Degradation of plastic waste using newly developed biocatalysts

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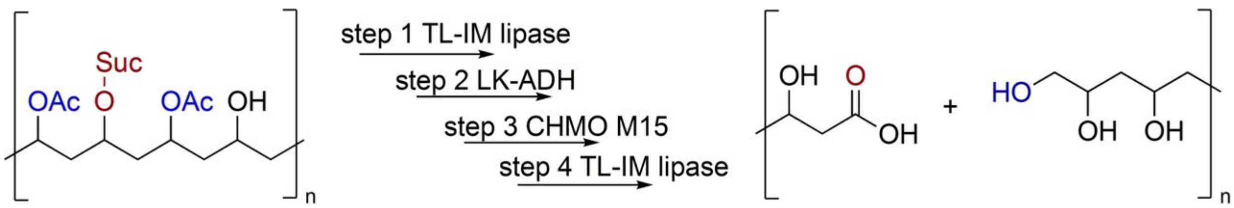

Graphical Abstract.B iodegradation of water-soluble PVA by microorganisms is slow and frequently involves pyrroloquinoline quinone (PQQ)-dependent enzymes. In this study, we present a modified PVA film with improved properties as well as a PQQ-independent novel enzymatic cascade consisting of a lipase, an alcohol dehydrogenase and a Baeyer–Villiger monooxygenase for the degradation of modified and unmodified PVA. Credit: *Angewandte Chemie International Edition* (2023). DOI: 10.1002/anie.202216962

The plastic materials polyurethane and polyvinyl alcohol can now be degraded under mild conditions with the help of enzymes as biocatalysts.

Scientists from the University of Greifswald have developed corresponding methods together with the German company Covestro and teams from Leipzig and Dublin, as recently published in the journal *Angewandte Chemie International Edition* in two separate articles. It has thus been possible to establish a sustainable and environmentally-friendly process to recycle these polymers.

This helps to address the worldwide problem of plastic waste based on the example of these two synthetic polymers, which are produced industrially at large scale.

Plastics are currently indispensable for the production of construction materials, electric insulation, drinks and food packaging, textiles and many more applications. Unfortunately, the mass production of synthetic polymers, especially for packaging materials, has led to an enormous waste problem for the environment. The polymers polyurethane and polyvinyl alcohol contribute to approximately 8 percent of the European plastic production.

For several years methods to achieve an environmentally-friendly recycling of plastics have been the subject of intense investigations. This would not only relieve the environment, but also reduce the amount of petrol required to make new plastics chemically. Furthermore, less of the greenhouse gas CO_2 would be emitted by garbage incineration plants that currently burn plastic waste.

Polyurethanes (PUR) are used for the production of mattresses, insulating materials, thermoplasts (i.e. for sport shoes) and for coatings (sealants, painting, glues). Chemical methods have been developed for the degradation of these compounds, but they require high amounts of energy as high temperatures and pressures are required.

Biotechnological methods using microorganisms or enzymes as natural biocatalysts represent an alternative as they enable the degradation and especially recycling—the isolation of the building blocks to make new plastics—at moderate temperatures of no more than 40°C and without the use of chemical reagents.

Prof. Dr. Uwe Bornscheuer's team at the University of Greifswald's Institute of Biochemistry, together with scientists from the company

Covestro (Leverkusen), has now identified the key enzymes, which are able to degrade polyurethane into its building blocks after a chemical pretreatment.

"The search for these specific biocatalysts was very laborious as we had to screen about two million candidates in order to discover the first three enzymes, which have been proven to break the special chemical bond present in polyurethanes," explains Ph.D. student Yannick Branson (University of Greifswald), describing the challenge of this project.

"With this ground-breaking discovery we now have the precondition to tailor-design these biocatalysts using methods of protein engineering that aim to develop an industrial recycling of polyurethanes," explains Prof. Dr. Uwe Bornscheuer (University of Greifswald) further. "Using these newly identified enzymes, we get much closer to our target of a circular economy for the polymer industry," adds Dr. Gernot Jäger, head of the Competence Center for Biotechnology at Covestro AG (Leverkusen).

Polyvinyl alcohols (PVA) have versatile properties and are also widely applied, for instance for the coating of fibers and as foils for packaging. So far, no mature processes exist for the degradation of PVA. Here, the team of Professor Bornscheuer was also able to develop the basic principles for a biotechnological process together with a polymer expert from the University College Dublin (Ireland) and scientists from Leipzig. The degradation of PVA could be achieved through the elegant combination of three different enzymes, which are then able to modify the polymer in a stepwise fashion to obtain fragments of the polymer, which then can be used for its recycling.

More information: Yannick Branson et al, Urethanases for the Enzymatic Hydrolysis of Low Molecular Weight Carbamates and the Recycling of Polyurethanes, *Angewandte Chemie International Edition* (2023). DOI: 10.1002/anie.202216220

Gerlis von Haugwitz et al, Synthesis of Modified Poly(vinyl Alcohol)s and Their Degradation Using an Enzymatic Cascade, *Angewandte Chemie International Edition* (2023). DOI: 10.1002/anie.202216962

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