Review Article

Biodegradation of plastic by insects: A Review

ABSTRACT

Plastic poses a persistent threat to various ecosystems and organisms due to its prolonged environmental existence. Traditional methods of managing plastic waste, such as landfill disposal and chemical treatments, have proven environmentally harmful. Despite the recognition of insects as potential agents for plastic degradation, the practical application of this concept remains limited. While the exact mechanisms of insect-mediated plastic breakdown are not fully understood, utilizing insect larvae for this purpose offers advantages such as cost-effectiveness and minimal secondary pollution. This review aims to comprehensively analyze recent research on plastic degradation by insects and microorganisms, shedding light on the processes involved and exploring the potential applications, challenges, and future directions in plastic biodegradation.

Keywords: Biodegradation, Challenges, Cost-effectiveness, Environment, Insects, Plastic, Secondary pollution

1. INTRODUCTION

Plastics made from synthetic material are highly valued materials in all modern countries. This is because of their remarkable traits that evolve with time, such as low price, stability, and resilience due to their polymeric characteristics, making plastics an integral element of every aspect of our everyday lives. (Ru et al., 2020). Plastics have become one of the most widely utilized substances on the planet as usage has grown fast. Plastic is commonly used to package foods, cosmetics, chemicals, medications, and detergents. Industrial manufacturing of plastic began in the 1950s and has risen at an astonishing rate (Alabi et al., 2019). A number frequently utilized plastics, such as polyethylene (PE), polystyrene (PS), polyethylene terephthalate (PET), and polyvinyl chloride (PVC), have been found to be detrimental to ecosystems because of their capacity to generate problems, including long-term persistence in the environment, thus posing an eternal threat for many kinds of life, particularly those that inhabit aquatic and terrestrial ecosystems (Arp et al., 2021). Plastic trash contamination is now widely recognized as a major environmental issue. A recent study indicates that up to 6,300 million metric tonnes of plastic garbage have been generated to date (Geyer et al., 2017). However, fewer than 50% of the manufactured plastic garbage was either disposed of in landfills or recycled. Global plastic manufacturing has surged in recent decades, reaching 359 million tons in 2018 (Lebreton and Andrady, 2019). Polyethylene (PE), with an annual global production of around 140 million Mg (tonnes), is the most widely used synthetic polymer (Sivan, 2011). Plastics are produced annually at a rate of 180 million Mg (tonnes), with supply and demand increasing year after year. Plastic pollution is expanding around the world as the amount of plastic consumed grows. By 2050, up to 26 billion tonnes of plastic garbage are predicted to be created, with more than half ending up in landfills and then entering ecospheres including oceans and wetlands, causing significant environmental contamination (Lönnstedt and Eklöv, 2016). This additionally impacts the soil biomass and biodiversity (Ali et al., 2021). It releases atmospheric greenhouse gases that are hazardous to human well-being (Al-Tohamy et al., 2023). Plastics in water bodies trigger global warming by impeding plankton growth, which causes elevated temperatures. Plastics are hydrophobic in nature, which increases their ability to combine with other pollutants like organic pollutants, and polychlorinated biphenyls (Ali et al., 2021). Furthermore, plastic waste in soil ecosystem influences the makeup and function of the microbiome, as fragmented plastic debris leaches into the soil, increasing toxin levels (Lear et al., 2021). When birds consume plastic fabrics, they have neurological disorders, sterility, and immune system abnormalities (Alimba & Faggio, 2019). The discovery of microplastics in several parts of the human body, such as the blood (Leslie et al., 2022), lungs (Amato-Lourenço et al., 2021), and placenta (Ragusa et al., 2021), has raised global awareness. These compounds are classified as toxic because of their harmful properties and tendency to spread throughout ecosystems.

Given this dilemma, it is necessary to seek environmentally friendly alternatives to conventional disposal, such as biodegradation (Ali et al., 2021). Plastic biodegradation is a crucial step toward mitigating the impacts of plastic pollution (Wierckx et al., 2018). However, there is still a dearth of understanding of the mechanics and efficacy of plastic biodegradation. The present also addresses the concept of invertebrates, such as insects, in the decomposition of plastics, emphasizing their vital role in the future.

