Thickness based Degradation Study of Commercial Polyethylene Waste Carry Bags using *Galleria mellonella* Worms

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Abstract

Modern world is facing lot of polymers which degrade land and will reduce agricultural yield .in many ways. Thus, the cost-effective degradation or recycling is being studied by the researchers. This study reformed settings to study the Galleria mellonella wax worm's impact on polyethylene polymer degradation. This work isolated the worms from waste honey comb and treated five worms with the collected polymers. Trials were conducted at different seasons and monitored the degradation. Trials results showed minimum average degradation of 86 mg over 216 h with five matured worms. The results showed that worm saliva degraded polymers. In addition to coverings, rough and flexible textile Cary bags disintegrates quickly.

Despite diverse settings, matured larvals degrade rapidly at night and in summer. The trials showed that larval angriness and worm quantity caused degradation inconsistency. Waxworm mediated degradations are effective for small polymer quantities with countless worms. This work proposed that the waste honeycomb with worms can be mixed along with the small village dumping yards for the minimum polymer waste degradation which is simple and easy.

Keywords: *Galleria mellonella* worms, Degradation, Polyethylene bags.

Introduction

Polythene revolutionised human lifestyles and sparked most of the industrial and technical revolutions of the 19th and 20th centuries[10]. Polythene, a linear hydrocarbon polymer of ethylene monomers, is the most prevalent non-degradable solid waste[4]. Polythene is produced by efficient catalytic polymerization of ethylene monomers from cheap oil or gas petrochemical supplies[6].

Plastic is a popular polymer worldwide which exists from kitchen to office to industries and is used everywhere. It is used in the manufacturing of bottles, carry bags, detergent bottles, disposable articles (use and throw), garbage containers, margarine tubs, milk jugs, plastic bags and water pipes[11]. Its ease of manufacturing and low cost were found responsible for increasing the demand of the plastic around the globe.

As per the reported data, 243.5 million tons of polymers were produced up to 2006. But, the quantity is increasing more than that nowadays due to urbanisation, globalisation and population density at metropolitan cities[15,17]. Hence, this work is involved in degradation of waste polyethylene polymers. Polythene's simple processing makes it useful for conveying food, packaging fabrics, making scientific instruments and automobile parts. Polythene is used in large quantities to make bottles, carry bags, disposable goods, rubbish containers, margarine tubs, milk jugs and water pipes. Polyethylene makes polyethene bags. Synthetic polymers are hydrophobic and of high molecular weight. Polythene bags are used worldwide 500 billion to 1 trillion times per year[3].

In India, most of the metropolitan cities with human population are producing high quantity of polyethylene wastes which are dumped in dumping yards near water reservoirs and agricultural lands. In addition, most of the developed countries are dumping their last quality polymers as toys in developing countries like India. Extended activities will cause higher impact in Indian agriculture productivity and bio magnification. Plastics, for example, are the biggest environmental issues in nature. Plastic wastes threatened wildlife and the ecosystem[5]. Pollution affects air, water and soil. Urban and industrial wastes pollute soil. Humans cause soil pollution.

Plastic trash and wastewater-soluble synthetic polymers pollute the environment. Waste plastics kill many animals by trapping them or causing environmental damage by swallowing them[8, 14]. Plastic trash and sewage water synthetic polymers pollute the environment. Waste plastics kill many animals by trapping them or causing environmental damage by swallowing them. Plastics that imitate hormones harm humans. IARC classifies vinyl chloride as carcinogenic[18]. It causes animal mammary cancer. Plastic garbage can be recycled, incinerated, or buried[13]. Biodegradation decreases pollutants. Enzymes and microorganisms can degrade the polymers. Biodegradation reduces molecular weight by decomposing bacteria, fungus, enzymes etc. Microorganisms destroy the polymer which is an expensive biodegradation. Microbial activity altered plastic qualities such as tensile strength, crystallinity and water uptake in early biodegradation experiments[1,2].

Apart from various methods, this work planned to investigate the possible low cost method to adopt the insect for domestic polyethylene waste degradation. Waxworms (*Galleria mellonella L.*), mealworms (*Tenebrio molitor L.*) and superworms (*Zophobas atratus L.*) can depolymerize polyethylene (PE) and polystyrene (PS) after eating[12]. Previous reports stated that the serine hydrolase a potential enzyme degrades plastic[9]. Hence, this work selected the *Galleria mellonella L* for the various thickness polymer covers degradation. Worms are isolated from waste honeycombs (HOC) and treated with different thick polymer covers for 48 h. The observations are recorded and reported for the future investigations.

