STUDY OF DEGRADATION OF SYNTHETIC POLYMER NYLON 6 BY COMPOSTING METHOD

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ABSTRACT

Nylon is a generic designation for a family of synthetic polymers known as polyamides. This tends to give polymers useful properties such as flexibility and elasticity. Because of durability and visibility of polyamides hazards of discarding polyamides is called as ‘White Pollution’. Present study has examined the feasibility of composting for actively degrading Synthetic Polymer Nylon 6. For present experiment, Nylon 6 sheets were submerged in semi natural environment carried in Borosil glass for specific duration of 3 months to observe degradation. Physiochemical Analysis of compost was carried out for concentration of organic carbon, Potassium, Phosphorous and Electrical conductivity. Nylon 6 sheets were analyzed for degradation study which was monitor by weight reduction, thickness reduction; chemical analysis etc. composting conditions degrade the polymer which is confirmed by 10% weight loss, 13% thickness reduction and weakening in amide bond in polymer.

Keywords: biodegradation, composting study, Nylon 6

INTRODUCTION

Plastics are made up of long chain molecules called polymers. Polymers are made when naturally occurring substances such as coal, natural gas and oil are transformed into other substances with completely different properties. Polyamide is a polymer, which contains recurring amide groups (R-CO-NH-R') as integral part of the main polymer chain. Synthetic polyamides are produced by a condensation reaction between monomers, in which the linkage of the molecules occurs through the formation of the amide groups [1]. Biodegradation of polyamides is chemical changes by changes in bands like stretching, weakening etc., by microorganisms. Polymeric materials are not easily biodegraded. Efforts have been directed to develop mild physicochemical procedures, which
includes thermal and radiation pre-treatments to enhance the biodegradation process [2]. Degradation is the process in which a product is capable of being chemically degraded, changing its mechanical and chemical properties. A product is degradable when it can change its properties in a time scale due to the action of heat, light or mechanical stress. Any physical or chemical change in polymer as a result of environmental factors, such as light, heat, moisture, chemical conditions or biological activity is termed as degradation of plastics.

Polymeric materials are not easily biodegraded. Efforts have been directed to develop mild physico-chemical procedures which include thermal and radiation pretreatments to enhance the biodegradation process (Albertson et al., 1987). The degradation of plastics in nature is a very slow process which is first initiated by environmental factors followed by wild micro-organisms. The environmental factors include temperature, humidity, pH and UV. Biodegradation is the ability of micro-organism to influence abiotic degradation through physical, chemical or enzymatic action [2] [3] [4] [5]. Interplay between biodegradation and different factors in the biotic and abiotic environments are very important. The micro-organism reported for the biodegradation of the polyethylene include fungi (Aspergillus niger, Aspergillus flavus, Aspergillus oryzae, Chaetomium globusum, Penicillium funiculosum, Pullularia pullulan), bacteria (Pseudomonas aeruginosa, Bacillus cereus, Coryneformes bacterium, Bacillus sp., Mycobacterium, Nocardia, Corynebacterium, Candida and Pseudomonas) and Actinomycetales, Streptomycetaeae. Their activity on the polymer was studied by growth tests on solid agar medium for a definite period of time. The changes in molecular weight, structure, crystalinity, density, weight loss, mechanical, optical or dielectric properties, etc., were also measured [6] [7] [8] [9] [10]. Unlike polypropylene, more research articles are published on studies relating to biodegradation of polyethylene. Fungi that include A. niger, Penicillium funiculosum, Fusarium redolens and A. vesicolor, and soil microorganisms (mixed culture as well as Rhodococcus rhodochorus, Cladosporium cladosporoides) have been reported to degrade polyethylene [2].

Plastics are biodegraded aerobically in wild nature, anaerobically in sediments and landfills and partly aerobically and partly anaerobically in compost and soil. Carbon dioxide and water are produced during aerobic biodegradation and carbon dioxide, water and methane are produced during anaerobic biodegradation. Some basic composting methods which have been developed for degradation of plastic.

MATERIALS AND METHODS

Materials
Polymer Nylon 6 was purchased from Sigma Aldrich Company. Sheets of Nylon 6 are exposed for composting conditions. For Compost preparation kitchen waste, cow dung, are used.

Disinfection of the sample
The sample sheets were sterilized before they were inoculated into the composting condition. The nylon 6 sheets were dipped in 1 % hypochlorite for a few hours. Washed with distilled water thoroughly in order to remove all the hypochlorite and later dried. No physical or chemical changes were observed in the sample after hypochlorite treatment.

Biodegradation of Nylon 6 sheet under Semi-Natural Environment Composting
Biodegradation of Nylon 6 was carried out by keeping the sheets under semi-natural conditions of environment that is composting. Semi-natural is word used to describe the laboratory conditions. Its in-vitro composting method for degradation of polyamides. But in this semi-natural method composting was carried in Borosil glass tray. Composition of composting in which
concentration of manure and soil as 1:3 ratios. Green and brown leaves, waste as carbon source, moisture condition moderately maintained. In semi-natural composting, special type of tray is used which is made up of Borosil (glass) named as “Square Cake Dish” (small). Usually, for composting, plastic large trays are used but in semi-natural composting, glass trays are used which is kept in laboratory under aerobic conditions. Sheets of polyamide under composting condition were kept for about 3 months for completion of compost. Different composting parameters are checked as pH, organic carbon, Phosphorous, potassium, electrical conductivity etc. nylon 6 sheets are observed for biodegradation for weight reduction, thickness reduction, chemical analysis by I. R. Spectroscopy. Morphological changes were monitor by inverted microscope. Also thermal analysis of plastic was checked by TGA analysis.

