Microbial Degradation Mechanism of Microplastics

Xueqin Wang*
Chongqing College of Architecture and Technology, China

Keywords: Microplastics, Microorganism, Microplastic Degradation Mechanism, Insect.

Abstract: Microplastics refer to plastic particles with less than a diameter of 5mm and are a widely distributed, persistent pollutant with environmental toxicity and biotoxicity. Microbial degradation of microplastics is an environmentally friendly treatment technique without secondary pollution. On the basis of exploring the degradation mechanism of microplastics by animals and microbial degradation mechanism of microplastics, this paper analyzes the problems in the existence of microplastics degradation research, and puts forward the research of microplastics degradation in the future, so as to provide a basis for the deep degradation research of microplastics.

1 INTRODUCTION

Microbial degradation of microplastics mainly is the use of microbial feeding, metabolism and other processes to convert plastics and other organic waste into water and carbon dioxide and other end products into the geochemical cycle. Microbial degradation of plastics is an environmentally friendly, no secondary pollution, and relatively economical treatment technology. At the same time, microbial genes are heritable and adaptable, microbial genome is small, and there are a large number of suitable molecular operation means and tools can be used, which on the one hand is conducive to the study of metabolic mechanism, also to improve the efficiency of microbial degradation or metabolic path, achieve the actual production application demand. Therefore, the biodegradation of microplastics has been widely concerned by scholars. At present, on the biodegradation of microplastics, one part studies the rodent degradation effect of animals (mainly insects and soil animals) on microplastics, and the other part focuses on the study of microbial degradation of microplastics, including some bacteria, fungi and actinomycetes.

2 MECHANISM OF MICROPLASTICS DEGRADATION BY ANIMAL

The degradation of plastic by insects or soil animals mainly depends on the role of intestinal microbial populations and enzymes with biodegradable plastic in their intestines (Giacomucci, 2019). Different insects have different ability to degrade plastics, and different insects degrade different plastics. However, the degradation efficiency of microplastics isolated from the intestines of these animals in vitro is much lower than that in the gut of (Yang, 2015), which may mean that the degradation of plastics in insect (or soil animal) intestines is the result of a combination of biological-chemical reaction mechanisms.

The plastic degradation process by animals can be divided into the following four steps:

1) Animals use mouthparts to chew plastic film and grind in the foregut. This is mainly a physical process.

2) Gut microorganisms in insect's or soil animal's gut adhere to and erode plastic fragments. Bacillus, Corynebacterium, microptococcus and streptococcus erode the plastic and change its physical and chemical properties in preparation for further degradation.

3) Plastic fragments are bioenzymatic or enzymatically hydrolysed into oligomer fragments.

* Wang Xueqin (1984-), female, associate professor, master

Wang, X.
Microbial Degradation Mechanism of Microplastics.
DOI: 10.5220/0012021500003633
In *Proceedings of the 4th International Conference on Biotechnology and Biomedicine (ICBB 2022)*, pages 392-395
ISBN: 978-989-758-637-8
Copyright © 2023 by SCITEPRESS – Science and Technology Publications, Lda. Under CC license (CC BY-NC-ND 4.0)

Key enzymes such as lipase and mitochondrial carnitine acetyltransferase in insects or soil animals cause-C-C-breakage of plastic and eventually degrade plastic membranes.

4) After being degraded into oligomers by the above three processes, plastics are further degraded and metabolized, and they are eventually absorbed or excreted by gut microbes or insect bodies.

Figure 1 summarizes the mechanism of plastic degradation by microorganisms and key enzymes in the gut of insects or soil animals.