Material and Methods

This investigation collected the waste polymer production data from the Hand in Hand India waste management yard, Mudichur, Kancheepuram District, Tamil Nadu, India through National Service Scheme activity. This work purchased the honeycombs (HOC) from Thean Kudil, Chennai and Aidparry honey farm, Erode, Tamil Nadu, India. Safeseed mini digital thickness gauge caliper electronic pocket micrometer was used for 0 to 12.7 mm. LCD digital portable width measuring tool was used to measure the thickness. The insect on polymer was photographed using 3in1 USB digital microscope 1600X 3 LED magnification endoscope microscope. The test polymer covers were washed initially using distilled water and dried. The dried polyethylene covers are weighed initially and finally using professional digital weighing balance 2XAAA. 250mL beakers and mosquito mesh were used to conduct the trials.

Characterization: The tested polymers with saliva of *Galleria mellonella L* are characterized using FTIR – ATR mode. Jasco 6300 was used to characterise the samples FTIR spectra

Degradation study using median larval stage and matured larval stage: From the collected honeycombs, worms are isolated and segregated into two types such as matured worms and immature median worms. After the worm collection, four different polymer covers such as 20µ, 30µ, 20µ (Black) and 300µ (Textile shop carry bags-TSCB) were sized in to 15 X 8 cm^2 and weighed. All covers are kept in small boxes along with 5 matured wax worms. The setup was kept ideally for 48 hrs at normal room condition. The degraded weight was measured and the trials were triplicated. The trials were conducted at different seasons and the weight loss recorded.

Results and Discussion

Recent research indicates that 6,300 million metric tonnes of plastic trash have been produced[7]. From 2010 onwards, researchers are trying to find the solution for polymer degradation using insects. Hence, this work examined thickness parameters with different seasons using waxworms to find low cost polymer degradation method. According to the reports, *G. mellonella* enzymes and bacteria are degrading polyethylene by producing ethylene glycol. The trials were conducted at different seasons such as monsoon (mon), spring (spr), summer (sum) and winter (wint). Also, trials were extended at different time intervals with and without HOC. The observed degraded quantity at different time and seasons are presented in table 1.

From the outcomes, this work revealed that the degradation rate was higher when the polymer was treated with countless waxworms. Likely, when compared to mature and immature worms, immature worms destructed more quantity of covers which may be due to angriness of fresh worms. Mature worms movement is lower when compared to immature worm. Also, this work observed that the mature worm is staying at particular place and weaving shell around it. But, immature worms are moving around the covers and degrading the polymers as much as possible.

This research carefully watched the movement of the *G. mellonella* and its degradation at night. At night time, the rate of degradation is more and worms are active. The degraded area under candle light has been presented in fig. 2. Along with HOC, both worms degraded the polymers with high rate.

(a) (b)

Fig. 1: Trials with various thickness of polymer covers with worms both a and b at RT for 48 h

Table 1
Wax worm (Matured) with polymer cover loss and conditions at room temperature

Weight loss in mg							
Condition	**Thickness of polybag in mm**	**No. of worms**	**Trial 1**	**Trial 2**	**Trial 3**	**Average**	**± Std.Dev**
Im. Larva + HOC+ Poly 48h	0.02	Countless	400	320	407	375.7	48.3
	0.03	Countless	180	210	235	208.3	27.5
	0.3 (TSCB)	Countless	104	90	127	107.0	18.7
	0.02 black	Countless	40	50	62	50.7	11.0
Mat. Larva +HOC 48h	0.02	Countless	430	380	290	366.7	70.9
	0.03	Countless	115	250	393	252.7	139.0
	0.3 (TSCB)	Countless	124	89	98	103.7	18.2
	0.02 black	Countless	54	65	45	54.7	10.0
Mat larva + polymer (Night) 12h 6pm to 6am	0.02	5	40	55	67	54.0	13.5
	0.03	5	76	47	55	59.3	15.0
	0.3 (TSCB)	5	127	312	338	259.0	115.1
	0.02 black	5	--	--	--	--	--
Mat larva + polymer (day) 12h 6am to 6pm	0.02	5	25	30	18	24.3	6.0
	0.03	5	32	33	36	33.7	2.1
	0.3 (TSCB)	5	98	90	95	94.3	4.0
	0.02 black	5	88	49	56	64.3	20.8
Mat larva + polymer (mons-Sep) 48h	0.02	5	12	15	19	15.3	3.5
	0.03	5	14	22	19	18.3	4
	0.3 (TSCB)	5	14	31	22	22.3	8.5
	0.02 black	5	16	16	18	16.7	1.2
Mat larva + polymer (Spr -Feb) 48h	0.02	5	15	17	28	20.0	7.0
	0.03	5	21	33	26	26.7	6.0
	0.3 (TSCB)	5	15	95	35	48.3	41.6
	0.02 black	5	22	23	45	30.0	13.0
Mat larva + polymer (sum -May) 48h	0.02	5	40	47	55	47.3	7.5
	0.03	5	33	110	93	78.7	40.5
	0.3 (TSCB)	5	50 (Ro)	92	58	66.7	22.3
	0.02 black	5	47	45	60	50.7	8.1
Mat larva + polymer (wint -Dec) 48h	0.02	5	25	21	28	24.7	3.5
	0.03	5	15	29	35	26.3	10.3
	0.3 (TSCB)	5	30	36	52	39.3	11.4
	0.02 black	5	22	27	43	30.7	11.0
Total average loss						**86.14**	

