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ECOFRIENDLY BIODEGRADATION OF LOW DENSITY POLYETHYLENE

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Abstract

The environmental impact and seasonal variation of polyethylene generation and disposals are making ecological threat and this unavoidable one. Biodegradation of polyethylene in the natural environments is the slow process; the alternative ideas can make the polyethylene as degradable by microbial consortia. The aim of this study was biodegradation of LDPE (Low Density Polyethylene) using various carrier materials for the enhancement of the biodegradability. The microorganisms of biodegradable LDPE were already ascertained and these microorganisms with carrier materials of Farm yard manure, Lignite and coal of combined mixture prepared and LDPE were treated. The maximum weight loss observed in Farm yard manure + Actinomycetes consortia combined mixture treated LDPE 39.14 % followed by other carrier based combined mixture treatments of Bagasse + Bacterial consortia treated LDPE and Lignite + Bacterial consortia treated LDPE. The chemical structural reductions were investigated. These results agreed as the farm yard manure with the Actinomycetes have great degradable carrier for LDPE degradation.

Key words: Biodegradation, Polyethylene, Bagasse and Bacterial consortium.

1. Introduction

Polyethylene is a synthetic polymer from a hydrocarbon source and is a primary building block of polyethylene resin. It is made up of a large number of small molecular units that are engineered, manipulated and then processed for the purpose of bonding together into long polymer chains (Szabo, 2005). Majority of the domestic needs of materials packaged by low density polyethylene for the safety thus disposals accumulates in soil and water posing major problems in our environment. Burning of this polyethylene wastes and burying releases harmful toxic materials and gases which is a major pollutant in environment. About 3 % of plastic material is recycled while remaining remains as litter or land filler. These all have known negative effects on human and animal health, mainly affecting the endocrine system. There are also toxic monomers, which have been linked to cancer and reproductive problems (Shah *et al.*, 2008). However, in recent years the emphasis in polymer biodegradation has shifted from simply protecting the environment from unwanted plastics packaging litter to recovering value from the plastics used (Scott *et al.*, 1998). Most of the methods are laborious and slow, therefore there is an urgent need to have a rapid biological method for the degradation of polyethylene to avoid environmental pollution. Keeping the above facts into consideration, the present investigation method was carried out to enhance the biodegradation using certain biodegradable microbial consortia were combined with polyethylene along with various carrier materials.

2. Materials and Methods

The carrier materials of fresh bagasse wastes were collected from sugarcane juice shops in Chidambaram and made as small pieces, coal

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(Lignite) were collected from NLC (Neyveli Lignite Corporation of India) and farm yard manure were collected from Animal husbandry of Veterinary Science Department, Annamalai University.

The bacterial species of *Pseudomonas aeruginosa*, *Bacillus* sp., *Alcaligenes* sp., *Bacillus anthracsis*, *Shigella sonnei*, the fungal species of *Aspergillus niger*, *Aspergillus flavus*, *Fusarium* sp. and actinomycetes species of *Streptomycetes griseus* and *Streptomycetes albus* were isolated from municipal polyethylene waste and identified by standard biochemical tests.

Table -1: Preparation of combined mixture for biodegradation of polyethylene

S. No	Combine mixture
1	CM-1 Farm yard manure + LDPE + bacteria
2	CM-2 Farm yard manure + LDPE + fungi
3	CM-3 Farm yard manure + LDPE + actinomycetes
4	CM-4 Farm yard manure + LDPE + bacteria + fungi
5	CM-5 Farm yard manure + LDPE + bacteria + Actinomycetes
6	CM-6 Farm yard manure + LDPE + actinomycetes +fungi
7	CM-7 Farm yard manure + LDPE + Bacteria + fungi + actinomycetes
8	CM-8 Lignite (coal) + LDPE + Bacteria
9	CM-9 Lignite (coal) + LDPE + fungi
10	CM-10 Lignite (coal) + LDPE + actinomycetes
11	CM-11 Lignite (coal) + LDPE + Bacteria + fungi
12	CM-12 Lignite (coal) + LDPE + Bacteria + actinomycetes
13	CM-13 Lignite (coal) + LDPE + fungi + actinomycetes
14	CM-14 Lignite (coal) + LDPE + Bacteria + fungi + actinomycetes
15	CM-15 Bagasse + LDPE + bacteria
16	CM-16 Bagasse + LDPE + fungi
17	CM-17 Bagasse + LDPE + actinomycetes
18	CM-18 Bagasse + LDPE + bacteria + fungi
19	CM-19 Bagasse + LDPE + bacteria + actinomycetes
20	CM-20 Bagasse + LDPE + fungi + actinomycetes
21	CM-21 Bagasse + LDPE + bacteria + fungi + actinomycetes

Recovery of polyethylene films

After the incubation the LDPE films were recovered the films were rinsed by distilled water for removal of carrier material particles, air dried, immersed with 77 % ethanol for removal of adhering microorganisms and kept in the Hot air oven for dehydration and the temperature has been maintained at 60 °C for 10 minutes.