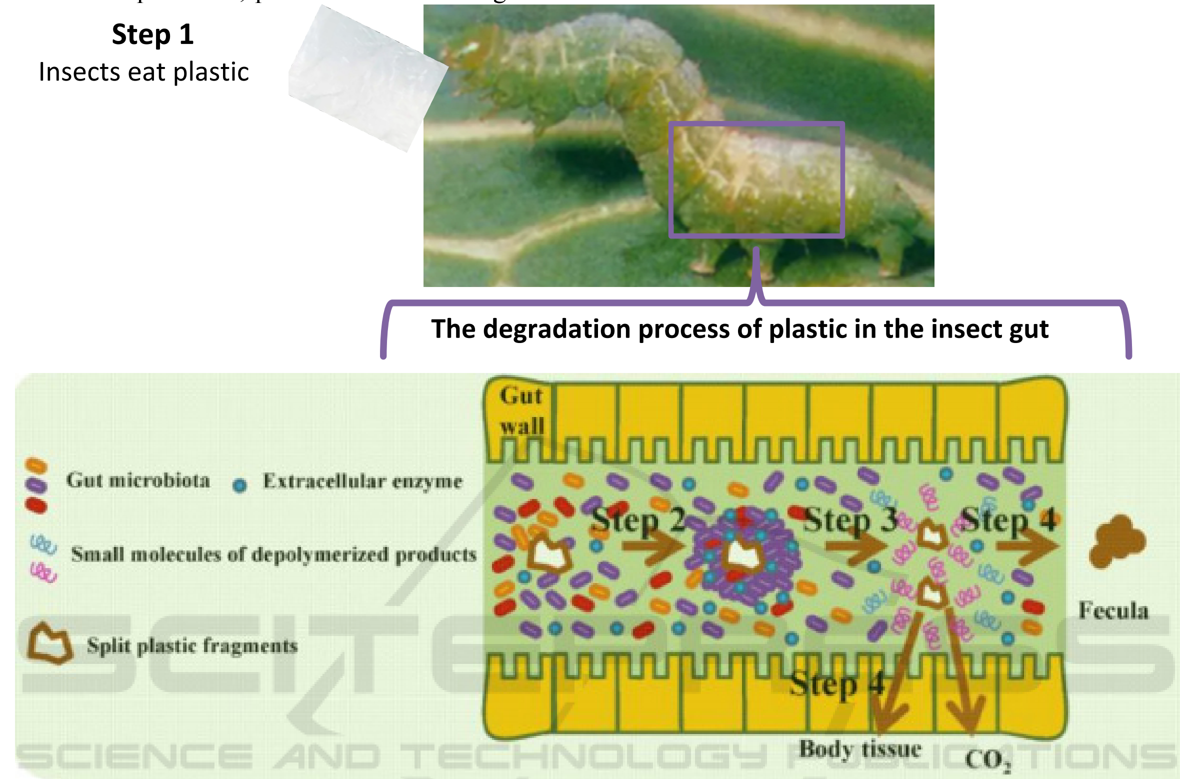

Figure 1: Mechanism of plastic degradation in insect's or soil animal's gut.

As can be seen from Figure 1, the degradation mechanism of plastic by insects or soil animals is quite complicated. The degradation process of plastic is the result of the chewing and crushing of plastic by insects or soil animals, and the combined action of enzymes, special secretions and microorganisms on plastic particles in the insect gut.

3 MECHANISM OF MICROBIOLOGICAL DEGRADATION BY MICROPLASTICS

In addition to animal gut microorganisms can degrade plastic, microorganisms in the natural environment or some special environment have the ability to degrade plastic, and some bacteria can use plastic as the sole carbon source.