2. IMPACTS AND DISPOSAL METHODS OF PLASTIC WASTE

Plastic waste is increasingly recognized as one of our most serious environmental problems, second only to climate change (Jambeck et al., 2015). In landfills, plastic waste occupies substantial space, with 10,000 tonnes of plastic dumped in just 0.067 hectares, releasing significant amounts of harmful chemicals in the process (Lithner et al., 2011). These chemicals can leach into the soil, degrading soil quality and contaminating groundwater (Crompton, 2007). Buried polyethylene (PE) waste can disrupt drainage patterns, harm soil fauna, and reduce soil quality, leading to lower agricultural yields. Plastic pollution also enters the ocean at a staggering rate of 0.48 to 1.27 million tonnes per year and is doubling roughly every ten years (Crompton, 2007). This plastic contaminates marine ecosystems and the food chain, affecting food meant for human consumption (Lusher et al., 2017). The incineration of plastic wastes such as polystyrene (PS), PE, polyvinyl chloride (PVC), and polyethylene terephthalate (PET) releases airborne pollutants like polycyclic aromatic hydrocarbons (PAHs), dioxins, and nitro-PAHs, which are carcinogenic (Al-Salem et al., 2009). Harmful contaminants from plastic waste, including microplastic particles, are likely to enter food chains, impacting important ecological species such as salt marsh grasses, mussels, and corals (Uhrin and Schellinger, 2011; Browne et al., 2008). These plastics and their related chemicals can accumulate in the bodies of humans and marine life, causing damage to cells and other tissues (Pauly et al., 1998).

3. DIFFERENT METHODS OF PLASTIC DEGRADATION

Natural plastic degradation is extremely slow, leading to an accumulation of plastic waste that poses a significant environmental threat. Various factors, such as age, weathering, polymer type, temperature, pH, and irradiation, influence plastic degradation (Akbay and Özdemir, 2016). Due to the lack of effective degradation methods, plastic treatment primarily consists of 77% reclamation, 13% incineration, and 10% mechanical and chemical recovery. Reclamation can pollute soil and groundwater, as burning polyethylene waste releases toxic carcinogens like ketones and acrolein, as well as greenhouse gases such as methane, posing significant health and environmental risks (Briassoulis, 2006). Mechanical recycling has been the primary method for reusing thermoplastic wastes; however, repeated manufacturing cycles negatively affect the properties of most recycled products, diminishing their market appeal. Chemical recycling, on the other hand, can recover monomers and other substances from various plastic wastes, but its effectiveness depends on the cost of the process and the efficiency of catalytic agents (Rahimi and García, 2017). Plastic biodegradation by fungal and bacterial strains has been identified as a potential solution for eliminating plastic waste without generating secondary pollution (Lee et al., 2020). However, this method has limitations, including slow processing times and the need for optimal conditions for effective biodegradation. An emerging solution is the biodegradation of plastic waste by arthropods. Several plastic-eating worms have been discovered that can digest plastic and convert it into non-hazardous compounds (Bombelli et al., 2017). To date, insects have been found to degrade seven types of plastics: polyethylene, polystyrene, polyvinyl chloride, polypropylene, polyphenylene sulfide, ethylene-vinyl acetate, and extruded polystyrene. The exact mechanisms of plastic degradation in insects are still being studied, but it is believed that enzymes and gut microbiota play a significant role.

3.1 Insect species capable of degrading plastic materials

Microorganisms, algae, and insects can biologically mitigate microplastics through processes like bioaccumulation, bioaugmentation, and biodegradation (Goveas et al., 2023). Researchers have noted the capacity of various insect orders, particularly coleopterans, and lepidopterans, to infiltrate and chew plastic materials, a phenomenon documented for over a decade (Pivato et al., 2022). As far back as the 1950s, scientists found that certain beetles and their larvae from families like Tenebrionidae, Anobiidae, and Dermestidae possessed remarkable abilities to break down plastic packaging (Boschi et al., 2023). Among the insect larvae identified as plastic consumers *Galleria mellonella*, *Tenebrio obscurus*, *Tenebrio molitor*, and *Zophobas atratus* are currently the most extensively researched plastivores, displaying higher efficacy in plastic degradation compared to other insect species. According to Goveas et al. (2023), larvae species of *Tenebrio* and *Galleria* have been observed degrading significant amounts of microplastics. These larvae demonstrate the ability to break down various types of plastics, such as polyethylene (PE), polystyrene (PS), polyvinyl chloride (PVC), polypropylene (PP), and low-density polyethylene (LDPE), gradually reducing their molecular weight and generating biomass (Yang et al., 2021; Wang et al., 2022).

