Keratin Protein Based Bioplastic Mixed With Microcrystalin Cellulose

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ABSTRACT

In this study , keratin protein (KP) consisting of cystine amino acids was obtained by precipitation of human hair in an alkaline environment. The obtained protein was mixed with microcrystalline cellulose (filler) (MS), plasticizer at appropriate proportions and temperature until it reached gel consistency. According to the results obtained, it is seen that the highest degradation is achieved in sea water, whereas KP-based bioplastics do not have a very long-term resistance to dissolution in soil and sea water under normal conditions, dissolve in a short time and do not cause pollution in the environment. Therefore, KP bioplastics can be used in industrial applications such as the food, packaging, and agriculture industry.

Key Words : *MS, KP , bioplastic, biodegradation, alkaline environment*

1 Introduction

More than 300 million tons of petroleum-based or gas-based polymers are produced annually worldwide, and mostly in almost all areas of daily life (agricultural, packaging, construction, transportation, electrical and electronic equipment, etc.) and the processing industry (chemical, food, aerospace, pharmaceuticals, etc.) are used in the production of non-biodegradable plastics for a wide variety of applications [1]. For environmental pollution caused by the wide application of petroleum-based plastics, the production of biodegradable materials based on naturally occurring resources including proteins, polysaccharides, lignin, etc. has become a new research topic in materials science and engineering. [2-4] Bio-based plastics represent a broad spectrum of materials that can be synthesized by living organisms (i.e. naturally produced bio-based polymers such as proteins or polysaccharides) or that can be derived from renewable sources in their monomer forms that require chemical change to convert to a polymer (e.g. PLA from lactic acid). Among these, protein is the most promising bio-based sources for bioplastics, as protein-based materials tend to form three-dimensional macromolecular networks stabilized and reinforced by hydrogen bonds, hydrophobic interactions, and disulfide bonds [5]. Among them, the keratin protein has a large structure that provides an outer covering in the form of hairs, wool, feather horns and nails in most mammals, birds, and reptiles. Biodegradation is an organic, biodegradable polymer resulting from the cross-linking of long, strong covalent bonds in its structure [6]. Typically, the production of protein-based bioplastics involves chemical, thermal or pressure-induced protein denaturation as a first step. Due to the diversity and unique structures in the assembly of protein networks, a wide variety of biodegradable materials can be produced and various functional properties can be given [7]. However, protein hydrolysates are prepared to increase their solubility, nutritional supplementation, and their use for functional enhancement [8]. One of the most interesting potential uses of these products is the production of bioplastics that solve the problem of environmental pollution. However, a variety of different protein concentrates have been used to produce bioplastics [9-11]. It has also been suggested to use mixtures of these proteins with synthetic additives to achieve good mechanical properties for biodegradable plastics (for example, for the production of food packaging) [12-15]. Before heat treatment during the production of a bioplastic, it is necessary to obtain a pulp, which is a mixture of protein concentrate and plasticizer [16]. The role of the plasticizer is to reduce the glass transition temperature (Tg) and provide mobility to polymeric chains, reducing electrostatic and hydrophobic interactions [17] and therefore a polar and low molecular weight plasticizer such as glycerol (GL) is used.

In the present study, keratin protein (KP), which is composed of cysteine amino acids, was obtained by precipitation of human hair in an alkaline environment. The obtained protein was mixed with microcrystalline cellulose (filler) (MS), plasticizer at appropriate proportions and temperature until it reached gel consistency. Then, the viscous mixture was poured into molds and freezing was achieved. The biodegradable plastic formulation may contain a lubricant to easily remove the bioplastic from the mold. Protein and plasticizer ratios are pre-optimized for the production of keratin-based bioplastics. Biodegradability of the obtained bioplastics was tested in soil and sea water. In addition, the water absorption percentage of the bioplastic was also determined.

2 Materials and Methods

Natural human hair that has not undergone any chemical treatment such as dyeing and conditioning was provided from the hairdresser. Analytical grade sodium hydroxide, glycerin, microcrystalline cellulose, hydrochloric acid and nano titanium dioxide (N-TiO2) were purchased from Sigma Aldrich (St. Louis, USA). Natural habitat soil and sea water were used for biodegradability testing of KP-based bioplastics.

After cleaning 50 g of human hair with ethanol and distilled water, the cleaned, dried and mixed hair was incubated in 1 L sodium hydroxide (1 N) solution at 50 ° C for five hours with continuous stirring, After that, the solution was washed with distilled water and filter paper. filtered with. The resulting keratin protein was then allowed to dry at room temperature for bioplastic synthesis. (Fig.1).

