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Variations in Degradability Properties of Low Density Polyethylene Blended with Potato Starch

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The conversion of existing synthetic plastics to biodegradable would be one of the efficient path to reduce the solid waste in environment with the reduction of durability and inertness. In the present study, the extent of degradation of low density polyethylene (LDPE) blended with potato starch was evaluated. Samples were processed with different concentrations of potato starch (5, 10, 15, 20 and 25 %). Glycerol as a plasticizer and $Fe_2(SO_4)_3$ as a pro-oxidant were added to the compound. The effect of potato starch variations on the mechanical properties (tensile strength and elongation), melt flow rate and density of the blended materials were examined. The biodegradation of the compounds in soil was evaluated in terms of loss of mass on regular intervals of 2, 4 and 6 months. Further the outcomes were also verified by FTIR and SEM. The results shown that with higher percentage of potato starch content, the biodegradability of the compounds enhanced. The biodegradation of the samples in soil burial after six months shown that the mass of the compounds decreased with higher percentage of potato starch concentrations.

Keywords: Plastics, Low density polyethylene, Biodegradable plastics, Starch, Green additives.

INTRODUCTION

Converting the existing non-biodegradable synthetic polymers to biodegradable would be the most efficient path to overcome the solid waste in environment. It could reduce the durability and resistance to biodegradation. It also reduced the inertness of plastics. The low density polyethylene is inert and could become more degradable by incorporating green additives to it. Starch is used as a biodegradable green additives [1]. Low density polyethylene and potato starch compounds are liable to macro biodegradation *i.e.* disintegration caused by the organisms of higher size than bacteria or fungi, such as insects and higher animals [2]. Low density polyethylene is used at high level for packaging and manufacturing of bags, composites and mulches [3,4]. The use of biodegradable polymers would be an ecologically green and affordable alternative to decrease the accumulation of solid plastics waste and the related disposal problems [5]. Blending is cost effective and multifaceted way to gain modified compounds with a vast scope of expected properties [6].

Now a starch based plastics have drawn much more attention, however it is repeat concept rather than a new one [7]. Potato starch is a semicrystalline green polymer, composed of two major components 1,4-α-D-glucopyranosyl: amylase and amylopectin [8]. Starch is a low cost material used as biodegradable green additive. Starch contained plastics did not have any adverse influences neither on food quality nor on any other packed materials [3]. Starch blended plastic also did not have any bad environmental effect and reduced the green house effect [9]. The blended polymers are the class of polymeric materials in which two or more materials are added together to form a new and distinguish polymer by properties [10].

In this present paper, the compounds of low density polyethylene (LDPE) and starch with different level of variations were made. Mechanical and physical properties of the compounds were examined by international standard test procedures. Apart from this, bio-disintegration in soils was also examined. The samples of soil of Amanishah drain of Sitapura industrial area, Jaipur and garden soil were taken to bury the compounded samples. The ultimate aim of the present study was to determine the effect of different variations of potato starch on biodegradability of low density polyethylene.

EXPERIMENTAL

Low density polyethylene of 16MA400 grade, processed by high pressure process was taken from Reliance Polymers, India. Starch powder was extracted from the potato (*Solanum tuberosum).* About 98 % purified glycerol of Merk Co., Germany was added as a plasticizer. Hydrated crystal purified $Fe_2(SO_4)_3$ of Merk co., Germany was added as pro-oxident.

