GENERAL ARTICLE

Plastic eating insects: Current contrivance for plastic pollution

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Global plastic manufacturing has expanded over the past few decades and reached 359 million tonnes in 2018 (Lebreton and Andrady, 2019). Since plastics consumption has grown so quickly, they are now among the materials that are used the most frequently on Earth. As the amount of plastic used increases, plastic pollution is spreading around the globe (Lönnstedt and Eklöv, 2016). Today, everyone agrees that plastic waste contamination is a serious environmental burden. By 2050, it is anticipated that up to 26 billion tonnes of plastic garbage would be generated, with more than half of that waste ending up in landfills before infiltrating ecosystems like wetlands and oceans, seriously polluting the environment (Lönnstedt and Eklöv, 2016). According to a recent study, the total amount of plastic garbage produced to date could reach 6,300 million metric tonnes (Geyer *et al*., 2017). However, less than half of the plastic garbage generated was recycled or dumped in landfills. Our world, which has become known as the "Plastic World," is littered with a sizable amount of remaining plastic garbage (Rochman *et al.*, 2013). Polyethylene, Polystyrene, Polypropylene, and other thermoplastic materials can be heated and moulded into any shape, but thermosetting materials, such as polyurethanes and phenol-formaldehyde cannot be heated or moulded into another shape after they have been set into one (Ghosh *et al*., 2013). Thermoplastics can be recycled in several different ways, however, due to their physicochemical properties, they exhibit varying degrees of resistance to biodegradation. Polyethylene (PE) is one of the major persistent plastics that are not biodegradable at considerable rates in most environments. The inherent resistance of polyethylene to biodegradation stems from its three-dimensional structure, high molecular weight, hydrophobic nature, and lack of functional groups recognizable by microbial enzymatic systems (Harshvardhan and Jha, 2013). Polystyrene (PS) is a synthetic hydrophobic polymer with high molecular weight. Due to its hydrophobic nature and high molecular weight, it is not readily biodegradable (Tsuchii *et al*., 1997). Polypropylene (PP) belongs which upon exposure to ultraviolet radiations and oxidation at high temperatures breaks down into simpler molecules and in microbial degradation, several species of fungi and bacteria can degrade this plastic (Sivan, 2011).

Ways to degrade the plastic…

Traditional techniques for degrading plastic trash, such as dumping it in a landfill or burning it, chemically treating it, or using heat to break it down, are dangerous to the environment and have negative effects on living things (Yang *et al*., 2011). The primary method of recycling thermoplastic wastes has been mechanical recycling, however after multiple manufacturing cycles, the qualities of most recycled goods have been badly impacted, and the resulting commercial attractiveness is modest. The success of chemical recycling, which is an alternative, depends on the cost of procedures and the potency of catalytic agents (Rahimi and Garca, 2017). Chemical recycling will recycle monomers and other materials from 61 different plastic wastes. Plastic biodegradation by fungal and bacterial strains has been highlighted as a potential solution for removing plastic waste without producing secondary pollution (Lee *et al.*, 2020), but they have some limitations they are slow in the process, and they required optimum conditions for biodegradation.

Can insects combat the issue of plastic pollution?

As the most diverse organisms on the planet, insects are recognised to have a variety of uses that are now being researched by humans. Recent research on plastic decomposition by insects has emerged as an intriguing area in discussions of environmental plastic contamination. Early in the nineteenth century, it was discovered that the insects were eating the plastic container used for insect rearing, albeit digestion had not yet been established. However, chewing on the plastic resulted in the formation of galleries and holes through which the larvae escaped (Singh and Jerram, 1976). Since then, numerous studies have been conducted to determine how amazing insect digests plastic. Seven types of plastics are degraded from the insects till now (Polyethylene (PE), polystyrene (PS), polyvinyl chloride (PVC), polypropylene (PP), polyphenylene sulphide, ethylene-vinyl acetate (EVC), and extruded polystyrene) (Table 1). There are different plastic-eating insects are identified which can digest plastic and convert it into non-hazardous compounds (Bombelli *et al*., 2017). These insects are known to consume plastic since the structural similarity between their food substrate and plastic is almost the same. For instance, bee wax and PE have structural similarities, hence *G. mellonella* biochemical machinery for beeswax metabolism may be used for PE metabolism (Bilal *et al.*, 2021).

Table 1: List of plastic eating insects

Sl. No	Type of plastic	Plastic utilizing insects	References
1	Polyethylene (PE)	*Galleria mellonella; Plodia interpunctella; Tenebrio molitor; Achroea grisella;; Corcyra cephalonica*	Yang *et al*., 2014; Zhang *et al*., 2019; Kundungal *et al*., 2019; Kesti and Thimmappa, 2019; Brandon *et al*., 2018
2	Polystyrene (PS)	*Tenebrio molitor; Uloma spp*; *Zophobas atratus*	Kundungal *et al*., 2019; Yang *et al*., 2020
3	Polyvinyl chloride (PVC)	*T. molitor*	Peng *et al*., 2020
4	Ethylene-vinyl acetate (EVA)	*T. confusum*	Abdulhay, 2020
5	Polyphenylene sulfide	*Z. atratus*	Lee *et al*., 2020

