Chronicle of Bioresource Management 2025, 9(2):068-071

Chronicle of Bioresource Management
An International E-magazine

June, 2025 Popular Article

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Citation: Balraj et al., 2025. Insect Plastic Degradation: A Novel Approach to Tackling the Global Plastic Crisis. Chronicle of Bioresource Management 9(2), 068-071.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

Keywords:

Gut microbiota, insects, meal worms, plastic degradation

Article History

Article ID: CBM6323
Received on 29th April 2025
Received in revised form on 04th June 2025
Accepted in final form on 20th June 2025

Insect Plastic Degradation: A Novel Approach to Tackling the Global Plastic Crisis

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Abstract

The alarming rise of plastic pollution has driven the search for innovative, sustainable solutions beyond conventional recycling and disposal. Insects have emerged as promising agents for plastic biodegradation, offering a natural, eco-friendly alternative to chemical and microbial processes. The degradation abilities of several insect species such as *Galleria mellonella*, *Achroia grisella*, *Plodia interpunctella*, *Tenebrio molitor* and *Corcyra cephalonica*, which have shown potential to consume and decompose polyethylene (PE), polystyrene (PS) and other synthetic polymers. The process involves mechanical breakdown via chewing, microbial action from gut flora and enzymatic depolymerization into simpler, biodegradable compounds. These insects not only tolerate plastic diets but, in some cases, complete life cycles, making them viable for long-term biowaste strategies. However, challenges like process scalability, environmental safety, and incomplete knowledge of gut microbiota mechanisms remain. Continued research into insect physiology, microbial consortia, and genetic pathways is crucial. Insect-mediated plastic degradation offers a complementary pathway towards addressing global plastic waste sustainably.

1. Introduction

Plastics are extensively used in various fields, *viz.*, construction, automotive, packaging, textile, and agricultural sectors, because of their affordability and accessibility (Dris et al., 2015; Yang et al., 2023). The most common polymer resins globally used are polyethylene (PE, 36% of global plastic production by weight), polypropylene (PP, 21%), polyvinyl chloride (PVC, 12%), polyethylene terephthalate (PET, <10%), polyurethane (PUR, <10%), and polystyrene (PS, <10%). In total, these 6 types of polymer resins account for about 92% of all plastic ever produced. Packaging production, dominated

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by PE, PP, and PET resins, accounts for roughly 42 % of the global resins used. Over 9200 million metric tonnes of plastic have been produced worldwide to far (Singh and Walker, 2024). Our continents are overrun by plastic garbage, which also contaminates our oceans and spreads across the entire world, transforming it into a "Plastic World" (Rochman et al., 2013). We all submerged by garbage and worst part of this big chunk of garbage are actually plastic pollution. Convention methods to manage plastic pollution are recycling, incineration, land filling and microbial degradation. These methods have some disadvantages like a plastic can be recycled most probably five to six times and cost of recycling is not effective. To solve plastic pollution releasing toxic gases to atmosphere by incinerating the plastic waste is not acceptable and left over option is to dump all the waste in landfills, again it's creating soil and underground water pollution. After so many years of research scientist have found that microbes are able to degrade the plastic but the rate of degradation is very slow when compared to production of plastic waste. Here comes the role of insects to degrade the plastic. Insect biodegradation of plastic as a novel source of microbial strain and enzymes of biotechnological value, capable of degrading the most common synthetic polymers found in waste streams and the natural environment.

2. Insects Involved in Plastic Degradation

Some of the insects are used as plastic degrader *viz.*, *Tenebrio molitor*, *Tenebrio obscurus*, *Zophobas morio*, *Zophobas atratus*, *Galleria mellonella*, *Plodia interpunctella*, *Achoria grisella*, *Corcyra cephalonica* and *Hermetia illucens*. These insects have capability for chewing, ingesting and partially degrading synthetic polymers.