In the process of plastic degradation, microorganisms often secrete extracellular enzymes to promote the degradation of plastic, which is the most core active material in the process of plastic degradation (Albertsson, 1998). For example, trichomonas testosterone Comamonas testosteroni is capable of producing different enzymes on the broken link of ester bonds and the open ring of the benzene ring, monooxygenase in microbial cells oxidizes PE to hydroxyl group, which is further oxidized by alcohol dehydrogenase, which can be further oxidized to ester group, which further hydrolysis into carboxylate low molecule products catalyzed by esterase, and finally the product enters the central metabolic cycle in the cell (Wasserbauer, 1990). PET enzymes in the strain first hydrolyze PET into ethylene glycol terebenzoate monomer (MHET) and terephthalic acid (TPA) (Yoshida, 2016). Subsequently, the enzyme speculated as lipoprotein MHET enzyme hydrolyzes MHET into terephthalic acid and ethylene glycol (EG). TPA is metabolically oxidized by 1,2-dioxygenase, 1,2-dioxygenase, 1,2-dihydroxy-3,5-cyclohexadiene-1,4-diethyl acetate dehydrogenase after being transported to a specific unit. The benzene ring on the end product, primary catechin acid (PCA), is opened by PCA3,4-dioxygenase.Figure 2 summarizes the metabolic pathwayfor microbial degradation of PE and PET .