Insect plastivores accomplish biological remediation through the action of natural microbes and enzymes found in the digestive system of the insects (Yasin et al., 2022). The biodegradation of plastic progresses through three successive phases: biodeterioration, biofragmentation, and assimilation, ultimately leading to the complete breakdown of the plastic. Biodeterioration initiates when various plastics degrade upon exposure to environmental elements like high temperatures, sunlight radiation, and fluctuations in water pH, before being consumed by insects. However, the effectiveness of degradation relies on both the duration of exposure and the intensity of the environmental factors. For instance, plastics in areas with elevated temperatures will degrade into microplastics more rapidly than those in cooler environments (Folino et al., 2020; Bahl et al., 2021; Yasin et al., 2022). The biofragmentation stage occurs during the digestion process within the insect's gut, facilitated by microbes. These microbes, particularly various bacterial strains, secrete enzymes like lipase, proteinase k, pronase, and dehydrogenase, capable of breaking down polymer chains into oligomers and monomers through processes such as depolymerization and hydrolytic cleavage (Bahl et al., 2021). Finally, during the assimilation stage, plastic monomers are converted into biomass by microbes and enzymes through processes like oxidation and biomineralization, releasing by-products such as water, carbon dioxide, and methane. Subsequently, the biomass, along with its by-products, is excreted as waste by the insect. Although the biodegradation process by various insect larvae is generally slower compared to physical and chemical methods, it remains an environmentally friendly, cost-effective, and practical approach to plastic remediation (Mughini-Gras et al., 2021; Seeley et al., 2020; Ali et al., 2021; Goveas et al., 2023). However, it's important to note that not all insects possess the capability to fully degrade microplastics into harmless biomass.

Plastic material	Insect Scientific name	Symbiont Microbes

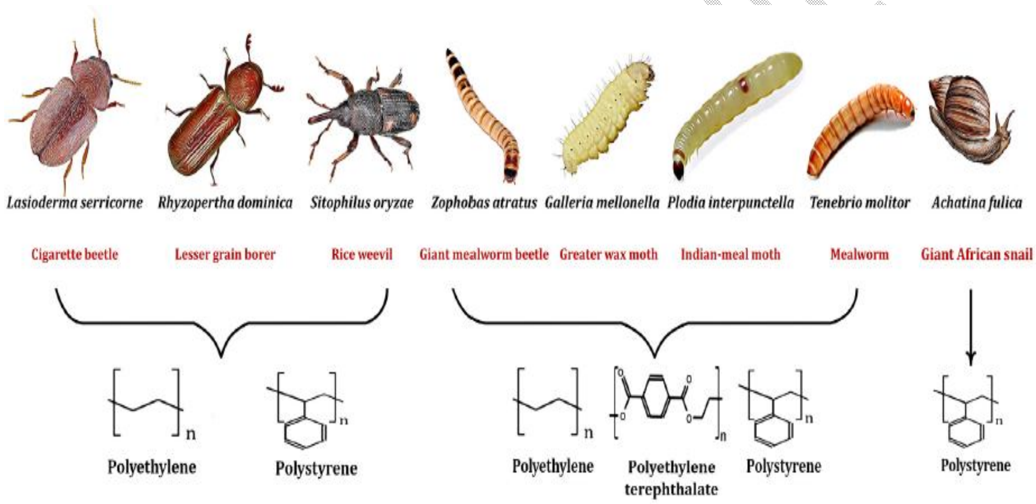

Fig .1 **Insect species capable of degrading plastic materials**

Source: Sameh et al. (2021)

Polyethylene	*G. mellonela*	*Enterobacter asburiae* YT1 *Bacillus* sp. YP1 *Enterobacter* sp. D1 *Aspergillus flavus*
	A. grisella	-
	P. interpunctella	*Bacillus* sp. YP1 and *Enterobacter asburiae* YT1
	C. cephalonica	-
	T. molitor	*Citrobacter* sp. and *Kosakonia* sp.
	Z. atratus	*Pseudomonas aeruginosa*
Polystyrene	*T. molitor*	*Exiguobacterium* sp. YT2, *Klebsiella*, *Pseudomonas* and *Serratia*.
	T. obscurus	-
	Z. atratus	*P. aeruginosa*
	T. castanium	*Acinetobacter* sp. AnTc-1
	Uloma spp	-
Polyphenylene sulphide	*Z. atratus*	*P. aeruginosa*
Ethylene-vinyl acetate	*T. confusum*	-
Polyvinyl chloride (PVC)	*T. molitor*	-