FTIR- ATR analysis of recovered polyethylene

Besides the formation of carbonyl groups, the reduction of native bonds observed in the FTIR-ATR spectrum of polyethylene also serve as an indication that the polymer has been broken down to shorter chains (Soni, *et al*., 2009). The recovered polyethylene erosion of the film surface was observed in the vicinity of the microorganisms and the decay of oxidation products in the surface of the polymer film was measured by FTIR measurements and was found to be associated with the formation of protein and polysaccharides, attributable to the growth of the microorganisms.

3. Results and Discussion

Among the 21 treatments of combined mixtures, the best results of weight loss were observed in CM-3 farm yard manure + actinomycetes + polyethylene - 31.14 % was observed within the three months followed by Bagasse + polyethylene + bacteria - 27.09 %, and Farm yard manure + Polyethylene + bacteria + Actinomycetes - 23.037 % and from carrier material based results we observed as Farm yard manure + polyethylene + actinomycetes was giving best result of weight loss and followed by Bagasse and Lignite has been observed and the all the treatment results shown in following Fig. – 1.

After 30 days of incubation period, the percentage of weight reduction was estimated, low density polyethylene films incubated with bacterial Isolate 1 and isolate 2 showed weight loss of 1.29 % and 1.31 % respectively which was found to be greater than the weight loss obtained in control. Degradation of LDPE by microorganism had been known for several years. Previous reports have studied on the degradation capacity of bacterial and fungal consortium under natural conditions (Kathiresan, 2003) very few have reported *in vitro* activity of the microorganisms under controlled conditions.

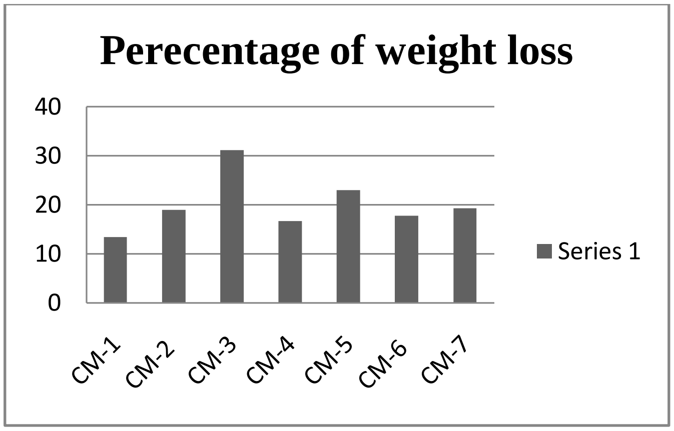


Figure - 1: Combined mixture of Farm yard manure + LDPE + Actinomycetes

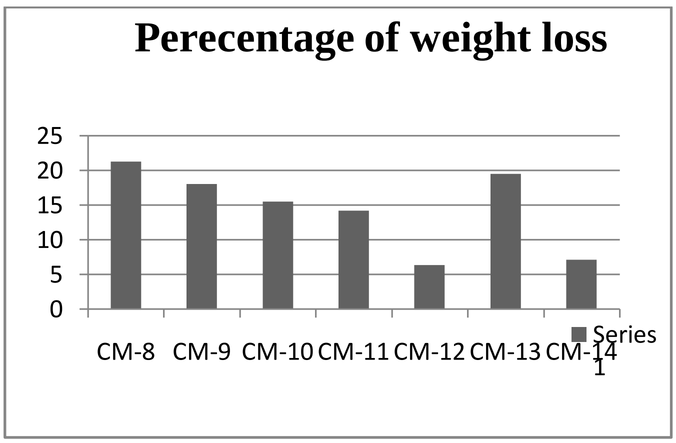


Figure-2: Combined mixture of Lignite (coal) + polyethylene + Bacteria

Formation and Reduction of Functional Groups in Degraded LDPE

The maximum intensity reductions of absorption peak O–H stretching, H–bonded alcohols, phenols were observed in CM-3 (FYM + actinomycetes consortia treated LDPE), the absorption range between 3500–3200 cm^{-1}, the intensity of C–H stretch alkanes, –C=C– stretch alkenes aromatics compounds of C–C stretch (in–ring) and C–N stretching of aliphatic amines at the ranges between 3500–3200 cm^{-1}, 3000–2850 cm^{-1} and 1250–1020 cm^{-1}. The deformation of C–Br stretching alkyl halides group were observed at the range of 668 cm^{-1} and the deformation of N–O asymmetric stretching nitro compounds absorption peak were observed at ranges between 1550 – 1475 cm^{-1}, when compared with untreated LDPE.

