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Mitigation of Soil Pollution by Biodegradation of Plastic Materials through Activity of Mealworms

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

An excellent illustration of this idea is the use of insects in circular production systems, since they are capable of converting a variety of organic waste and byproducts into nutrient-rich feedstocks that are subsequently recycled back into the production cycle. This study reviews the use and applicability of mealworms (Tenebrio molitor) in many industries, including food, agriculture, pharmaceuticals, and more, in order to investigate their potential in circular production systems. This insect is highly versatile and has the potential to replace other sources of nutrients and other vital

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components, but its adoption and acceptability are currently hampered by a number of behavioral and legislative issues. The majority of plastics made from petroleum do not biodegrade in the environment. Research on the biodegradation of plastics by insects was prompted by observations of damage, penetration, and ingestion of plastics by insects and their larvae. More investigation is required to fully understand the mechanisms underlying the fast biodegradation of PS and PE. It is probable that intestinal microbial activities and the host digestive system work in concert to produce this effect. This review's primary goal is to examine insects' potential from a circular economy standpoint, with a particular emphasis on mealworm larvae. This research will also help to mitigate climate change by lowering soil contamination.

Keywords: Plastic; mealworms; soil pollution; biodegradation; soil health.

1. INTRODUCTION

The majority of plastics made from petroleum do not biodegrade in the environment. Research on the biodegradation of plastics by insects was prompted by observations of damage, penetration, and ingestion of plastics by insects and their larvae. Darkling beetle larvae (Coleoptera: Tenebrionidae), in particular Tenebrio molitor and Tenebrio obscurus larvae, demonstrated the ability to rapidly degrade polystyrene (PS) in the gut in a manner that is dependent on gut microbes. Larvae of T. molitor also break down low-density polyethylene (LDPE) [1]. Plastic mass balance, ingested polymer modification, the creation of biodegraded intermediates, and 13C isotope tracer assays were used to assess the biodegradation. After one or two weeks of adaptation, ingested PS or LDPE polymer can depolymerize by up to 60–70% in 12–24 hours. The larvae receive energy from ingested PS or PE for survival, but not for growth. Co-feeding a regular diet, such as bran, greatly increases the rate at which PS and PE are consumed [2-4]. Following the larvae's feeding with PS or PE, changes occurred in the gut microbial populations. Though they grow slowly on plastics, a few gut bacterial strains that break down plastic have been identified from the gut of T. molitor. The host digestive system and the synergistic effects of intestinal microbial activities are probably the cause of the rapid biodegradation of PS and PE, but more investigation is required to determine the exact mechanisms [5,6].

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2. GLOBAL SIGNIFICANCE

Plastic trash contamination of soil results in serious environmental damage and may cause crop productivity to fall. A 10,000-ton landfill's worth of plastic wastes takes up 0.067 hectares of land. In addition, the disposal of plastic wastes releases a significant number of chemicals, such as oligomers, catalyst residues, solvents used in polymerization, and a variety of plastic additives [12]. These dangerous substances may seep from the plastic trash and affect nearby groundwater and soil quality. Plastic waste has been a big worry in water contamination as it damages the aquatic ecosystem, affects huge ocean species, and deteriorates the fishing sector. According to a recent analysis, the amount of plastic garbage that finds its way into the ocean each year ranges between 0.48 to

1.27 million tonnes. This amount of plastic waste is expected to double in ten years. The rate at which plastic is being introduced into the ocean is remarkable. According to studies, 60–80% of all marine debris is made up of plastic wastes that are found throughout the marine environment, including on the seabed, shorelines, and sea surface. Over 50% of plastics have chemical constituents that are considered harmful, according to a hazard-ranking model based on the Globally Harmonized System of Classification and Labelling of Chemicals developed by the United Nations [13-15]. These dangerous substances are more likely to seep into food webs as tiny or micro plastic debris or leach from plastic wastes. They may also have an effect on corals, salt-marsh grasses, mussels, and other ecologically significant species. Chemicals from plastics and tiny or micro plastic particles can collect in the bodies of humans and mussels, harming cells and other tissues [12].

3. PLASTIC WASTES MANAGEMENT STRATEGIES

Aside from the dangers and threats to public health and environmental security, inappropriate handling and disposal of plastic trash negatively detracts from the natural beauty of both urban and rural areas. There are two primary categories into which plastic waste generation can be divided [16].

3.1 Industrial Plastic Wastes

Postconsumer plastic wastes: Plastics that are abandoned throughout the plastic production and product fabrication processes are referred to as Preconsumer or industrial plastic wastes. The production and processing departments can reuse and recycle certain types of plastic wastes directly. Solutions for the sustainable management of plastic wastes should use processes or technologies that satisfy the standards for effective resource recycling without producing toxic or hazardous byproducts or end products that endanger human health or the environment [17].

Biodegradation of polystyrene wastes: PS Wastes are Biodegraded by PS-Eating Mealworms Tenebrio molitor Linnaeus is a holometabolic insect that goes through the stages of egg, larva, pupa, and beetle before producing yellow mealworms. These are commercial animal feed that is sold in pet stores and markets, as well as pest insects for storage [18]. In the 2000s, some middle and high school students used the public media (newspapers and the internet) for science fairs to report on their findings about mealworms consuming Styrofoam and the isolation of germs from the mealworms' stomach. But because they did not produce peer-reviewed articles or isolate archiving, these early investigations did not garner scholarly attention. Plastic foam, such as Styrofoam, is something that mealworms like to chew and consume [19].

Future research and perspectives of microbial degradation of plastics: The mealworms' guts metabolized up to 40–50% of the PS they had eaten in the span of their 12- to 15-hour gut retention period. Antibiotic-related research has revealed that PS biodegradation is probably dependent on gut microbes. However, no isolated microbe—including strain YT2 from the mealworm gut—has been shown to be able to break down PS as quickly as mealworms. To fully comprehend the processes underlying PS biodegradation in mealworm guts and the interactions between the mealworm host and gut microorganisms, more research is required [6]. In order to choose highly effective mealworm strains and microbes, it is important to look into the global ubiquity of PS biodegradation by mealworms in connection to their gut microbiota. Subsequent research in microbiology should concentrate on isolating and characterizing more PS-degrading single cultures as well as identifying high-efficiency mixed cultures (if any) from different PS-degrading mealworm species [20].

4. CONCLUSION

The need to find alternate sources of protein is growing, and in the coming years, it is anticipated that the production of insects will increase considerably. Considering the "zero waste" environment and the requirement to support the circular economy, it is essential to utilize every part of the insect, including its frass. According to this study, there is a lot of potential for using frass to replace mineral NPK fertilizer, either entirely or in part. In fact, straw is just as effective as NPK fertilizer at supplying N, P, and K and maintaining biomass output because of its quick mineralization and high concentration of immediately available nutrients. Additionally, the presence of frass reduces the concentration of water soluble P up to five times more than that of mineral fertiliser by preventing P from sorption onto soil constituents and loss. Most significantly, when paired with mineral fertiliser, frass may enhance microbial metabolic activity and diversity, indicating improved soil functioning. Since this study was conducted in a greenhouse, more in situ investigations are necessary because the timing of mineralization under controlled conditions may differ from that of mineralization in the field due to variations in soil, moisture, temperature, and crop biodiversity, among other factors. These variations may also have an impact on the timing of nutrient release for plants. However, our results imply that the anticipated increase in the amount of frass produced in the near future could represent a viable substitute for traditional fertilizer and a sustainable resource for controlling NPK nutrition in cropping system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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