2.1. Greater wax moth (Galleria mellonella)

The larvae of *Galleria mellonella*, also known as wax worms (ww), can oxidize PE within one hour from exposure. It is serious pest of apiculture. It can chew and consume PE films because they can feed on and digest bee wax. Since bee wax and PE have structural similarities, biochemical machinery for bees wax metabolism may be used for PE metabolism. *G. mellonella* has a remarkable capacity to use pre-existing metabolic mechanism to get energy from PE as a sole source of food. These worms were able to soften and metabolize thin film PE shopping bags into ethylene glycol which can be degrading in natural environment within few weeks. Salivary glands can help in polyethylene degradation by forming pitting and degradation intermediates containing carbonyl groups. The function of putative lipid oxidative enzymes is significantly greater in larvae that fed PE (Le Moine et al., 2020). Some bacterial (*Enterobacter* sp, *Enterobacter asburiae* YT1) and fungal (*Aspergillus flavus*) strains have been identified in the gut of larva which are capable of degrading PE.

2.2. Lesser wax worm (Achroia grisella)

High-density polyethylene (HDPE) degradation capabilities of the larvae of *Achroia grisella* (lesser wax worm) and its ability to complete its life cycle when fed with HDPE. Effects of added nutrition on PE degradation were assessed, providing wax comb as co-feed (PE-WC) (Kundungal et al., 2019). The ecological and behavioural similarities of these insects sparked interest in exploring their potential for plastic degradation. Unlike other plastic-consuming species, they exhibited superior survivability and were able to complete their entire life cycle solely on a diet of high-density polyethylene (HDPE), successfully producing a second generation. In controlled studies, a group of 100 lesser wax worm larvae significantly reduced the weight of HDPE within just eight days. Remarkably, the addition of wax comb to their polyethylene (PE) diet further enhanced the degradation process. Chemical analysis of larval frass revealed the presence of biodegradable intermediates such as alcohols, carbonyl compounds, and unsaturated hydrocarbons-indicating active biochemical breakdown of plastic. Interestingly, prior observations by Chalup et al. (2018) reported *Achroia grisella* feeding inadvertently on silo bags composed of multilayer PE and an anti-UV layer. Despite these promising findings, the precise biochemical mechanisms behind HDPE degradation remain largely unknown.

2.3. Rice moth (Corcyra cephalonica)

The first reports of *Corcyra cephalonica* degrading plastic were made by Kesti and Thimmappa (2019). Rice moth larvae subjected to low-density polyethylene (LDPE) films demonstrated significant degradation activity in their investigation. While LDPE films without antibiotic intervention showed a 25 per cent weight drop, the larvae lost 21 per cent of their body weight when fed a mixture including antibiotics. This discrepancy implies that the insect's gut flora and digestive enzymes both aid in the breakdown of LDPE. Nevertheless, despite these encouraging results, no more research has been done to separate or pinpoint the precise gut microorganisms or enzymes in charge of the breakdown process.

2.4. *Indian meal moth (Plodia interpunctella)*

The Indian meal moth, *Plodia interpunctella*, a common pest of stored grains, has demonstrated the ability to feed on and degrade plastic by chewing through and creating holes in plastic films. Yang et al. (2014) were the first to report this behaviour, identifying and isolating two bacterial strains associated with the insect: *Enterobacter asburiae* YT1 and *Bacillus* sp. YP1. When these bacteria were cultured on polyethylene (PE) films for 28 days, the surface of the plastic developed pits and cavities, accompanied by notable weight loss, reduced hydrophobicity, diminished tensile strength, and the emergence of breakdown products. Over a longer period of 60 days, the YP1 strain proved more efficient in depolymerizing PE than the YT1 strain.

2.5. *Mealworms*

Yang et al. (2015) conducted feeding trials with mealworms from Beijing and Qinhuangdao to observe their eating habits of Styrofoam. The polystyrene samples that were used had no additives and had not been pre-treated in any kind. Polystyrene was immediately consumed by the mealworms from all sources. Mealworms (20–25 cm in length) showed a high level of eating activity and made cavities in the Styrofoam blocks. Even though the mealworms were bought from three distinct locations, the identical observations were made more than three times.

3. Mechanism of Plastic Degradation by Insects

The process of degrading plastics by insects can be divided into five stages based on relevant studies (Figure 1).