Table 1: Plastic types degraded by Insects and their Symbiont microbes (Bilal el al., 2021)

3.2 Factors affecting the degradation process of plastics

Plastic degradation is typically influenced by a combination of biotic and abiotic factors, with physicochemical processes occurring before biological degradation. Biotic factors encompass degradation facilitated by enzymes or microorganisms like fungi, algae, and bacteria, which are often present in insects. Fungi have been noted to secrete a greater quantity of enzymes for plastic degradation compared to bacterial diversity, making fungi more efficient degraders in terms of enzyme activity (Ali et al., 2021). Studies have indicated that abiotic factors, including soil composition, water content, weathering conditions, temperature variations, moisture levels, oxygen availability, and pH, play a crucial role in promoting higher rates of biodegradation and microbial growth compared to biotic factors such as microbial and enzyme activity (Bahl et al., 2021; Yasin et al., 2022). Plastics undergo degradation in the environment through several mechanisms, including photodegradation, hydrolysis, thermo oxidative degradation, and biodegradation. In natural conditions, the breakdown of common plastics like high density polyethylene, LDPE, and PP typically begins with photodegradation, primarily induced by UV-B radiation, followed by thermooxidation, and to a lesser extent, hydrolysis. Throughout degradation processes, plastics are fragmented into smaller pieces, leading to a decrease in the polymer's molecular weight (MW). The breakdown of these low-molecular-weight (low-MW) molecules can be facilitated by microorganisms (Andrady, 2011; Webb et al., 2013; Ali et al., 2021). However, the efficacy of living organisms in degrading microplastics is contingent upon the concentration and diversity of the microbes. Consequently, the moisture content of soil or water can stimulate insect microbes, indirectly impacting biodegradation, particularly during hydrolytic cleavage reactions (Bahl et al., 2021). Additionally, Pischedda et al. (2019) identified soil temperature as a significant factor influencing biodegradation by soil-dwelling microbes.

Although assessing and comparing the exposure of different types of plastics to various environmental factors presents challenges, recent research has emerged on the biodegradation of plastics (Peng et al., 2023; Luo et al., 2021; Nabi et al., 2021). The structural characteristics of plastic materials, including type, shape, size, molecular weight, chain length, strength, and physicochemical properties, along with additives and biosurfactants, significantly influence the biodegradability of plastics by microorganisms (Ahmed et al., 2018; Ali et al., 2021; Bahl et al., 2021; Pivato et al., 2022). Moreover, Bulak et al. (2021) noted that biodegradation in plastics consumed by insects is strongly influenced by factors such as insect consumption rate, larval growth rate, morphological changes (quantity and effectiveness of microbiota), and the chemical composition of the plastic. The efficacy of biotic biodegradation by microbes and enzymes from insect-fed plastics largely depends on the type of microbes, dominant microbial strains, developmental stage of the insect, substrate for feeding, and the structural properties of the plastic (Peng et al., 2023). Ahmed et al. (2018) also highlighted the crucial role of natural enzymes released by microorganisms, particularly bacterial and fungal species, in the bioremediation of plastics.

3.3 Mechanism of degradation of plastic by insect larvae

Before insects degrade plastic, exposure to various abiotic factors like heat, weathering, and UV radiation significantly affects the breakdown and degradation process by microbes and enzymes in the insect's diet. For example, weathered plastic exposed to high temperatures and UV light degrades faster than newly produced plastic of the same type. Additionally, studies by Du et al. (2021) and Akarsu et al. (2022) indicate that when insects are exposed to different plastic types, the plastics undergo significant changes, such as developing cracks and holes, leading to reduced molecular weight and morphological alterations. Worms and moths are particularly effective at degrading various plastics compared to other insects or microorganisms. In the past decade, interest has grown in the ability of insect larvae to degrade plastics such as PP, PS, and PVC. This suggests that the enzymes used by larvae to break down plant-derived and refractory polymers could also be used to degrade synthetic polymers. However, it is not yet clear if the larvae's capability to break down lignocellulose extends to other types of polymers, like plastics. Nevertheless, insects and their larvae have demonstrated the ability to biodegrade certain plastics, including PS and PE (Al-Tohamy et al., 2023).