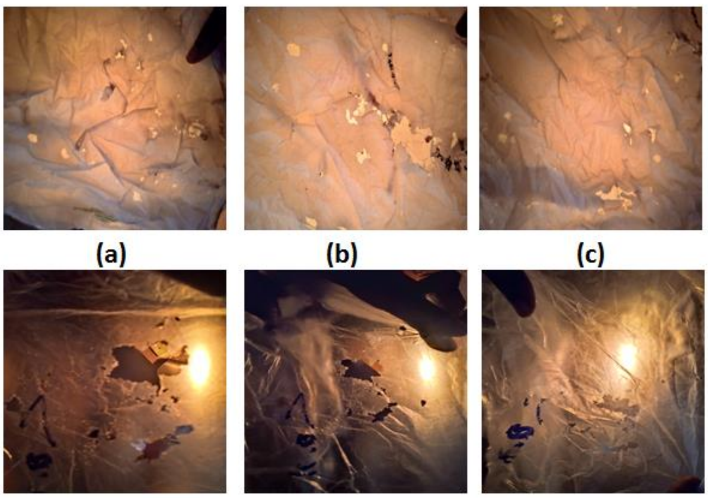

Fig. 2: Degraded polybags; (a, b, c) textile polybag degraded area, (d, e, f) transparent polybag degraded area

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When compared with the tested thickness polymers, textile shops providing bags are degraded by the worms very fast due to the roughness on the surface. Remaining covers surfaces are smooth in nature in which the worms were unable to move fast. Similarly, the degradation and eating process were higher at night time and along with HOC. This is because, at dark conditions worms were moving faster than at light conditions. These are the unpredictable nature of the worms and caused the inconsistency. According to the entomology statement, the worms are eating the polymers at extraordinary stage of food requirement.

From the overall trials, this work obtained the average loss of 86mg/216h. The range is almost near to the reported value of Sanluis-Verdes et al[16]. The trial conducted polymer covers with saliva of *G. mellonella* as shown in fig. 3. Covers with saliva are carried for FTIR analysis.

The FTIR peaks (Fig. 4 and fig. 5) are showing multiple peaks due to the mixture of compounds with different functional groups. Peaks are observed at 3637.75 (-OH), 3514.30 (-OH; NH), 3251.98 (-OH; NH), 3012.81 (-C-C-), 2897.08 (-C-N-), 2245.14(-CH), 1789.94 (-C=CH), 1759.08 (-C=O) and 1593.20(-C-O). All spectral data exhibited the similar functional groups with small differences. These results revealed the peptide bond and hydrogen bond present in saliva exposing enzyme presence in the *G. mellonella* saliva.

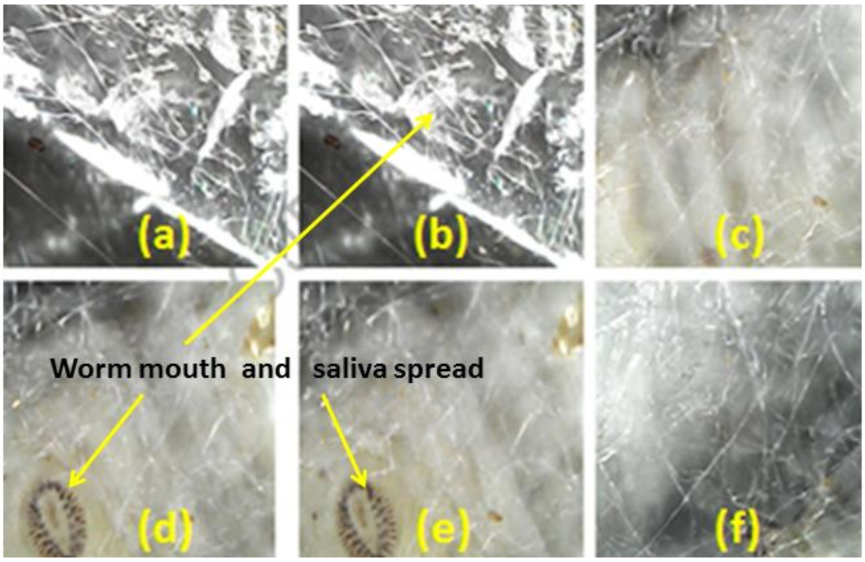

Fig. 3: (a, b, c) Wax worm saliva on the polymer covers, (d, e) wax worm spreading saliva and eating process, (f) saliva on smooth surface polymer

