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Biodegradation of Low Density Polyethylene in Aqueous Media

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Abstract

Low Density Polyethylene (LDPE) is the most common packaging material used for packaging a wide range of products. The efficient disposal of these plastic materials is a herculean task as they are not easily degradable and pose detrimental effects on the environment. An efficient approach is to degrade them into simpler compounds that can be disposed safely. Out of the various degradation techniques, biodegradation is vastly used as it is more economical method. Biodegradation may either be carried out in a specific aqueous medium so designed for the most efficient degradation. The present work is on the study of biodegradation of LDPE in aqueous media. For biodegradation studies various combinations of LDPE and starch i.e., LDPE, LDPE+10% starch, LDPE+20% starch, LDPE+30% starch, LDPE+40% starch, and LDPE+50% starch samples of size 15 mm x 15 mm were used and were exposed to minimal medium in a shake flask maintained at a pH of 7.5. The inoculums of bacterial consortium were added to each flask and a control was also maintained for each set of samples. In the liquid cultures the degradation followed the same pattern i.e., the degradation increased with increase in starch content. The degradation observed on day 150was 1.53 %, 1.67 %, 1.50 %, 5.06 %, 40.65 % and 54.33 % for pure LDPE, 10 %, 20 % 30 %, 40 % and 50 % starch blended plastics respectively. For the blended starch plastics at each level the degradation increased with time. At the lowest levels the degradation was almost uniform in the early stages but at higher starch content LDPE the degradation increased with time.

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Keywords:Biodegradation, Plastics, Poltethelene, Bacterial Consortium, LDPE, Starch;

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1. Introduction

Approximately 35% of plastics produced in the developed countries are consumed for packaging. Today the plastic consumption for food packaging in India itself is about 308,000 tones, which forms 8-10% of all types of packaging materials used in food packaging. LDPE is more popularly used for packaging as it possesses most of the characteristics of an ideal packaging material. It is, majorly, used to package foods, milk, agricultural products, shrink-wrapping, electronic goods, vehicles, and so on. An alternate arrangement that was suggested over the use of LDPE was the use of biodegradable plastics. Biodegradable plastics are plastics that will decompose in the natural environment. Biodegradation of plastics can be achieved by enabling microorganisms in the environment to metabolize the molecular structure of plastic films to produce an inert humus-like material that is less harmful to the environment. However, biodegradable plastics can't be viably used as packaging materials as they are not always degradable under normal conditions. Furthermore, degradable plastics are not consistent with plastics recycling, a viable approach to help solve the municipal solid waste problem.

LDPE is more susceptible to the attack of microorganisms in determined conditions. One of the viable alternatives to accelerate the biodegradation by microorganisms to LDPE is the addition of natural polymers, like starch, to guarantee at least a partial biodegradation.

In these systems containing starch, the mechanical and rheological behaviour, and also the susceptibility to degradation, will depend on various factors. Degradation can be defined as a change in the chemical structure of a plastic involving a deleterious change in properties. The material is degraded under environmental conditions (e.g., microorganisms, temperature, light, water) and in a reasonable period of time in one or more steps (Calmon-Decriaud et al. 1998). Under thermal degradation elevated temperatures can significantly increase the rate of various chemical reactions, such as oxidation, and therefore lead in an indirect way to degradation of the polymer (Dilara and Briassoulis 2000, Albertsson et al. 1992). In Photo-degradation method the UV radiation (290 and 400 nm), can be absorbed by the plastic and lead to bond cleavage and de-polymerization, causing photo-degradation (Dilara and Briassoulis 2000). The second major contributor to the photo-degradation of plastics is ketone photolysis which proceeds via two major reactions called Norrish I and Norrish II (Klemchuk 1990). Mechanical degradation of materials is a large field comprising fracture phenomenon, as well as chemical changes imposed by mechanical stress (Dilara and Briassoulis 2000). Natural macromolecules, e.g. protein, cellulose, and starch are generally degraded in biological systems by hydrolysis followed by oxidation. Most of the reported synthetic biodegradable polymers contain hydrolysable linkages along the polymer chain (Chandra and Rustgi 1998). Low molecular weight hydrocarbons can be degraded by microbes (Nakamura et al. 2005). They are taken in by microbial cells, 'activated' by attachment to coenzyme-A, and converted to cellular metabolites within the microbial cell. However, these processes do not function well in an extracellular environment and the plastic molecules are too large to enter the cell. This problem does not arise with natural molecules, such as starch and cellulose, because conversions to low molecular weight components by enzyme reactions occur outside the microbial cell (Chandra and Rustgi 1998, Pometto et al. 1993, Saroja et al. 2000).The objective of this work is to study the feasibility of biodegradation of LDPE in aqueous media and in particular to study the changes in properties during degradation & also to observe the separation of components using high performance liquid chromatography (HPLC).

2. Materials and Methodology

Six different types of packaging material grade plastics varying in starch content (LDPE, LDPE+10% starch, LDPE+20% starch, LDPE+30% starch, LDPE+40% starch, LDPE+50% starch) were used in the present study. A commercially used biodegradable plastic was also subjected to biodegradation. The inoculums for degradation studies used include the individual isolates of the consortium (Pseudomonas Putida, Pseudomonas Fluorescens, Pseudomonas Dominate, Burkhplderia, Flavobacterium species, Vibrio Alginolytious, Pseudomonas Aeruginosa, Pseudomonas Stutzeri, Anabena species and Pseudomonas Flurescans) and grown in nutrient broth for 72 hours and the cells were then harvested by centrifugation. The bacterial cells were then induced in aqueous media.

The above said six different packaging material grade plastics used for the study were of size 15 mm x 15 mm in duplicates and were exposed to minimal (M4) medium in a shake flask containing potassium dihydrogen