RESULTS AND DISCUSSION

Degradation of Nylon 6 sheets in semi natural composting condition was observed for 90 days. Results presented in the following sections were obtained from two independent sets of degradation experiments.

Table no.1 Compost parameters observed during 90 days for Nylon 6.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Inoculated with Nylon 6</th>
<th>pH</th>
<th>Temperature</th>
<th>organic carbon</th>
<th>phosphorus oxide</th>
<th>potassium</th>
<th>electrical conductivity (µm/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Before composting</td>
<td>7.7</td>
<td>25°C</td>
<td>0.678</td>
<td>256.655</td>
<td>1572.48</td>
<td>0.92</td>
</tr>
<tr>
<td>2</td>
<td>After composting</td>
<td>8.2</td>
<td>29°C</td>
<td>1.002</td>
<td>211.876</td>
<td>1451.52</td>
<td>1.08</td>
</tr>
</tbody>
</table>

Table no. 2 Percentage (%) Weight loss observed in Nylon 6 sheets during composting study

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Time Duration</th>
<th>% Weigh reduction of sheets of nylon 6 in composting condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 Days</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1 month</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>2 month</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>3 month</td>
<td>10</td>
</tr>
</tbody>
</table>
Graph no. 2 Percentage (%) Weight loss observed in Nylon 6 sheets during composting study

![Graph](image)

Table No. 3 Percentage (%) thickness reduction observed in Nylon 6 sheets during composting study

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Time Duration</th>
<th>% thickness reduction of Nylon 6 sheets in composting condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 Days</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1 month</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>2 month</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>3 month</td>
<td>13</td>
</tr>
</tbody>
</table>

Graph No. 3 Percentage (%) thickness reduction observed in Nylon 6 sheets during composting study

![Graph](image)
Chemical study of Nylon 6 sheet

Fourier Transformed Spectroscopy Study of Nylon 6

FTIR Spectra of Nylon 6 sheet (Control)

FTIR Spectra of Nylon 6 sheet (expose to composting conditions)

Table No. 4 Thermo gravimetric study of Nylon 6 sheet treated with composting

<table>
<thead>
<tr>
<th>Sample</th>
<th>Temperature °C Corresponding to weight loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>Nylon 6 (Control)</td>
<td>413</td>
</tr>
<tr>
<td>Nylon 6 treated with composting condition</td>
<td>412</td>
</tr>
</tbody>
</table>
Morphological changes observed in Nylon 6 Sheet

![Nylon 6 (Control)](image)

![Nylon 6 sheet treated with composting condition](image)

RESULTS AND DISCUSSION

**Composting parameters observed**

The compost which was prepared from kitchen waste material shows increase in some parameters as Temperature, pH, organic carbon, electrical conductivity etc. the compost prepared was show high nutrient content due to organic carbon. As the carbon content was increase up to 1.02 mg/l. the conductivity was also found to be increased up to 1.08 μm/cm. (Table no 1).

**Degradation of nylon 6 sheets**

Present study was related with the study of biodegradation of nylon 6 under composting conditions. The study was carried out under composting conditions. In case of nylon 6, the physical parameter such as weight and thickness was observed to be reduced to some extent. It was observed that the weight loss was observed up to 10% (Graph 1) and thickness of sheets was reduced up to 13%.(Graph 2). Chemical analysis by using FTIR shows the weakening in the amide bonds. The strength of characteristic bands of C (O) NH occurring around 3300, 1640, 1550 and 1018 cm⁻¹ decreased after composting. There may be formation of new groups like CH₃, CONH₂, CHO and COOH, may be formed due to hydrolysis and oxidation [11]. The thermo gravimetric results explain the thermal stability of nylon polymer. At control condition the polymer was found to be stable and show 80% degradation at 482°C, while the nylon 6 sheets treated at composting condition shows 30% weight loss at 445°C, 60% weight loss at 467°C and 80% weight loss at 480°C temperature. (Table no.4) This indicates the decrease in temperature for the degradation, which indicates the degradation of polymer. The morphological study shows change in colour of nylon 6 sheet as it changes to brown color and smoothness of sheets are changes to rough surface area of sheet.
CONCLUSION

Present study was related with the biodegradation of nylon 6 polymers at composting condition. The study concludes that the polymer nylon 6 which is found to be hard for degradation degraded partially in composting process. The microorganisms which are present in compost play important role in degradation of polymer as the degradation was observed by 10% weight loss and 13% thickness reduction. Chemical characterization also explains the weakening in amide bond while the TGA study shows that the polymer has lost thermal stability due to degradation. Composting is found to be very good method for biodegradation of polymer. It takes more time to degrade the polymer as it is combined action of microorganisms.

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REFERENCES