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Studies on Biodegradation of Plastic Packaging Materials in Soil Bioreactor

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ABSTRACT

The development of either degradable plastic or suitable microorganisms to degrade plastics would be the best strategies for plastic waste problem. In this study, six different types of packaging plastics varying in starch (low-density polyethylene [LDPE], 10%, 20% 30%, 40%, and 50% of LDPE starch) were studied for biodegradability of soil amended with microbial consortium in compost reactor. A laboratory scale bioreactor was used to study the biodegradability of two best degraded samples in soil and compost. In compost bioreactor, the weight loss in 50% starch-blended LDPE was 10.06% and was 0.0343% for pure LDPE on day 65. Finally, the study was done to know the biodegradability of commercial plastics in soil, and it was found that microbial consortium can degrade LDPE. The study results showed that the degradation in terms of weight loss was 19.8% on day 100. The loss in tensile strength was 81.24% on day 97, respectively. The percentage elongation also decreased by 13.70% and 68.27% on day 71 and 100, respectively. The total organic carbon was 30.63 mg on day 100. The phosphates and nitrates showed a decrease by 92.04% and 96.16%, respectively.

Key words: *Polyethylene, Biodegradation, Microbial consortium, Microorganisms, Starch, Plastics.*

1. INTRODUCTION

The development of science and technology adds to traditional disciplines a new knowledge and its application for practical purposes of increasing importance. A packaging technology is such discipline, its modernization, initiated by increasing demands on package quality and by economic aspects, was undoubtedly made possible by the development of macromolecular chemistry and the technology of the production and processing of the plastics [1-4].

The biodegradation for materials exposed to natural environment means fragmentation, loss of mechanical property, or chemical modifications through the action of microorganisms.

The biodegradation for materials exposed to natural environment means fragmentation, mechanical property or chemical modifications through the action of microorganisms. Biodegradation is natural process by which organic chemicals in the environment are converted to simpler compounds, mineralized and redistributed through elemental cycles such as the carbon, nitrogen, and sulfur cycles.

Low-density polyethylene (LDPE) is one such material manufactured by adding polymerization of ethylene gas under a high pressure of 1000-3000 atm and is fairly soft, slightly translucent, and flexible material with waxy feel. The density of LDPE varies between 0.91 and 0.925 g/cc. It is a good barrier to water and water vapor but a poor barrier to gases. It has an excellent chemical resistance particularly to acids, alkalies, and inorganic solutions. However, it is sensitive to hydrocarbons, halogenated hydrocarbons, oil, and grease. It is an omnipresent polymer having found numerous applications although both low- and high-density polyethylene have been used in packaging agricultural applications. It is clearly stated that polyethylene is an inert polymer with good resistance to microorganisms (Albertson *et al*., 1987). With more and more plastics employed in human life and increasing pressure being placed on capacities available for plastic waste disposal, the need for biodegradable plastics and biodegradation of plastic waste has assumed increasing importance in the past few years. Additives such as pro-oxidants and starch are applied in synthetic materials to modify and make plastic biodegradable. Thermoset plastics such as aliphatic polyester and polyester polyurethane are

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easily attacked by microorganisms because of the potential hydrolytic cleavage of esters or urethane bonds in their structure. Some microorganisms have been isolated to utilize polyurethane as a sole source of carbon and nitrogen. Aliphatic-aromatic copolyester has active commercial applications because of their good mechanical properties and biodegradability.

The biological surroundings in which polymers are present include the biological agents responsible for the deterioration of polymeric substances. Biological agents such as bacteria, fungi, and their enzymes consume a substance as a food source so that its original form disappears. Under appropriate conditions of moisture, temperature, and oxygen availability, biodegradation is relatively rapid process. Two types of microorganisms are of particular interest in the biodegradation of natural and synthetic polymer, i.e., fungi and bacteria (Rustgi *et al*., 1998).

Composting is a natural process by which organic material is decomposed into humus, a soil-like material. The major groups of mesophilic and thermophilic microorganisms involved in composting are bacteria, fungi, and actinomycetes. These organisms decompose the organic matter as their food source. This process requires carbon, nitrogen, water, oxygen, and heat. Organisms that decompose organic matter use carbon as a source of energy and nitrogen for building cell structure. The presence of water is a necessity for biodegradation (Alberts *et al*., 1992).

Compostability of compostable plastic is a plastic that undergoes biodegradation by biological process during composting to yield CO_2, water, inorganic compounds, and biomass at a rate consistent with other known compostable materials and leave no toxic residue. Degradation of polymers in a compost environment occurs mainly through mechanical, thermal, and chemical degradation (Table 1). Off all the degradation mechanisms, chemical degradation is the most important for biodegradable polymers (Kale *et al*., 2006).

