. in many industrial areas. It is forecasted that bioplastic production will be 7.8 million tons in 2019 in the world [12]. Therefore, it is thought that the future of bioplastics shows great potential. Nevertheless, the cost of the bioplastic produced from microbial resources is still higher [13, 14] than produced from renewable resources. For this reason, most of bioplastic manufacturers have focused on the production via renewable resources.

Among the renewable resources, starch is a potentially useful material for bioplastics because it is inexpensive and easily available [13, 15, 16]. Starch has been used in many industrial areas such as paper, corrugated boards biofuels [17], pharmaceutical, textile [18] and especially food industry. On the other hand, many companies have already begun to use the starch for the production of bioplastic. In spite of its abundance, low cost and natural origin, there is still a major concern about the use of this type of renewable resources for production. Furthermore, many researchers advocates that when there is hunger in the world, renewable sources such as starch should not be used in non-food areas. Also, the bioplastic industry can decrease the land that is available for food production or in order to create more arable land, it can increase the incentives to cut down the forested areas [19]. Recently, in order to ensure the potential competition with agricultural resources for foods and also to provide additional raw-material sources, utilization of wastes is the current trend [20].

In this study, the overall purpose was to investigate the utilization of the food industry wastes in order for the bioplastic production. To achieve this objective, the production of bioplastics from potato peel waste was investigated. In addition, some properties of the produced bioplastics such as water absorption capacity and biodegradability were analyzed.

2. Materials and Methods

The glycerin used in the experiments was obtained from a firm located in Konya, Turkey. Starch-based bioplastic spoon were purchased from www.amazon.com as market, cleaned up after using and divided into small pieces at about equal size for further use. This purchased bioplastic is called as commercial bioplastic (CB) in this study.

2.1 Bioplastic production

Potatoes were cleaned up and peeled for further studies. Potato peels were granulated and centrifuged at 15000 rpm for 20 min. The supernatant was filtered and the starch was obtained. 13.5 g dried starch was extracted from 330 g wet potato peels. After filtration, starch was dried at 50 °C for 2 h and kept in a zip-locked airtight environment until the processing [21]. After the starch was obtained, 13.5 g of starch was weighed and 135 mL of tap water, 16.2 mL of vinegar, and 10.8 mL of glycerin was added to the starch. This mixture was heated on a hot plate till to 100 °C and kept waiting at that temperature for 20 min. The mixture was led to air dry for about 48 h and the bioplastic was produced in a sheet form (Figure 1).

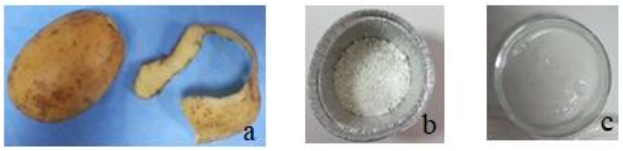

Figure 1. (a) Potato peel; (b) potato starch; (c) bioplastic

This produced bioplastic from potato peel waste is called as PPB at the rest of study.

2.2 Measurements of water absorption

Water absorption of two type of bioplastic (PPB and CB) was measured according to ASTM D570-81. Bioplastics having the same surface-area and weigh were dried in an oven at 50 °C for 24 h and cooled in a desiccator before weighing. Bioplastics were submerged in distilled water at 25 °C. After 2 h, the bioplastics were removed, their surface water dried with a paper towel, they were immediately weighed, and re-submerged into

the water. They were weighed again after another 24 h following the same procedure. Water absorption was calculated as a percentage of initial weight [22, 23]. For the determining of water-soluble content of the samples during soaking, PPB and CB samples were dried at 50 °C for 24 h. At the end of 24 h, samples were weighed again and weight loss of the samples was calculated. The sum of the weight gain following soaking plus the weight loss after drying is defined as the total absorbed water [23]. All water absorption measurements were performed in three replications.

2.3 Biodegradability analysis

The biodegradability of PPB and CB samples were investigated in different controlled environments [24, 25]. After weighing, two different PPB and CB samples also were buried under 50 g of moist soil and 50 g of vermicompost [26] in petri dishes, respectively. Bioplastic samples, whose initial masses were known, were weighed after burying weekly. All experiments were performed in three replications.

According to European Committee for Standardization (CEN), biodegradation is a degradation caused by biological activity, especially by enzymatic action, leading to a significant change in the chemical structure of a material. Also, the weight loss measurement is a standard method for biodegradation of polymer [27]. Amount of biodegradation was calculated by the following Equation 1 [28].

$$WL(\%) = \frac{(Wo - W)}{Wo} x100 \quad (1)$$

W_0 and W are the initial and final weight of bioplastic samples, respectively. Also WL refers to the Weight Loss.

