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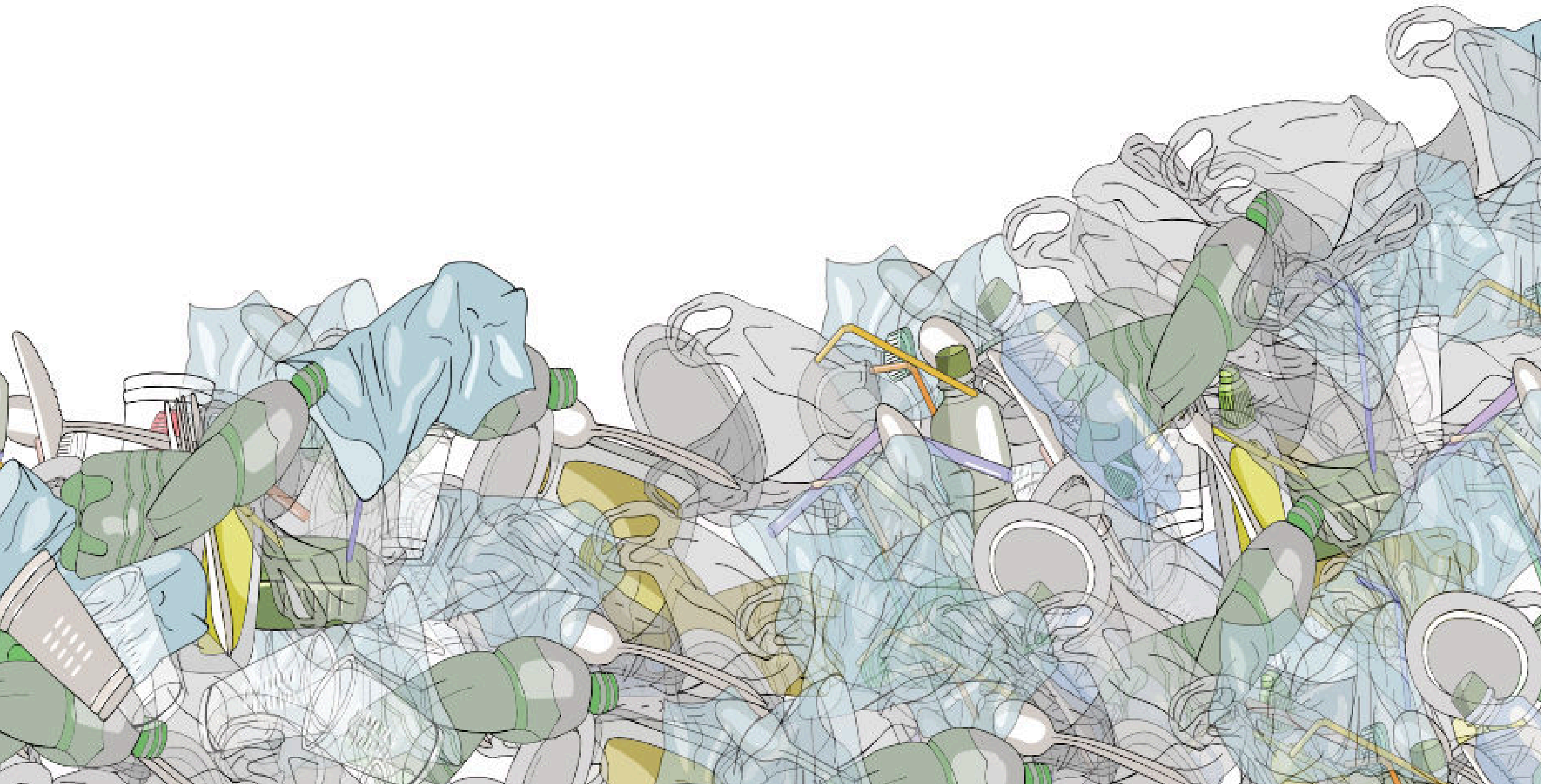
WORLD CAFÉ: THE POWER OF ENZYMES FOR PLASTIC RECYCLING

SUMMARY OF THE FINAL EVENT
THREE BIO PATHS, ONE SOLUTION FOR PLASTICS
9-10TH APRIL 2024, MADRID



TOPIC ENZYMES

This discussion began by examining the current situation. Our ongoing projects have produced a variety of enzymes capable of processing several plastic substrates. However, not every plastic type is suitable for enzymatic breakdown.