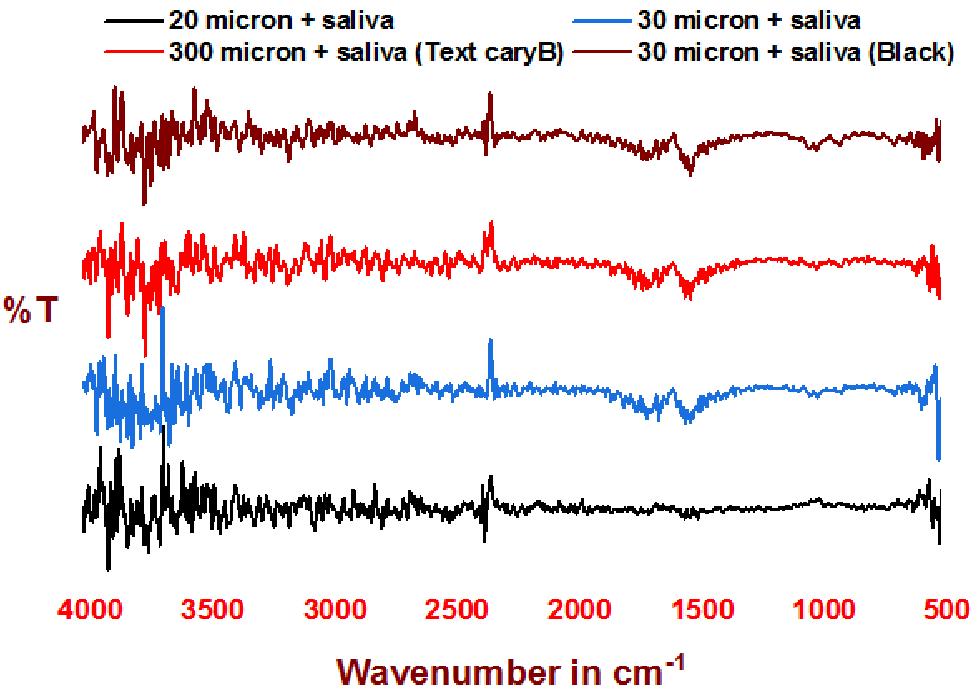

Fig. 4: FTIR spectrum of different thick polymers with saliva

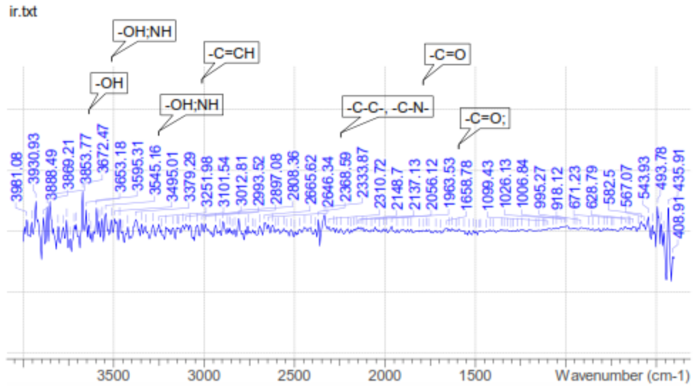

Fig. 5: FTIR spectrum of 20 µ polymer with *G. mellonella* saliva

Conclusion

The results revealed that the saliva spread by the worms over the polymers was involved in the degradation. Apart from various covers, rough and flexible textile carybags are degraded with high rate. This work finally concluded that the Waxworm involved degradations are effective for small quantities of polymers and are inconsistent. Enzyme analysis is very big challenge in this investigation. In addition, isolation of worms from honeycomb and applied for the polymer degradation is the major problem which is cost effective. This project successfully completed the various trials and interpreted the trial outcomes.

Likewise, each characterization report was carefully monitored and outcomes were drafted orderly for the future research. This work noticed various drawbacks and future strategy. According to the findings of this study, waste honeycomb that contains worms can be combined with tiny village dumping yards in order to achieve the least amount of polymer waste breakdown possible. This process is straightforward and uncomplicated.

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