A recent study (Yang et al., 2015) found that *T. molitor* larvae, commonly known as mealworms, can chew and consume expanded polystyrene (EPS). However, their inclination to eat plastic may be related to the digestive activity of gut microbes that assist in the digestion process. Symbiotic bacteria have been identified in the stomach, body cavity, and cells of various insects (Hosokawa et al., 2006). Based on this, it can be inferred that microorganisms significantly contribute to the breakdown of plastic compounds in the guts of insects. However, the ease with which larvae can bite into the material may depend on the specific properties of the plastics tested, as increased hardness makes it more resistant. Conversely, a higher melt flow rate (MFR), indicating longer polymer chains, might protect the material from being chewed by larvae, although high degradation levels were still observed for EPS (Urbanek et al., 2020). The larvae possess six short legs, two rudimentary hind prolegs, 13 segments with yellow-brown rings at the joints, a dark patch on the head, and dark stripes at the tail end. Yang et al. (2020) studied *Z. atratus* larvae from Beijing, China, and found that the larvae consumed, depolymerized, and biodegraded PS. The depolymerization of EPS significantly slowed when gut microbiota were inhibited with a mixture of antibiotics (Peng et al., 2020). This degradation mechanism allows insect larvae to consume and digest plastics as their sole food source, rapidly breaking them down into CO_2 and lower molecular weight compounds as they pass through the digestive tract (Brandon et al., 2018; Yang et al., 2020; Zhu et al., 2022). Lepidopteran larvae have a chewing mechanism involving a pair of jaws, which becomes atrophied in adults. The larvae retain the chewing mouthparts (Pivato et al., 2022). However, some bacterial strains isolated from insect guts exhibit lower degradation rates than others. Although plastic breakdown in insects occurs through metabolic and enzymatic processes, various insect microbial species, including different bacterial strains, secrete distinct enzymes responsible for different microbial activities, such as plastic biodegradation. The predominant strains responsible for plastic biodegradation within insect guts belong to the phylum Pseudomonadota, followed by Bacillota. These strains can degrade various types of microplastics, particularly PE, PS, PVC, LDPE, and HDPE (Elahi et al., 2021). Species from the Bacillota phylum, such as *Bacillus siamensis*, release protease enzymes for plastic degradation. In contrast, fungal species like *Aspergillus niger* and *Aspergillus japonicus* use laccase enzymes for their catalytic activity (Ahmed et al., 2018; Elahi et al., 2021). According to Ghosh et al. (2013), the plastic biodegradation mechanism in insects primarily involves the metabolic and enzymatic actions of microbes, which lead to significant changes in polymer structure by reducing the molecular weight of the plastics.

3.4 Effect of plastic on the gut microbiota of insects

The degradation of microplastics by microbes directly impacts the growth and proliferation of the microbes within the gut. The specific type of plastic and the species of insect involved significantly determine the alterations observed in the bacteriome. In addition to individual bacteria, various microbial communities can degrade plastic polymers, and these consortia often exhibit higher efficiency in biodegradation compared to single strains. This efficiency can stem from direct participation in the degradation process or the removal of potentially harmful degradation byproducts. For instance, a consortium composed of five different *Bacillus* and *Pseudomonas* strains demonstrated synergistic growth when polyethyelene terephthalate (PET) was the sole carbon source, displaying collaborative behavior and cross-feeding abilities in a nutrient-limited environment. Specific members of microbial communities can indirectly enhance biodegradation by engaging in metabolic cross-feeding or producing metabolites that promote co-metabolic degradation. The abiotic breakdown of polyolefins like PE, PP, and PS, which are typically inert and resistant to microbial attack, is facilitated by microbes. Studies on microorganisms have established that plastic degradation by insects is primarily mediated by bacteria or fungi present in their gut. Consequently, research efforts have predominantly focused on investigating the involvement of the gut microbiome in the degradation process, operating under the hypothesis that larvae like *G. mellonella* can consume, digest, and derive energy from plastic. However, studies have indicated that the role of microorganisms in PE degradation by *G. mellonella* larvae is relatively minor compared to the larvae's own enzymatic activities, as evidenced by minimal variations in species diversity and richness indices. Additionally, several taxa commonly found in other lepidopterans are also present and well-represented in *G. mellonella*, further suggesting that the contribution of microorganisms to PE degradation is limited (Boschi et al., 2023).

