Topic: Enzyme Biotechnology

Mutant Enzyme Breaks Down Plastic: A Potential Solution to Global Plastic Pollution Crisis

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Plastics have become an integral part in our society and in our daily lives. Their everyday use is driven by their incredible versatility combined with their low production costs. While plastics have found indispensable place in our daily lives, their incredibly high resistance to biodegradation is a serious problem that results in ultra-long life times of these materials. In addition, recyclability of plastics is another major challenge. This implies that they can likely last centuries in the environment causing catastrophic global pollution threats.

The heavy dependence on plastics in our modern society can result in the continuation of massive build-up of plastics unless solutions are found to this global pollution threat, especially in marine ecosystems. According to an estimate, about 1 million plastic bottles mostly made of Poly(ethylene terephthalate) (PET) are sold each minute around the globe and, with just 14% recycled, many end up in the oceans, where they are believed to pollute even the remotest parts, thereby harming marine life and potentially also people who eat seafood. PET is one of the most abundantly produced synthetic polymers. However, the high resistance of PET to biodegradation results in its accumulation in the environment at a staggering rate as discarded bottle packaging and also textiles and pose environmental concerns [1].

Secreted Mutant Enzyme PETase (PET-Digesting Enzyme)

Enzyme Technology is one the most promising disciplines in modern biotechnology and offers hope to mitigate global plastic pollution crisis and associated environmental concerns. Enzymes have a wide range of applications because they are non-toxic, biodegradable and can be produced in

large amounts by microorganisms. Recently, biotechnologists discovered bacterium, *Ideonella sakaiensis* 201-F6 that was shown to exhibit the rare ability to grow on PET as a major carbon and energy source [2]. This plastic eating bacteria *Idonella sakaiensis* is unique and different from other plastic attacking micro-organisms as it can be grown easily and can adhere to PET effectively to facilitate degradation. Researchers have found that this bacteria when left in a jar with warm water and some nutrients can grow fast and easy. The PET biodegradation was shown to be triggered by a secreted mutant enzyme PETase (PET-digesting enzyme) (Figure 1) [1]. As illustrated in Figure 1, researchers demonstrated that an *I. sakaiensis* enzyme dubbed PETase (PET-digesting enzyme) converts PET to mono(2-hydroxyethyl) terephthalic acid (MHET), with trace amounts of terephthalic acid (TPA) and bis(2-hydroxyethyl)-TPA as secondary products. Subsequently, a second enzyme, MHETase (MHET-digesting enzyme), further converts MHET into the two monomers, TPA and ethylene glycol (EG). Both enzymes are believed to be secreted by *I. sakaiensis* and likely act synergistically to depolymerize PET [1, 2].

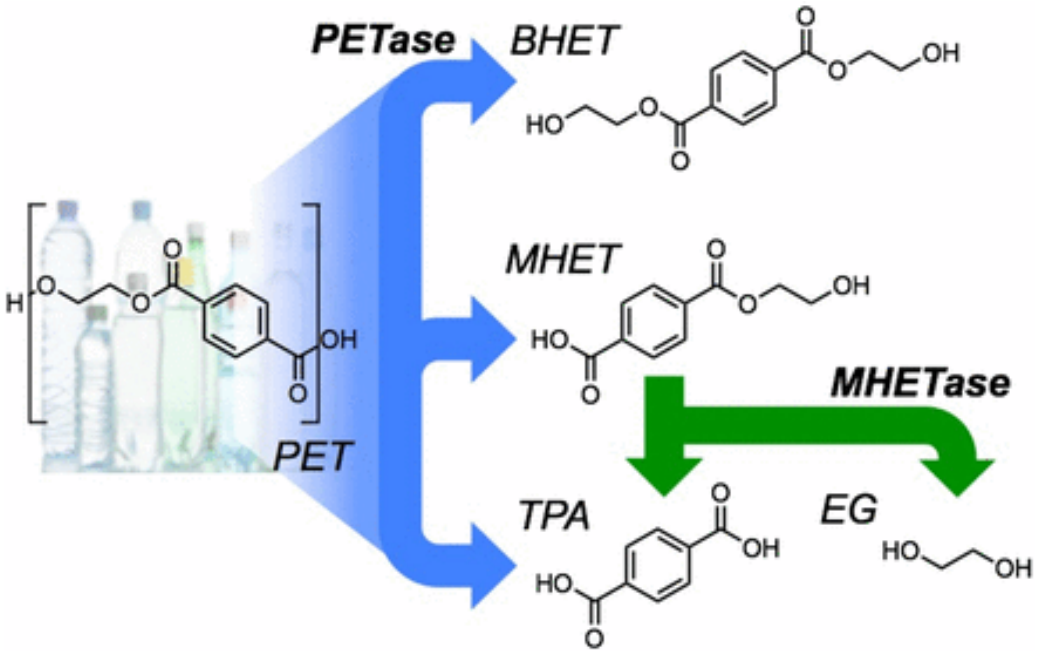

*Figure 1: Schematic illustration of mechanism of how PETase catalyzes the depolymerization of PET to bis(2-hydroxyethyl)-TPA (BHET), MHET, and TPA. MHETase is shown to convert MHET to TPA and EG [**Source:** PNAS 115, 2018].*

Researchers characterized the 3D structure of this newly discovered enzyme that can digest highly crystalline PET, which is the primary material that is used in the manufacture of single-use plastic beverage bottles, in textiles for clothing, and also in carpets. They engineered this enzyme for improved PET degradation capacity and further demonstrated its capability to further degrade an important PET replacement, polyethylene-2,5-furandicarboxylate.

The structure as revealed by crystallography of the enzyme was observed to be very similar to one evolved by many bacteria to break down cutin, a natural polymer that is used as a protective coating by plants. However, when the researchers manipulated the enzyme to explore this connection, they observed that its ability to eat PET was significantly improved. This provides new opportunities for bio based plastics recycling [1]. The structure/function relationships investigated by the researchers could be used to guide further protein engineering to more effectively depolymerize PET and other synthetic polymers. This innovative biotechnological strategy can help mitigate the environmental pollution of plastic accumulation in nature [1].

Concluding Remarks

The advances in enzyme biotechnology have enabled to open new R&D avenues to find biodegradable mechanisms of synthetic plastics. To this end, the discovery of a bacterium that uses PET as a major carbon and energy source offers hope to provide enzymatic mechanism functions that enable effective breaking of highly resistant polymeric substrate that appears to survive for centuries in the environment. Future research needs to be directed towards additional protein engineering to increase PETase performance and extend the knowledge of structure-property correlation for biodegradation to other synthetic polymers that are used in commercial packaging.

References for further reading:

[1] Austin H P et.al. (2018) Characterization and engineering of a plastic-degrading aromatic polyesterase, PNAS. 115 (19) E4350-E4357.

[2] Yoshida S, et al. (2016) A bacterium that degrades and assimilates poly(ethylene terephthalate). Science 351:1196–1199.

Author's Biography

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Dr Shyamasri (Shya) Biswas is executive publisher of Biotechnology Kiosk. She received her PhD in biotechnology from Banaras Hindu University, Varanasi, India. During her PhD, she received the prestigious DAAD sandwich research fellowship to carry out her PhD work at the University of Potsdam, Germany. After her PhD, she was a scientist in several labs in the United States that include University of Massachusetts, Worcester MA, North

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