OCTOBER 14 - 17, 2024

Mimicking the enzymatic plant cell wall hydrolysis machinery for the degradation of polyethylene terephthalate

Efstratios Nikolaivits, George Taxeidis, Evangelos Topakas

IndBioCat Group, Biotechnology Laboratory, School of Chemical Engineering, National Technical University of Athens, Greece

Introduction

Plastic pollution presents a global challenge, impacting ecosystems, wildlife, and economies. **Polyethylene terephthalate (PET)**, widely used in products like bottles, significantly contributes to this issue due to poor waste collection. In recent years, there has been increasing interest in plant biomass-degrading enzymes for plastic breakdown, due to the **structural and physicochemical similarities between natural and synthetic polymers**. Filamentous fungi involved in **hemicellulose degradation** have developed a complex mode of action that includes not only enzymes but also **biosurfactants**; surface-active molecules that facilitate enzyme-substrate interactions. For this reason, this study aimed to mimic the mechanism of biomass degradation by **repurposing plant cell wall degrading enzymes** including a cutinase and three esterases to cooperatively contribute to PET degradation. Surfactants of different charge were also introduced in the reactions, as their role is similar to biosurfactants, altering the surface tension of the polymers and thus improving enzymes' accessibility.

Fungal mechanism for plant biomass degradation

Bio-surfactant + Enzyme Cocktail

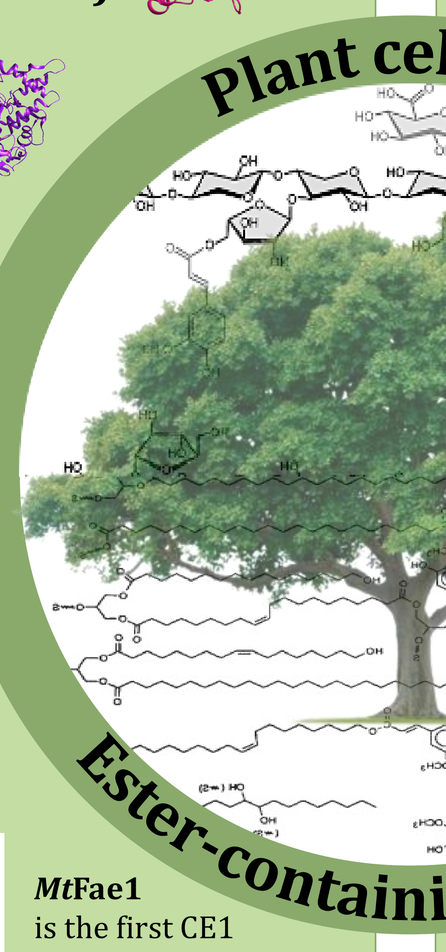
CE5 Cutinase (*Fo*Cut5a)

Hemicellulases

CE1 Feruloyl esterase B (*Mt*Fae1)

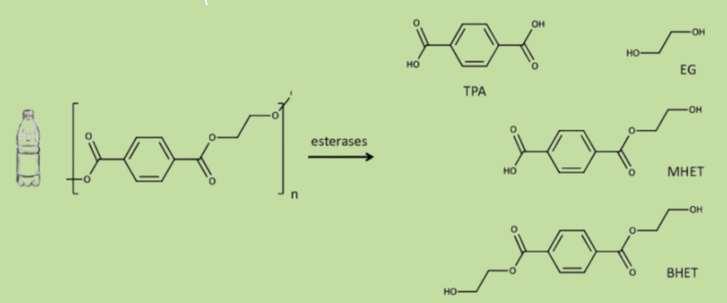
Tannase/Feruloyl esterase C (*Fo*FaeC)

CE15 Glucuronoyl esterase (*St*GE2)



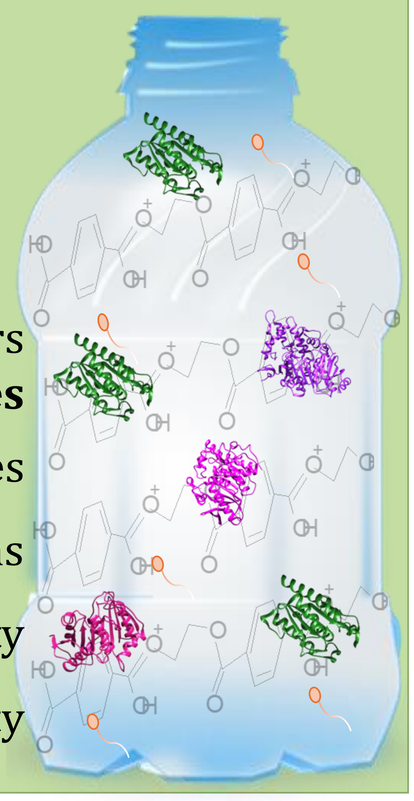
Mimicking natural mechanisms for synthetic polymer degradation