It is crucial to acknowledge that the growth and efficiency of insect microbes may be adversely affected by environmental factors like high temperatures and humidity. This can lead to the accumulation of toxic substances such as heavy metals and chlorine (Wei et al., 2019). Plastic incorporation into insect diets significantly alters gut microbiota, particularly the bacterial community, as highlighted by Goveas et al. (2023). This alteration negatively impacts bacterial populations by reducing levels of hydrolytic and acidogenic bacteria responsible for fermenting and hydrolyzing soluble organic monomers. Additionally, the inclusion of PVC in insect diets notably decreases species from the Firmicutes, Actinomycetes, and Bacteroidetes phyla.

However, while microplastic inclusion in insect diets appears to have a greater influence on fungal communities than bacterial diversity within the gut (Ahmed et al., 2018). The digestion of plastics by insects may harm the intestinal lining, disrupting normal cellular function and resulting in poor nutrient utilization necessary for growth and reproduction. This can lead to increased mortality rates in some insect species and exposure to reactive oxygen species (ROS) due to the reaction of molecular oxygen with microplastics (Li et al., 2024). Furthermore, in vertebrates, the deposition of microplastics can block digestive tracts, causing starvation and energy loss, potentially leading to severe illness or death (Goveas et al., 2023).

4. Challenges

In general, larvae of coleopteran species like *T. molitor, T. obscurus*, and *Z. atratus*, as well as lepidopteran species such as *Plodia interpunctella* and *Achroia grisella*, have demonstrated the ability to consume non-biodegradable polymers such as polystyrene, polyethylene, polyvinyl chloride, and polypropylene (Sanchez-Hernandez, 2021). These plastic-consuming larvae have been termed "plastivores" in a study conducted by Cassone et al. (2020). It is suggested that the ability of insects to digest plastic is facilitated by the gut microbiota present in their larvae (Cassone et al., 2020). In this process, the larvae mechanically fragment the polymers, and the resulting small fragments are then exposed to bacteria present in the insect's gastrointestinal tract. According to Bertocchini and Arias (2023), the presence of oxidized plastic pieces that can be metabolized by both bacteria and insect tissues presents challenges in the sorting of waste plastic**.** One of the main challenges in current plastic biodegradation studies is the absence of a standardized approach to accurately assess and compare the plastic-degrading capabilities of isolated microbes and enzymes. There is no universal benchmark for evaluating plastic biodegradation due to the diverse methods used to quantify it, including weight loss, biofilm formation, and reduction in tensile strength (Thew et al., 2024). Furthermore, besides influencing an insect's growth and development, different compositions and structures of plastics lead to variations in the degradation efficiency among various insect species.

Additionally, each dataset on gut microorganisms has shown a wide range of bacterial genera or families (Montazer et al., 2018; Ren et al., 2019), and the initial bacterial species identified in *P. interpunctella* and *T. molitor* have not been consistently observed again (Yang et al., 2014; Taghavi et al., 2021), despite the extensive data collected thus far. Given that the digestive system of these insects consists of a relatively uniform tubular structure without clear adaptations for hosting a structured microbiome, the lack of consistency in research findings, even within the same insect species, is not surprising. The bacterial communities present in the larvae's guts of lepidoptera are highly diverse and seem to be influenced by the specific environments in which each lives (Engel and Moran, 2013). Furthermore, achieving a balanced co-diet containing essential nutrients is crucial for enhancing larvae consumption and plastic degradation. Studies have shown that when larvae were provided with wheat bran or soy protein alongside polystyrene (PS), they consumed PS after consuming the protein. Compared to unfed controls, all feeding conditions resulted in higher survival rates. For mealworms given PS along with soy protein or wheat bran, as well as for larvae fed PS alone, the survival rate values were similar. However, the addition of soy protein or wheat bran significantly increased the rate of PS decomposition compared to PS alone (Yang and Wu, 2020).