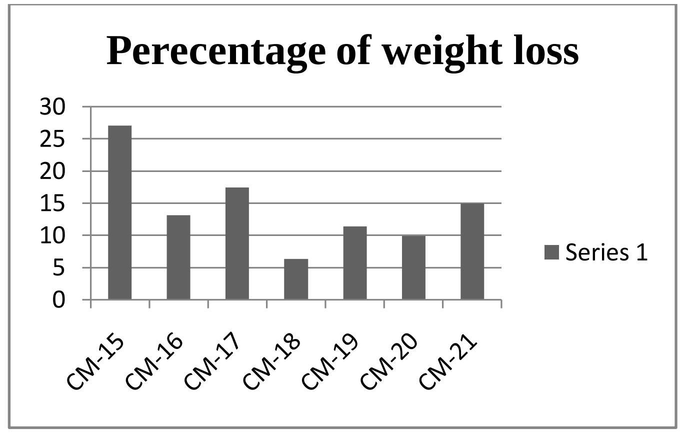
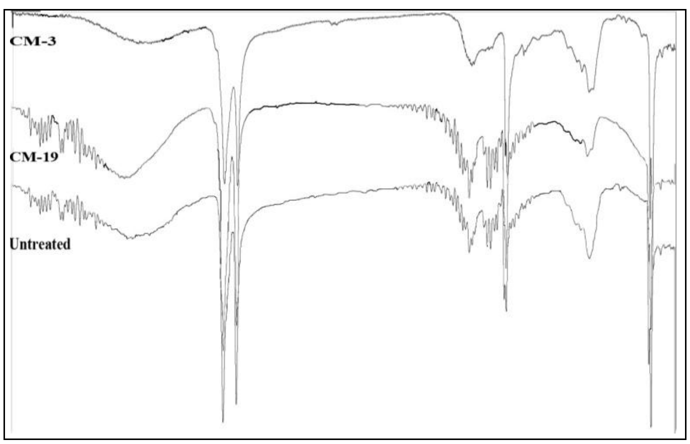


Figure - 3: Combined mixture of Bagasse + polyethylene + bacteria

The addition of new functional groups indicates the presence oxidative biodegradable microbial consortia and their released catabolic products. The maximum addition of absorption peaks (functional group) and increases of the intensity were observed in the region of 3566, 1683, 1670, 1635 and 1099 cm^{-1} *viz.* N-H stretching of amide with amine, amide C=O stretching of carbonyl groups and C–N stretching of aliphatic amines were formed in the CM-19 (Bagasse + bacteria + actinomycetes treated LDPE). Similarly Guadagno *et al.* (2001) found and agreed with the report of degradation of irradiated linear and low density polyethylene in which an increase in the -OH stretching region of hydroxylic group 3050 - 3570, due to formation of hydroxyperoxide and alcohol during photo-oxidation were observed. The main bands of the studied PE films consist of a band situated about 2900 cm^{-1} assignable to CH_2 as an asymmetric stretching, a band around 1461 – 1466 cm^{-1} revealing a bending deformation, and another band at 720 – 724 cm^{-1} which indicates a rocking deformation (Mouallif *et al.*, 2011). Results showed a decrease in the carbonyl group after microbial treatment and removal of -OH bounded compounds (alcohol, hydroxyperoxide and carboxylic acids) in the 3100 – 3600 cm^{-1} region.

These compounds which are degradation products along with the oxidized low molecular weight polymer have been reported to be assimilated by microorganisms (Hakkarainen and Albertsson, 2004).

The most prominent structural changes were observed in the LDPE of combined mixture FYM + Actinomycetes of combined two *Streptomyces* sp. by compared with other treated LDPE peaks. Thus, the study suggests that the combined mixture can accelerate the rate of degradation due to the enzymatic scission and assimilation of low molecular weight chains that were subsequently being produced due to microbial digestion of hydrocarbon backbone. The analysis is affirmative of the fact that the actinomycetes and bacteria degrading LDPE in various environmental sources and nutrient contents.



4. Conclusion

The microbial consortia of polyethylene degrading strains required essential nutrient content for their growth and development but the competitions for sufficient nutrient means they utilize available content of the environmental conditions and enzyme production occurred depending on the available nutrient. This study has proved the microbial consortia of combined bacteria, fungi and actinomycetes were actively associated with each other and producing their catalytic enzymes to degrade LDPE when used in various carrier materials.

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