(a)

(b)

Fig. 1: KP solution obtained (a) and infiltration (b).

PVA powder (15 g) was dissolved in 100 ml of water and stirred at 80 ° C for one hour. First, KP was mixed with 10% glycerol, cellulose (2%) and 30% PVA solution at 60 ° C. The mixture was then poured into silicone molds and oven dried at 50 ° C for 24 hours. Later, biodegradation time in soil and sea water, solubility in different solutions and water absorption were saved (Fig. 2).

Fig. 2: Production and molding of KP based bioplastics

The same amounts of mixture (3 g) were placed 15 cm below the bioplastic soil level in four locations for the degradation analysis of the synthesized bioplastics in the open air surrounding soil. After 15 days the mass loss change of the bioplastics was measured. Likewise, equal amounts (3 g) of bioplastics were added to four beakers containing 50 ml of sea water and kept for 15, 30, 45 days. The extracted bioplastics were freed in the oven (50 ° C), and the mass loss was calculated according to equation (1) by measuring the initial (Kb) and subsequent masses (Ks) of each. The degradation time of bioplastics for sea water and soil was tried to be determined by plotting the weight loss versus time .

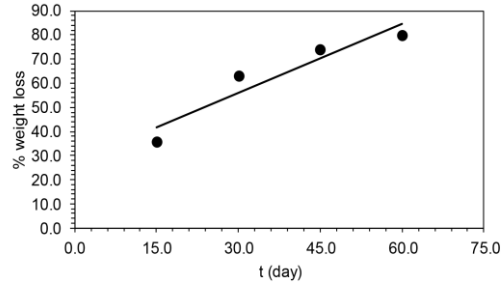
$$\text{Weight loss} = Kb\text{-}Ks / Kb \quad (1)$$

3 Results and Discussion

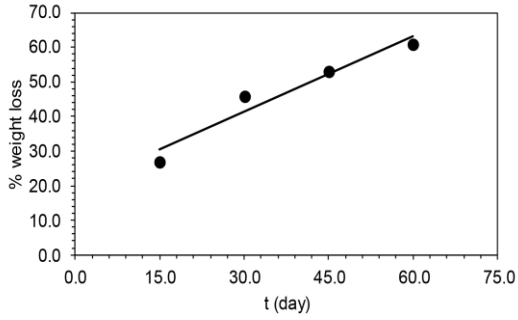
Biodegradable plastics was prepared by taking glycerin, microcrystalline cellulose and KP, NaOH, HCl in appropriate proportions . Biodegradability, solubility in different solutions and water absorption of the obtained bioplastics under room conditions (soil, sea water) were tested.

3.1 Biodegradability Tests

The percentage of weight loss of the obtained bioplastics in room conditions (soil and sea water) versus time is shown in Figures (3 a and b) , respectively. By comparison between these two figures, it is seen that the biodegradation of bioplastics is higher in sea water (78%) than in soil (59%). This situation is related to the increasing or decreasing in the degradation of the bioplastic as a result of the change of seawater flora (temperature, humidity and microorganisms etc) versus time.



(a)



(b)

Fig. 3: Weight loss vs. time of the degradation of KP-based bioplastics in soil (a) and seawater (b), respectively, under room conditions

3.2 Solubility Test

The solubilities of the KP-based bioplastic in different solutions, concentrated acid (a), concentrated base (b) and pure ethanol (c), are shown in Figure (4).

(a) (b) (c)

Fig. 4: Dissolution of KP-based bioplastics in different solutions

It is seen that bioplastics dissolve rapidly in the acid solution, where they form different colors while dissolving in solutions. Therefore, it is thought that KP-based bioplastic may be used in the packaging industry.

4 Conclusion and Suggestions

KP based bioplastics were obtained using analytical grade dilute HCl, NaOH, glycerine, microcrystalline cellulose and N-TiO2. The decomposition of the obtained plastics to their biological parts was found to be 59% and 78%, respectively, in soil and sea water. According to the results obtained, it is seen that the highest degradation is achieved in sea water, whereas KP-based bioplastics do not

have a very long-term resistance to dissolution in soil and sea water under normal conditions, dissolve in a short time without pollution in the environment. Therefore, KP bioplastics can be used in industrial applications such as the food, packaging, and agriculture industry.

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