5. Future prospects

Years of research in the field of microorganism biodegradation have heavily influenced the experimental approach to understanding plastic degradation by insects. The gut microbiota has been a central focus of research since the initial data collection. However, there has been questioning regarding the relevance of larval gut microbiota in plastic degradation, suggesting that the animal may possess some inherent mechanism for this function (Kong et al., 2019; Yang et al., 2021). A recent study on *G. mellonella* larvae showcased a remarkably rapid ability to oxidize untreated polyethylene (PE) within a few hours of contact (Sanluis-Verdes et al., 2022). Waxworms have been shown to degrade polyethylene using their saliva. After several hours of exposure in an aqueous solution at room temperature, the saliva oxidizes the polymer, resulting in the formation of small oxidized molecules as degradation by-products (Sanluis-Verdes et al., 2022). The study also identified waxworm enzymes in larvae saliva belonging to the family of phenol oxidase activities known as PEases. Gas chromatography-mass spectrometry analysis revealed degradation products such as small oxidized aliphatic chains, confirming the breakdown of the polymer into shorter molecules. Proteomic analysis of GmSal, a salivary protein in waxworms, indicated the presence of a few enzymes from the hexamerin/prophenoloxidase family (Sanluis-Verdes et al., 2022). This study marks the first instance of enzymes breaking down PE without any abiotic pretreatment, shedding light on the chemical mechanisms driving this enzymatic oxidation and opening avenues for future research.

Another avenue of research worth exploring is the identification of new insect species capable of plastic biodegradation. While coleopteran and lepidopteran larvae have shown promise in this regard, alternative candidates merit investigation. The black soldier fly (BSF), *Hermetia illucens*, for instance, is a dipteran larva known for its strong appetite and its role in bioconverting various organic wastes (Gold et al., 2018). Although there is limited evidence regarding *H. illucens* ability to consume plastic debris, recent studies suggest that utilizing these larvae for bioconversion of plastic-contaminated organic wastes may be feasible. Research indicates that the survival and weight of *H. illucens* larvae fed meat or vegetables containing 3–6% plastic packaging material did not differ significantly from larvae fed plastic-free food (van der Fels-Klerx et al., 2020). Termites, commonly found in soil environments, represent another group of insects with potential plastic-degrading capabilities, primarily attributed to their gut microbiota (Kumar et al., 2022; Lopez-Naranjo et al., 2013). While termites typically feed on biomass, they have been observed to degrade various polymers, despite plastics not being their natural food source. The resistance of plastics to termite attack depends on their mechanical hardness and surface structure, but similarities between plastic and lignocellulosic biomass enable termite gut microbes to contribute to polymer degradation. For instance, *Xylaria* sp., a fungus isolated from wood-feeding termites, demonstrated the ability to degrade polymer sheets and utilize them as a carbon source. Additionally, a consortium consisting of low-density polyethylene and a tri-culture yeast consortium exhibited significant LDPE degradation, with a 33.2% reduction in net LDPE mass compared to individual yeast treatments. These yeasts produced a range of LDPE-degrading enzymes, leading to the production of various metabolites such as alkanes, aldehydes, ethanol, and fatty acids. This research presents a novel approach utilizing LDPE-degrading yeasts from wood-feeding termites to biodegrade plastic waste (Elsamahy et al., 2023).

6. Conclusion

Plastic is widely used globally due to its low cost, ease of processing, and portability. However, improper disposal of plastic products has led to significant pollution, with no ideal solution for managing discarded plastics. Traditional methods such as landfilling and chemical treatment have shown limitations and substantial environmental impacts, as plastics are inherently difficult to decompose. Using insect larvae to degrade plastics offers advantages like low cost and no secondary pollution. Additionally, these insects can serve as valuable animal nutrition sources. Recent research has explored the breakdown of plastics by specific microorganisms and insect larvae, though practical applications remain limited. Further experiments are needed to identify new insect species capable of consuming plastic, determine the types of plastic preferred by different insects, and enhance the efficiency of plastic digestion by insect larvae. Recycling waste plastics by feeding them to insects could be a viable solution. To ensure safety, researchers must conduct toxicological analyses on insects that consume plastic to mitigate any toxicological risks or the accumulation of harmful substances.

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