TABLE-1
MECHANICAL PROPERTIES (TENSILE STRENGTH AND ELONGATION AT BREAK) BEFORE AND AFTER SOIL BURIAL

Samples of LDPE and potato starch with different level of variations	Tensile strength (MPa)			Elongation at break (%)		
	Before soil burial	After soil burial	Decrement (%)	Before soil burial	After soil burial	Decrement (%)
LDPE 100 %	10	9.8	2.0	40	38.9	2.8
5 % Potato starch	8.3	8.1	2.41	14.8	12.9	12.83
10 % Potato starch	7.3	7.1	2.74	13.0	11.1	14.62
15 % Potato starch	6.9	6.5	5.8	10.9	9.4	13.76
20 % Potato starch	6.6	6.0	9.1	8.4	6.5	22.62
25 % Potato starch	6.2	5.5	11.29	7.1	5.1	28.17

Equal volume of glycerol added in potato starch powder, $Fe_2(SO_4)_3$ (1 mass % of LDPE) compounded in it manually. The samples were made with different level variations (5, 10, 15, 20 and 25 %) of starch in two roll mill at 150-160 °C for 10-12 min. Sample sheets of 0.3 mm thickness were processed in compression molding under heat and pressure. One sample sheet of virgin LDPE was prepared to be kept as a control reference material.

The mechanical properties such as tensile strength and elongation at break were conducted by using tensile testing machine (H10K, Tinius Olsen) as per international standard test method ASTM D 638. The tests were conducted at 50 mm/min rate of straining. The average values of three specimens for all variations of potato starch were taken.

The rheological property that is melt flow rates of the compounds of different variations of potato starch were determined at 190 °C and 2.16 kg load as per international standard test method ASTM D 1238 by using melt flow indexer (Modular 7027, Ceast, Italy).

The physical property that is density of the compounds of all variations was determined as per international standard test method ASTM D 792 by using density apparatus (Mettler Toledo).

Strip shaped samples were buried in sampled soil for six months. Mass of all samples taken before buried in soil. The buried samples were removed from soil and mass taken at the end of second, fourth and sixth months.

Fourier transform infrared spectroscopy (FTIR) analysis was done on a Shimadzu spectrometer to study the structural changes in the samples before and after soil burial. Measurement range of wave number was 4000-400 cm^{-1}.

The scanning electron microscopic analysis of the samples was carried out using ZEISS scanning electron microscope at 10 KV. The surfaces of the samples were coated with metal such as gold.

RESULTS AND DISCUSSION

The values of mechanical properties in terms of tensile strength and elongation at break of the examined samples, before and after the soil burial has been mentioned in Table-1. It was obtained that the mechanical properties that is tensile strength and elongation at break had diminished with the higher concentration of potato starch. It was observed that diminish in mechanical properties (tensile strength and elongation at break) of control reference sample (virgin LDPE sheet) were avoidable. It is a very good indication of biodegradation in soil.

The test values of rheological property that is melt flow rate of the blended samples, before and after soil burial mentioned in Table-2. The comparative observation of the test values of melt flow rate before and after the soil burial explained that change in molecular structure of the samples was held due to biodegradation under soil. The melt flow rate decreased with increase of starch concentrations. It was observed that there was no variation in melt flow rate of controlled reference sample (Virgin LDPE sheet).

TABLE-2
RHEOLOGICAL PROPERTY (MELT FLOW RATE) BEFORE AND AFTER SOIL BURIAL

Samples of LDPE and potato starch with different level of variations	Melt flow rate (g/10 min)		
	Before soil burial	After soil burial	Deviation (%)
LDPE 100 %	30	30	0.0
5 % Potato starch	28.6	27.7	3.15
10 % Potato starch	26.5	25.0	5.66
15 % Potato starch	24.7	22.8	7.69
20 % Potato starch	22.3	20.3	8.97
25 % Potato starch	18.4	16.1	12.5

The test values of physical property that is density of the compounded materials, before and after soil burial has mentioned in Table-3. The values of density of the material were diminished with the higher concentrations of potato starch in comparison to before soil burial. The density of the compounded materials of 25 % concentration after soil burial was decreased even lower than the basic resin. It expressed the biodegradation of polymeric materials under soil.