Surfactants + Enzyme Cocktail

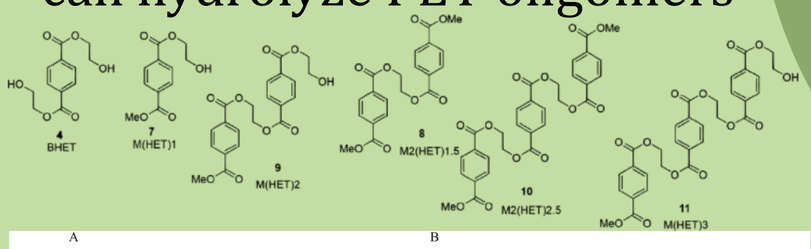


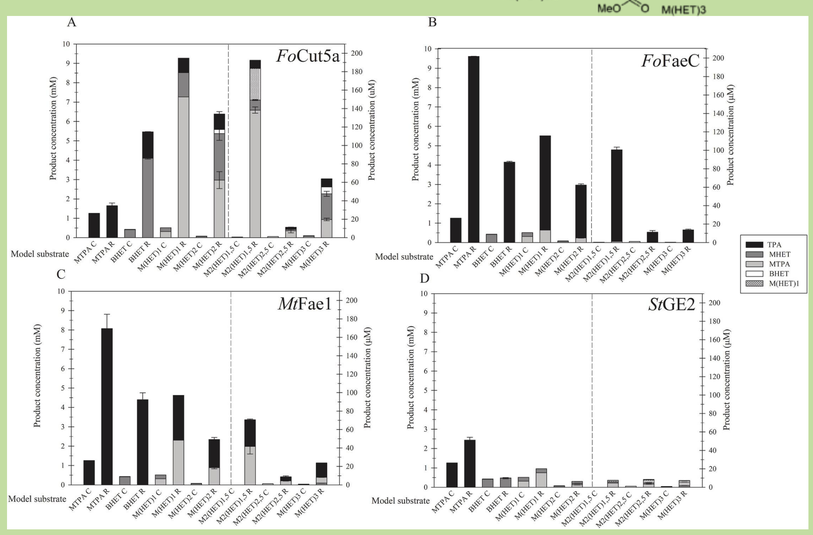
Natural and synthetic polymers share **similar properties**

- Chemical Bond Types
- Surface interactions
- Hydrophobicity
- Crystallinity



*Fo*Cut5a and Hemicellulases can hydrolyze PET oligomers



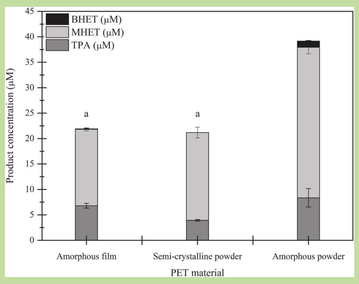


***Fo*Cut5a** breaks down longer PET oligomers more efficiently and can also degrade PET materials releasing mostly MHET.

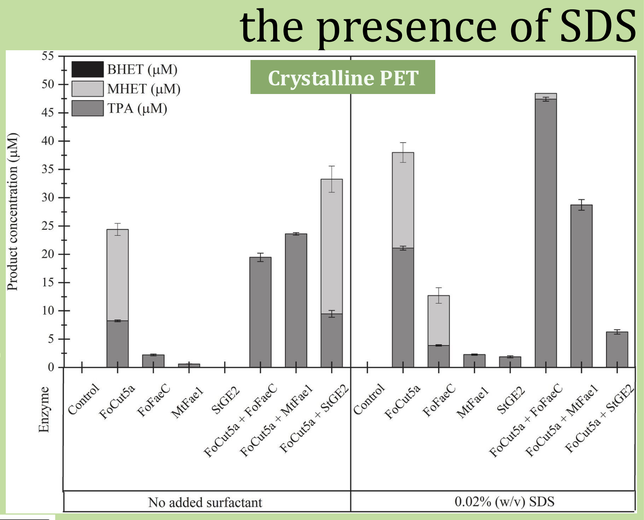
Even though ***St*GE2** shows similar mode of action as *Fo*Cut5a, it cannot degrade PET.

***Mt*Fae1** is the first CE1 feruloyl esterase reported to act as an MHETase.

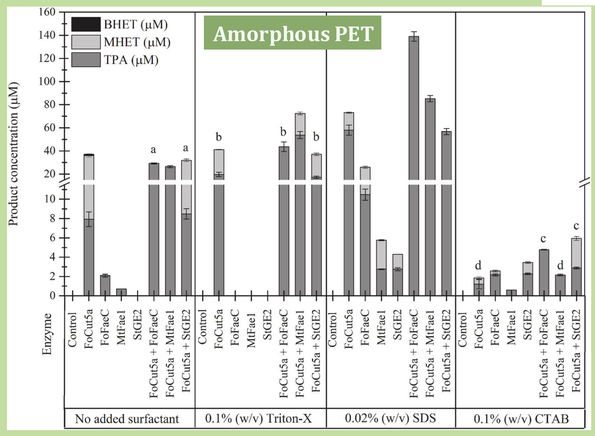
***St*GE2** is the first CE15 glucuronoyl esterase to break down plastic oligomers.



Improved degradation of crystalline PET with *Fo*Cut5a-*Fo*FaeC system in the presence of SDS



Cooperative degradation of PET in the presence of surfactants



Combining ***Fo*Cut5a** with the anionic surfactant **SDS** led to a **2.3- and 1.6-fold increase** in product release in amorphous and semi-crystalline PET, respectively.

***Fo*FaeC** and ***Mt*Fae1** demonstrated the ability to **completely convert MHET** released from ***Fo*Cut5a** into TPA in both crystallinity grades.

This research was implemented in the framework of H.F.R.I call "Basic research Financing (Horizontal support of all Sciences)" under the National Recovery and Resilience Plan "Greece 2.0" funded by the European Union – NextGenerationEU (H.F.R.I. Project Number: 15024).

H.F.R.I. Hellenic Foundation for Research & Innovation

Greece 2.0 NATIONAL RECOVERY AND RESILIENCE PLAN

Funded by the European Union NextGenerationEU

Follow us on Instagram!

@indbiocat

Scan to read the paper!