3. Results and Discussion

3.1 Results of the Water absorption measurements

The results of the water absorption experiments showed that PPB absorbed water by 48.46% within two hours and 83.57% within 24 hours. It was also observed that CB absorbed water by 2.04% within two hours and 7.48% within 24 hours (Figure 2).

It was found that CB had higher water resistance than PPB. It is thought that some additives might have been added to commercial bioplastic for increasing water resistance. Because of higher water absorption, PPB may not use in the food services industry but can be used as packing materials. However, mechanical property, tensile strength, hydrostatic pressure, elastic property, and strength property should be identified in order to determine the industrial usage areas.

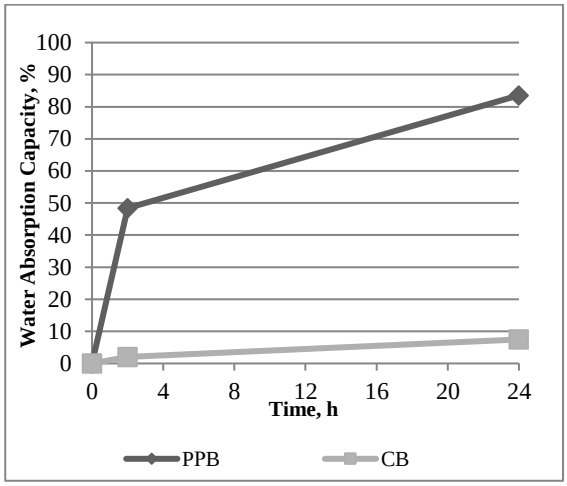

Figure 2. Water absorption capacity of PPB and CB

3.2 Biodegradability analysis results

Biodegradability tests showed that within four weeks, the PPB biodegraded at about 71% in moist soil and 100% in vermicompost (Figure 3). On the other hand, any degradation for CB was not observed in the soil or in the compost within four weeks.

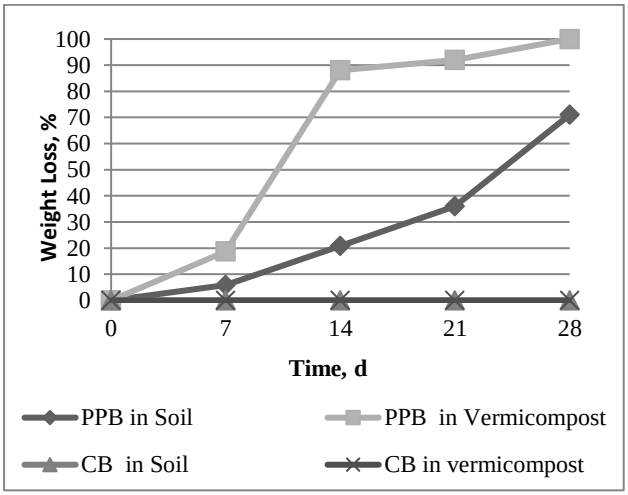

Figure 3. Weight loss of PPB and CB

Biodegradability is strongly dependent on the starch proportion [29]. It is known that PPB consist of 8% starch. But, the starch content of commercial bioplastic is unknown. Therefore it is thought that some additives may have been added to commercial bioplastic for improving mechanical properties such as durability, flexibility and etc. For example, additives used for enhancing antimicrobial properties may reduce or eliminate the biological degradability of bioplastics. Because of this, the structure of commercial bioplastic may have changed and this change may have also affected biological degradability. Furthermore, due to the natural conditions are not controlled, commercial bioplastics can biodegrade within a long time or cannot biodegrade.

4. Conclusions

Since many countries around the world are struggling with food shortages, producing bioplastics from wastes instead of foods is the best way to go. This study concluded that food wastes could be used for bioplastic production. In this study, it was determined that the bioplastics produced from potato peels completely biodegraded within 28 days, and it was suggested that these bioplastics can be used in packaging industry. The development of mechanical properties should be investigated for the utilization of it in different industrial areas. On the other hand, it was observed that the commercial bioplastic did not biodegrade in 28 days. Bioplastics usage has increased in recent years both in the world and Turkey. Therefore, for the sustainability of those called as 'biodegradable', the standards should be developed. In conclusion, a new guide for bioplastics should be developed for production, usage and waste management in Turkey as soon as possible.

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