TABLE-3
PHYSICAL PROPERTY (DENSITY) BEFORE AND AFTER SOIL BURIAL

Samples of LDPE and potato starch with different level of variations	Density (g/cc)		
	Before soil burial	After soil burial	Deviation (%)
LDPE 100 %	0.918	0.918	0.0
5 % Potato starch	0.935	0.927	0.86
10 % Potato starch	0.953	0.922	3.25
15 % Potato starch	0.984	0.920	6.50
20 % Potato starch	0.988	0.919	6.98
25 % Potato starch	0.992	0.906	8.67

The effect of soil burial duration on loss of mass of the compounds has mentioned in Table-4 and also shown in Fig. 1 for 2, 4 and 6 months. The loss of mass of compounded polymer samples during biodegradation in soil shows the degree of

TABLE-4
LOSS OF MASS OF SOIL BURIED SAMPLES

Samples of LDPE and potato starch with different level of variations	Loss of mass after 2 months burial (%)	Loss of mass after 4 months burial (%)	Loss of mass after 6 months burial (%)
LDPE 100 %	0.35	0.55	0.65
5 % Potato starch	1.1	1.69	2.26
10 % Potato starch	8.2	8.57	9.02
15 % Potato starch	9.41	10.22	10.79
20 % Potato starch	12.5	12.72	13.17
25 % Potato starch	19.85	20.63	21.42

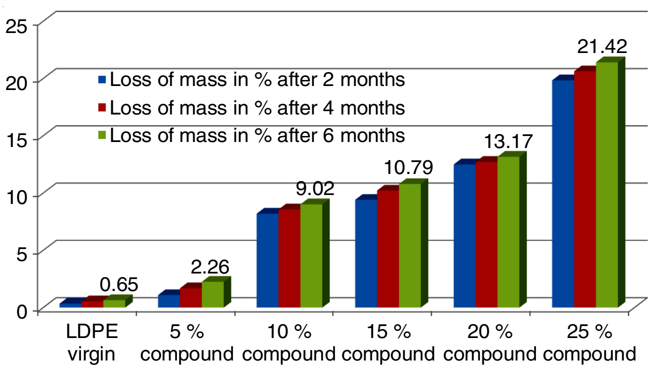

Fig. 1. Weight loss of soil buried samples

degradation in natural environment. The samples under the soil were attacked by bacteria and fungi. The surfaces of the samples were obtained rough when removed from soil, which expressed that the content of potato starch was absorbed by microorganisms present in soil. The avoidable change in loss of mass of controlled reference sample (Virgin LDPE-100 %) indicated that no attack held by microorganisms on virgin sample.

The FTIR spectra of blend of LDPE and potato starch before and after degradation in soil, the peaks which fall in between 1480-1380 cm^{-1} confirmed the existence of C-H groups. The peaks fall around 1750 cm^{-1} confirmed the existence of carbonyl groups. The retraction of peaks after soil burial indicates the degradation of the blend [11], which means the material, has been consumed by microorganism present in soil.

SEM test was conducted to confirm the degradation. Fig. 2 exhibits the scanning electron micrograph of virgin LDPE and blend of LDPE and potato starch before and after six months of soil burial. As shown in Fig. 2(a) and 2(b), the surfaces of virgin LDPE were smooth. The surfaces of virgin LDPE before and after soil burial were almost unchanged, it indicates the degradation occurred due to soil burial are negligible. On the other hand, in Fig. 2(c) and 2(d), the surfaces of the blends were different. As compare to before soil burial, in the image of blend after six months of soil burial the surfaces were found rough with some holes and bores. These roughness, holes and bores indicate the rate of biodegradation with the removal of starch from the blend.

Conclusion

Under the soil the compounded polymers degraded with the effect of microorganisms. Blending of potato starch with synthetic polymers is a probable way to make it biodegradable. The study focus on biodegradation of LDPE/potato starch compounds. It was obtained that the compounding of potato starch with LDPE enhanced the biodegradation of polymer in natural environment.