Plastic devouring insects

An array of insects that belongs to the order Coleoptera and Lepidoptera are known to degrade the complex plastic polymer into low molecular weight metabolites. *G. mellonella* larvae have a remarkable capacity to use pre-existing metabolic mechanisms to get energy from PE as a sole source of food (LeMoine *et al*., 2020). In the Coleoptera order, some species which are identified as plastic-feeding insects include Mealworm (*Tenebrio molitor*), Super worm (*Zophobas atratus*), Confused flour beetle (*Tribolium confusum*), *Uloma* spp, and red flour beetle (*Tribolium castaneum*). In the Lepidoptera order, species identified as plastic-feeding insects are the Indian meal moth (*Plodia interpunctella*), the lesser wax moth (*Achroia grisella*), the greater wax moth (*Galleria mellonella*), and the rice mealworm (*Corcyra cephalonica*) (Bilal *et al*., 2021). Insects were found to be capable of eating and quickly degrading up to 50 % of ingested plastic in just 24 hours, according to changes in chemical composition, molecular weight, and isotopic trace following tracks through the intestinal tract (Yang *et al*., 2015a). Hitherto, two kinds of weaponry are identified in insects against plastic degradation *viz*., through gut microbiota and/ or digestive enzymes. It's important to find out how insect enzymes and microbiota contribute to PE degradation (Kong *et al*., 2019).

Armament of insects in plastic degradation

The gut microbiota a degrading arm

Insects are known to harbour a variety of helpful bacteria in their guts known as symbionts, which frequently aid in the conversion of complicated compounds into simpler molecules in the insect body. According to reports, synthetic polymers are broken down by gut microbes. *Enterobacter tabaci* strain and *Bacillus subtilis* subsp. *spizizenii* strain was isolated from the midgut of Indian meal moth larvae, and they have a role in degradation (Mahmoud *et al.*, 2020). *Enterobacter* and *Aspergillus flava* are symbionts of *G. melonella* involved in plastic degradation. One strain of *Exiguobacterium* sp. YT2, isolated from the *T. molitor* gut was found to be capable of degrading 7.5 % of the weight of PS in less than 60 days (Yang *et al.*, 2015b). The PS, PE, and PPS can be degraded by *Pseudomonas aeruginosa* gut bacteria in *Z. atratus. P. aeruginosa* growth rates were not always proportional to biodegradation rates, and the structure and properties of intermediate molecules formed during plastic biodegradation may affect bacterial growth rates (Lee *et al.*, 2020). The gut microbiota of plastic or bran fed *T. castaneum* larvae revealed that *Acinetobacter* sp. was involved in degradation (Wang *et al*., 2020).

Digestive enzyme as a plastic degrading weapon

It can be inferred that an enzyme for the breakdown of LDPE may be created by an insect's digestive system (Kesti and Thimmappa, 2019). According to Przemieniecki *et al.* (2020), mealworms may break down polyethylene using enzymes including esterase and cellulase. By causing pitting and generating carbonyl-containing degradation intermediates in *G. melonella*, salivary glands can break down polyethylene (Peydaei *et al*., 2020). LeMoine *et al.* (2020) found that larvae fed PE had considerably higher activity of putative lipid oxidative enzymes.

Plastic as a sole diet for insects

As was already established, many insects can employ their metabolic processes to consume plastic as their only food supply (LeMoine *et al*., 2020). The best example is that *A. grisella* larvae ingesting and degrading PE as a sole diet survived for almost 1 month, developing into a second generation, though the PE diet did not provide enough nutrients needed for growth and survival. Provision of added nutrition enhanced PE degradation, allowing a high survival rate and enabling the breeding of a second generation with favourable PE biodegradation. It is also reported that mealworm (*Tenebrio molitor*) was capable of degrading and mineralizing Styrofoam (PS foam) when given as a sole diet (Yang *et al.*, 2020). An insect larva, super worm (*Zophobas atratus*), was newly proven to be capable of eating, degrading, and mineralizing PS. Super worms could live with Styrofoam as the sole diet as well as those fed with a normal diet (bran) over 28 days (Yang *et al*., 2020).

Conclusion

It might be beneficial to eliminate plastic pollution by creating innovative clean up techniques. Even though many microbes isolated from various locations have been reported up to this point practically, none of the organisms has been successful. The biodegradation of plastics needs to be thoroughly investigated, particularly the identification of insect microbiota that are symbiotic with plastic breakdown. Insects' complete physiological process depends heavily on the gut bacteria and digestive enzymes found throughout their entire digestive tract. The gut microbiota of insects that consume plastic may contain a variety of unique enzymes for plastic breakdown that might be exploited as a biocatalyst for the recycling and biodegradation of plastic waste. The development of remediation strategies for plastic wastes may benefit from the isolation and characterization of more plastic-degrading microbes from other sources as well as a deeper knowledge of the enzyme system involved in degradation. Additionally, the commercialization of identified enzymes and microbiota for plastic decomposition contributes to environmental sustainability.

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