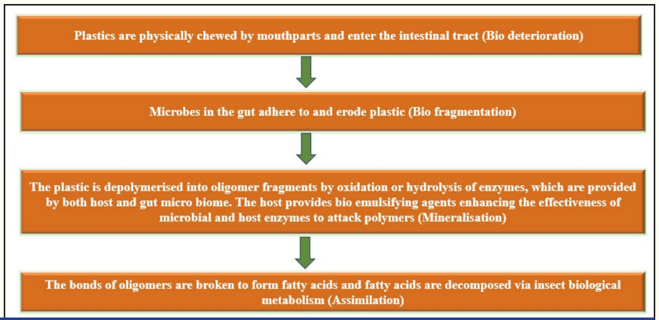

Figure 1: Mechanism of degrading plastics by insects

4. Advantages

- ❖ Eco – friendly
- ❖ Potential for circular economy
- ❖ Potential for localized and on-site treatment
- ❖ Natural and renewable process
- ❖ Complementary approach to existing methods

5. Challenges

- ❖ Efficiency and scalability
- ❖ Plastic types and complexity
- ❖ Environmental and safety considerations
- ❖ Regulatory frame work
- ❖ Economic viability
- ❖ Collaborative efforts

6. Conclusion

Insect-assisted plastic degradation represents a promising, eco-friendly innovation in mitigating global plastic waste. Various insect species demonstrate the capacity to break down synthetic polymers through physical and biochemical mechanisms. This approach provides added value through potential protein recovery and localized waste treatment. However, scientific and regulatory hurdles, including toxicity, scalability, and microbial understanding, must be addressed. Advancing this biotechnological frontier could lead to sustainable, circular solutions for plastic pollution, contingent upon further interdisciplinary research and practical implementation strategies.

7. References

Dris, R., Imhof, H., Sanchez, W., Gasperi, J., Galgani, F., Tassin, B., Laforsch, C. 2015. Beyond the ocean: contamination of freshwater ecosystems with (micro) plastic particles. Environmental Chemistry 12(5), 539–550.

Yang, X.G., Wen, P.P., Yang, Y.F., Jia, P.P., Li, W.G., Pei, D.S., 2023. Plastic biodegradation by *in vitro* environmental microorganisms and *in vivo* gut microorganisms of insects. Frontiers in Microbiology 13, 1001750.

Singh, N., Walker, T.R., 2024. Plastic recycling: A panacea or environmental pollution problem. Npj Materials Sustainability 2(1), 17.

Rochman, C.M., Browne, M.A., Halpern, B.S., Hentschel, B.T., Hoh, E., Karapanagioti, H.K., Thompson, R.C., 2013. Classify plastic waste as hazardous. Nature 494(7436), 169–171.

LeMoine, C.M., Grove, H.C., Smith, C.M., Cassone, B.J., 2020. A very hungry caterpillar: polyethylene metabolism and lipid homeostasis in larvae of the greater wax moth (*Galleria mellonella*). Environmental Science & Technology 54(22), 14706–14715.

Kundungal, H., Gangarapu, M., Sarangapani, S., Patchaiyappan, A., Devipriya, S.P., 2019. Efficient biodegradation of polyethylene (HDPE) waste by the plastic-eating lesser waxworm (*Achroia grisella*). Environmental Science and Pollution Research 26, 18509–18519.

Chalup, A., Ayup, M.M., Monmany Garzia, A.C., Malizia, A., Martin, E., De Cristóbal, R., Galindo-Cardona, A., 2018. First report of the lesser wax moth *Achroia grisella* F. (Lepidoptera: Pyralidae) consuming polyethylene (silo-bag) in northwestern Argentina. Journal of Apicultural Research 57(4), 569–571.

Kesti, S.S.K., Thimmappa, S.C.T., 2019. First report on biodegradation of low density polyethylene by rice moth larvae, *Corcyra cephalonica* (Stainton). The holistic approach to environment 9(4), 79–83.

Yang, J., Yang, Y., Wu, W.M., Zhao, J., Jiang, L., 2014. Evidence of polyethylene biodegradation by bacterial strains from the guts of plastic-eating waxworms. Environmental Science & Technology 48(23), 13776–13784.

Yang, Y., Yang, J., Wu, W. M., Zhao, J., Song, Y., Gao, L., Jiang, L., 2015. Biodegradation and mineralization of polystyrene by plastic-eating mealworms: part 2. Role of gut microorganisms. Environmental Science & Technology 49(20), 12087–12093.