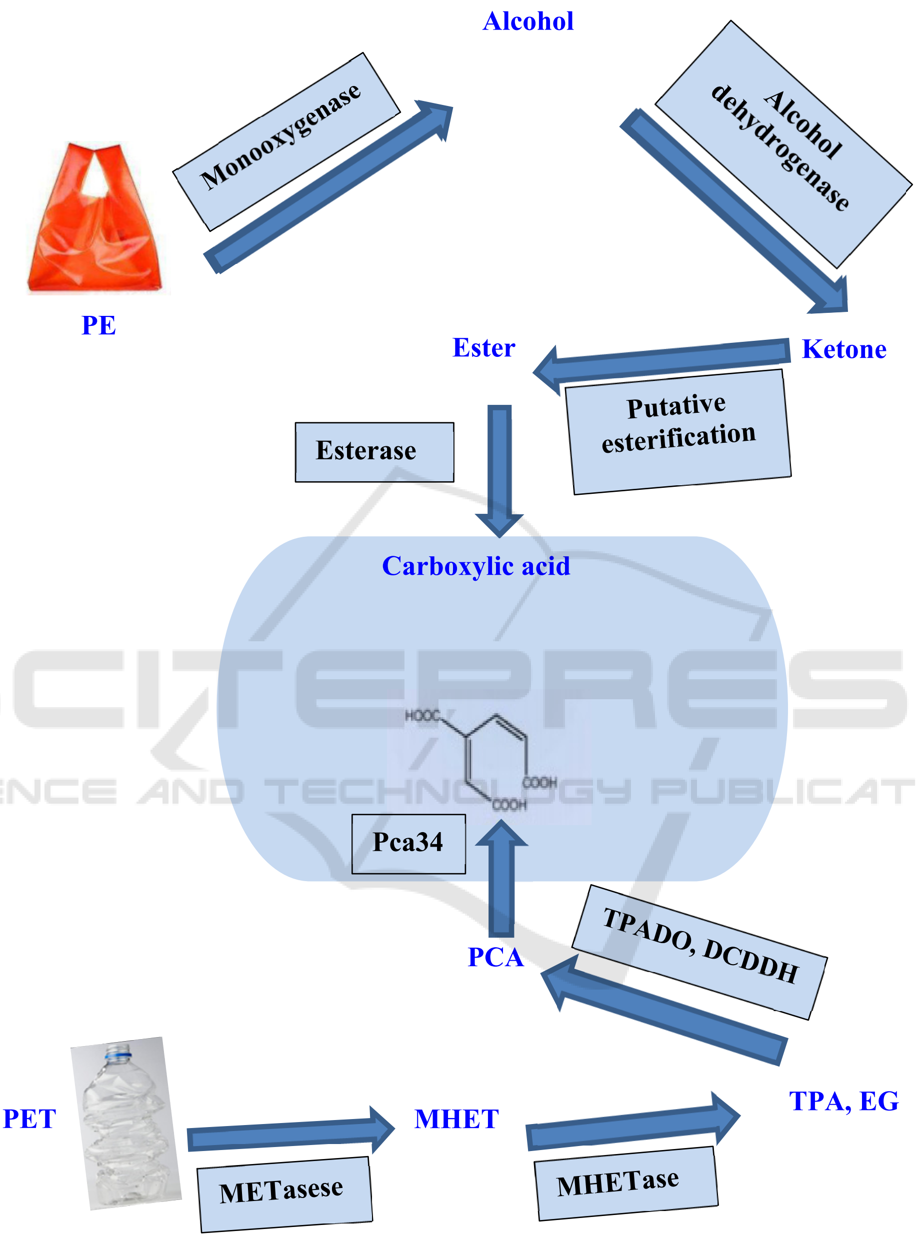

Figure 2: Putative metabolic pathway of PE and PET by microbes.

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

To sum up, the microbial degradation of microplastics is mainly divided into four steps.

1) Bio-deterioration. The microbial community and abiotic factors work together to intercept the polymer (plastic) into fragments.

2) Depolymerization. Microorganisms secrete enzymes and free radicals. Transform the polymer into an oligomer, dimer, or monomer. This process is mainly a process in which hyperomers are cleaved or oxidized to produce low molecular intermediates.

3) Assimilation. The depolymerized molecules are recognized by the receptors on the microbial surface to pass through the plasma membrane and enter the microbial cell. This process is when low

molecular products are taken up by microorganisms and assimilated into their own cellular material.

4) Mineralization. The molecules are depolymerized to small molecule compounds such as CO2, N2, CH4 and H2O. The depolymerization material is degraded by microorganisms into methane, water and so on under aerobic conditions.

4 CONCLUSION

So far, although it has been confirmed that a variety of plastics can be degraded by microorganisms, and the microorganisms or biological enzymes that degrade plastics have been found, but the current research on the microbial degradation of plastics still has the following problems.

1) At present, it is found that the degradation efficiency of plastics by microorganisms is very slow. So the means of optimizing microbial degradation should be further explored, and the microbial degradation pathway of high-efficiency plastics should be deeply studied.

2) At present, there are few kinds of strains with the ability to degrade plastics, so it is urgent to find the microbial and enzyme systems that effectively degrade plastics and enrich the resource pool of degraded strains.

3) The microbial degradation mechanism of microplastics is not clear, and is only a preliminary understanding of the degradation process. The research on the enzymatic, chemical and energy metabolism of the microplastic degradation process should be strengthened, the key enzymes and their mechanisms should be determined, and the gene modification research of the key enzymes for degradation should improve their activity and yield.

4) Some microorganisms in the gut of animals have the ability to degrade microplastics in animals, but not in the in vitro environment. In future studies, the degradation level can be improved by the modification of known degrading bacteria or the optimization of experimental conditions.

REFERENCES

Albertsson A., Erlandsson B., Hakkarainen M., et al. Molecular Weight Changes and Polymeric matrix changes correlated with the formation of degradation products in biodegraded polyethylene [J]. Journal of Polymers and the Environment, 1998, 6(4): 187 - 195.

Giacomucci L, Raddadi N, Soccio M, et al. Polyvinyl chloride biodegradation by *Pseudomonas citronellolis* and *Bacillus flexus*. New Biotechnol, 2019, 52: 35-41.

Wasserbauer R., Beranová M., Vancurová D., et al. Biodegradation of polyethylene foils by bacterial and liver homogenates [J]. Biomaterials, 1990, 11(1): 36-40.

Yang J., Yang Y., Wu W., et al. Biodegradation and Mineralization of Polystyrene by Plastic-Eating Mealworms: Part 1. Chemical and Physical Characterization and Isotopic Tests [J]. Environmental Science & Technology, 2015, 49(20): 12080-12086.

Yoshida S., Hiraga K., Takehana T., et al. A bacterium that degrades and assimilates poly (ethylene terephthalate) [J]. Science, 2016, 351(6278): 1196.