Truly, the polymer evaluated gone enhanced biodegradation, but the level of variations, conditions and duration used to enhance the extent of biodegradation, is entirely distinguish

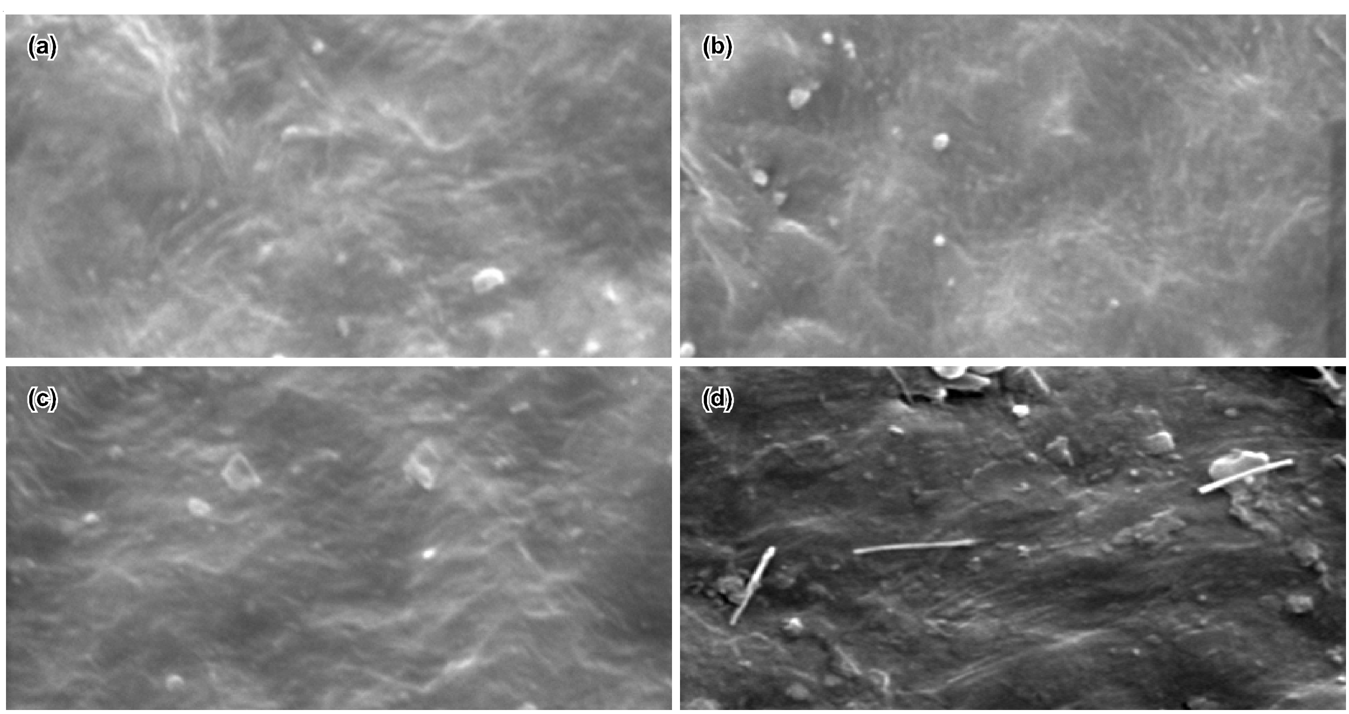

Fig. 2. (a) SEM image of sample (virgin LDPE 100 %) before soil burial, (b) SEM image of sample (virgin LDPE 100 %) after six months of soil burial, (c) SEM image of sample (LDPE + potato starch) before soil burial, (d) SEM image of sample (LDPE + potato starch) after six months of soil burial

from the concentrations, condition and duration taken in past. It is suggested that the potato starch is a strong accelerator, initiator and propagator for the biodegradation of polymers. As per our view the LDPE and potato starch compounds can be employed in the process of naturally degradable plastics.

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