Key questions are: Should we overthink the kind of plastics that we are using in our daily life? How can we align the capabilities of enzymes with different plastic types, and initiate a transition to alternative biobased plastics that reduce ecological impact and enhance recyclability.

The molecular design of the plastic is key for efficient depolymerization. Ester groups (or other functional groups) act as predetermined breaking points. This allows for chemical (including enzymatic) feedstock recycling as a complementary strategy (when classical recycling comes to its limits).

Biobased and biodegradable plastics present a high potential to substitute classical plastics, while offering new perspectives. In a future scenario, bio-based plastics store the fixed carbon from our atmosphere and enzymes break down the end-of-life (EoL) products to bring the monomers back into the cycle, which has positive impact on production capacity and cost.

The development of enzyme catalysts starts with environmental screening. Finding suitable enzymes through bioprospecting is crucial. Various projects have identified promising environments for sourcing these enzymes, including extremophile regions, marine hotspots, the guts of insects, and areas with extensive plastic use, such as agricultural mulching films.

Bioprospecting approaches like metagenomics are capable to spread more light into the terra incognita of the microcosms and in combination with computational approaches, new enzymes can be mined from datasets. The knowledge gain helps to better understand the mechanisms of such enzymes and provides information to engineer the enzymes in a subsequent step.

Once potential enzymes are found, they need to be optimized to increase the performance for a technical application. Participants highlighted that engineering is a key to success, and parameters such as thermostability, substrate/product inhibition or other industrially relevant parameters need to be considered and optimized. We are currently at the edge of real big changes: Engineering with the use of computational sciences and AI has the potential to save lots of time in the time-intensive steps of bioprospecting and optimization.

For the production of enzymes, cost-efficiency and productivity are important factors to establish enzymes in a plastic recycling process. Selection of suitable high yield expression hosts, cheap substrates (material that would otherwise end in a composting process) and efficient processes are important factors.

According to participants, recycling with microorganisms via whole cell processes has shown to be time-consuming and less efficient. Currently, isolated enzymes are a more effective choice.

TOPIC
RECYCLING PROCESS & UPCYCLING

The enzymatic recycling experts around the participants said that enormous efforts have been made recently so that enzymatic plastics recycling in lab scale is fine.

But how can the scale up for bringing this technology to the market be achieved and who pays for this premium?
Participants questioned the term biodegradable plastics, due to shocking findings of "biodegradable plastics" that were not degraded in the environment for a very long time. A clear definition of biodegradability is urgently needed. There is also a big difference, if the composting works under defined conditions or also when it is leaked into the environment.
One option is to encapsulate enzymes in biodegradable plastics to accelerate the degradation process for a composting scenario. Another option would be to collect the bioplastics, separate and recycle according to the state of the art until recycling isn't possible anymore. Then the enzymes come along, break it down and the monomers go back to the start.
Enzymatic recycling is still expensive. As a first step, waste has to be separated (enzymes do the sorting, but not time- or cost efficiently) and pre-treated e.g. enhanced surface area. If we would be ably to efficiently recover the enzyme, the costs could be significantly lowered. According to the experience of the participants, the more complex the mixtures of post consume plastics are, the lower the yield of good quality building blocks. Therefore, the mixtures need to be valorized for their purity and the volume to increase the quality yield of recovered chemicals. In some cases enzymes are specific enough to attack a specific polymer (for example PET) selectively even in a mixture and which is a very valuable property for enzymes.
Participants argued that upcycling should start with the identification of plastics that are eligible for upcycling (sorting adjustment is probably needed). Then appropriate protocols need to be put in place and the market addressed. Upcycling through the use of enzymes to recover chemicals is very promising and should be exploited.
By-products such as biomass from worms, insects and larvae can be utilised as dry fillers in biocomposites for applications in agriculture (pots etc.) or in the case of the exoskeleton as a source of chitin, a very valuable functional molecule.

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