Abstract

[Project Information]

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The huge amount of used synthetic polymers from petroleum has been discharging and mostly incinerating or landfilling because of lacking effective recycle method. Thereby, they cause serious global problems such as CO_2 emission and microplastic pollution. Thus, the development of the novel technology for re-cycling waste plastics is required strongly. In this research, to develop a novel upcycling technology for waste plastics, we studied the enzymatic degradation of nitrile rubber (NBR), polypropylene (PP), and polyethylene (PE) and the conversion of the decomposition products into valuable compounds such as biodegradable plastics, PHA. We have revealed the enzyme genes and metabolic pathway involved in the assimilation of NBR, PE, and PP. The first enzyme degrading these plastics were all membrane-bound oxygenase. Aldehydes, ketones, and alcohols were also identified as the degradation products. Since the plastic degradation rate of enzyme sample extracted from the membrane fraction was 0.1-0.6% in 24 h, we attempted to degrade these plastics using the recombinant enzyme. The recombinant enzymes expressed by E. coli were able to degrade the plastics and to produce aldehydes, ketones, and alcohols. For NBR degradation, in the multienzyme reaction with two types of aldehyde dehydrogenases, the aldehyde/ketone production rate (4.1 mM/30 min) enhanced by 12 times compared with the single enzyme. For PP degradation, all four recombinant enzymes moderately degraded 5-μm PP powder. A key enzyme was able to disappear 80% of the PP powder in 72 h at 37ºC. Moreover, the aldehyde production rate (12 mM/9 h) increased 3 times through a multienzyme reaction of four oxygenases. The key enzyme degraded 0.06%/24 h of PP sheet with high molecular weight (M_w 250,000, M_n 67,000), and aldehydes and primary or secondary alcohol were detected in the reaction mixture as the degradation products. We have also found a membrane bounded enzyme from a bacterium isolated from an insect was able to degrade 10% of a commercial HDPE film in 24 h, and produced aldehydes.

Furthermore, we succeeded in creating a one-pot microorganism capable of reducing the weight of waste plastics (PE and NBR) and synthesizing PHAs following cultivation. This was achieved by constructing or enhancing the PHA-producing pathway in the plastic-degrading microorganisms. We also

optimized plastic pre-treatment methods and culture conditions to enhance weight loss of the plastics and PHA production. The PHAs obtained in this study were poly(3-hydroxybutyrate) or PHA copolymers, and their molecular weights and thermal properties were comparable to commercially available PHAs.

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