Bioplastics can take different lengths of times to totally compost based on the material, where higher composting temperatures can be reached and are between 90 and 180 days. According to Bellia *et al*. (1999), the environmental conditions for composting include high temperature (58°C) aerobic conditions and proper water content about 50%. They have provided the scheme describing the aerobic biodegradation of polymers as:

Polymer + oxygen + biomass + nutrients (N, P, etc.,) $\xrightarrow{\text{degradation}}$ CO_2 + H_2O + biomass + low molecular weight substances + polymer residues

2. MATERIALS AND METHODOLOGY

Six different types of packing material grade plastics varying in starch content (10%, 20% 30%, 40%, and 50% of LDPE starch) of size 15 mm × 15 mm were exposed individually to sieved soil (200 g) in triplicates by completely immersing the sample inside the soil and were inoculated by bacterial consortium, one control specimen for each sample was also maintained. The inoculum for degradation was developed in the Central Food Research Laboratory by growing the individual isolates of the consortium (*Pseudomonas putida*, *Pseudomonas fluorescens*, *Pseudomonas* dominate, *Burkholderia*, *Flavobacterium* species, *Vibrio alginolyticus*, *Pseudomonas aeruginosa*, *Pseudomonas stutzeri*, *Anabaena* species, and *P. fluorescents*) in nutrient broth for 72 h, and the cells were then harvested by centrifugation. The compost used for degradation was obtained from composting plant treating the organic fraction of municipal solid waste mixed with vermin compost from Agricultural Department, Government of Karnataka, Mysuru. The soil used for plastic degradation was obtained from Garden of Jayachamarajendra College of Engineering campus, Mysuru, India. The soil samples for the study were taken 1 m below the soil surface and were sieved in 0.4 mm sieve.

Moisture content of the soil was maintained daily by adding distilled water at 40-45% by weight, and yeast was added every alternate day for duration of 150 days. The samples were removed periodically, and percentage weight loss was analyzed. Other parameters such as pH, colony-forming unit, total organic carbon, nitrates, and phosphates were also determined in soil.

3. RESULTS

Plastics studied in these experiments were blended plastics with starch varying from 10% to 50%. One control plastic without blending with starch was also used. Table 2 shows the initial properties of plastic used in this study.

Figure 1 shows the comparison of weight loss in six plastic samples varying in starch content. The degradation of starch-blended plastic showed an increase in weight loss with increase in incubation time. In all the plastics, the increase in weight loss increased with time and reached maximum on day 150. In LDPE without starch, the weight loss was only 1.28% on day 150. While the increase in weight loss was 1.77, 3.40, and 33.36, 42.94 times, respectively, for LDPE's containing 20%, 30%, 40%, and 50% starch.

Figure 2 shows the biodegradation of plastics in soil with compost material. The amount of carbon dioxide released from LDPE blended with 40% starch was 29.96 mg on day 75. This indicated slow degradation

Table 1: Results of bioreactor containing soil.

Days	Weight loss	Tensile strength	Percentage elongation
LDPE			
0	0	17.14	456.25
75	0.341	15	330
LDPE – 50% starch			
0	0	8.295	62.5
75	39.21	0.007554	25
LDPE – 40% starch			
0	0	12.9	96.875
75	29.31	0.69	34.375
Commercial plastics			
0	0	10	246.875
65	19.60	2.876	78.125

LDPE: Low-density polyethylene

Table 2: Initial mechanical properties of plastics.

Type of plastics	Percentage elongation	Tensile strength (Mpa)
LDPE	456.25	17.14
LDPE+10% starch	278.13	15.94
LDPE+20% starch	259.38	14.4
LDPE+30% starch	115.63	13.4
LDPE+40% starch	96.87	12.9
LDPE+50% starch	62.50	8.29

LDPE: Low-density polyethylene

of plastic material in bioreactor. In 50% starch-blended plastics, 55.38 mg CO_2 was released by day 75. There was no decrease of CO_2 release during incubation. This study showed that increase in starch content also increased the CO_2 content. In pure LDPE, 7.01 mg of CO_2 was released by day 65, which was very less. In commercial plastics, 71.36 mg CO_2 was released by day 65.

4. CONCLUSIONS

Due to the ever increasing use of plastic films, now a day's biodegradability has become a useful characteristic for plastics. The purpose of this study was to evaluate the biodegradation of different packaging plastics in soil media containing microbial consortium to enhance biodegradation. The degradation in soil increased with increase in starch content in LDPE. The best results were obtained in sample containing starch more than 30%. The degradation of LDPE/starch-blended plastic in soil inoculated with bacterial consortium was compared to that of obtained in inherent microorganisms of compost. The degradation in soil was better compared to that of compost. In the soil bioreactor, CO_2 release was very less in water flask bioreactor; the amount of CO_2 release was more compare to that of soil and compost due to lack of air supply. In the compost, the inherent microorganisms were capable of degrading these plastics but were less compared to that in soil. The degradation was high in 40% and 0% starch-blended plastics compared to 10%, 20%, and 30%.

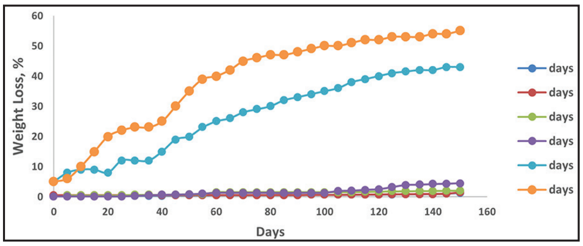

Figure 1: Weight loss in different plastics during biodegradation in soil.

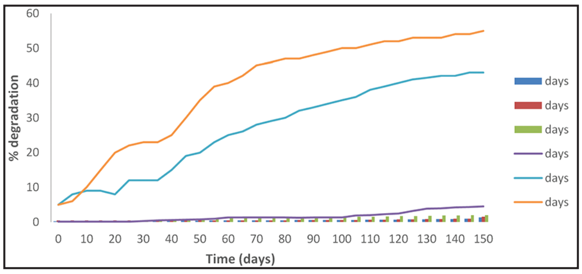

Figure 2: Plastics biodegradation in soil.

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