UNIVERSITÀ DEGLI STUDI DI PADOVA

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DAFNAE

Department of Agronomy Food Natural resources Animals and Environment

Un nuovo approccio promettente per il trattamento delle bioplastiche a fine vita

Prof. Lorenzo Favaro, PhD

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PROSPETTIVE DI RICICLO E COMPOSTAGGIO ALLA LUCE DELLA PROPOSTA DI REGOLAMENTO UE SUGLI IMBALLAGGI

Convegno tecnico-scientifico – 20 ottobre 2023

PLA, TPS, …

Compostabili

Biodegradabili

END OF LIFE

Biogas

Compost

Back to earth

Cosate de Andrade et al. (2016). *Journal of Polymers and the Environment*, *24*(4), 372-384
Rezvani Ghomi et al. (2021). *Polymers*, 13(11), 1854
Di Bartolo et al. (2021). *Polymers*, 13(8), 1229

PLA, TPS, …	→	END OF LIFE
Compostabili		Biogas
Biodegradabili		Compost

PLA, TPS, …	→	END OF LIFE
Compostabili		Riciclo chimico
Biodegradabili		Riciclo meccanico
		Riciclo biotech
		Biogas
		Compost

Riciclo biotech → Monomeri, Building blocks, Acidi organici, Biocarburanti, … → PLA, TPS, …

- Monomeri
- Building blocks
- Acidi organici
- Biocarburanti
- …

BIOTECNOLOGIE per END OF LIFE

micro organisms

BIOETANOLO

Bagassa di canna da zucchero

Crusca di grano

Scarti di passatrice

Scarti di lavorazione del riso

BIOH_2 & BIOCH_4

Frazione organica dei rifiuti solidi urbani

Scarti di lavorazione del riso

Scarti di lavorazione del caffè

BIOPOLIMERI

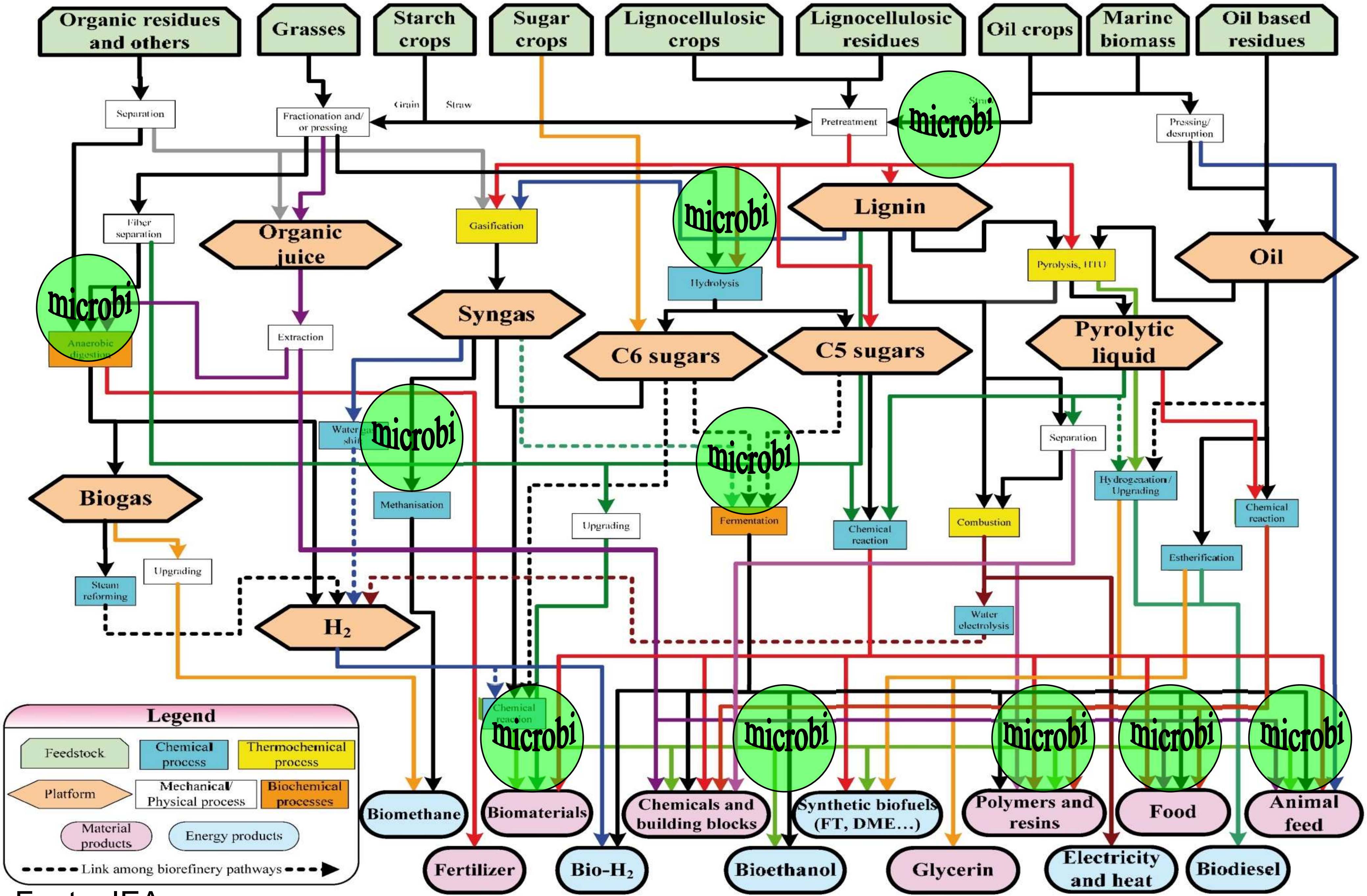
Siero di latte

Scarti di macello

Oli esausti

https://www.wastetobioproducts.com/Index.html

Microbi e bioraffinerie



Fonte: IEA

Un ceppo batterico con 1/K = 20' (K=3)

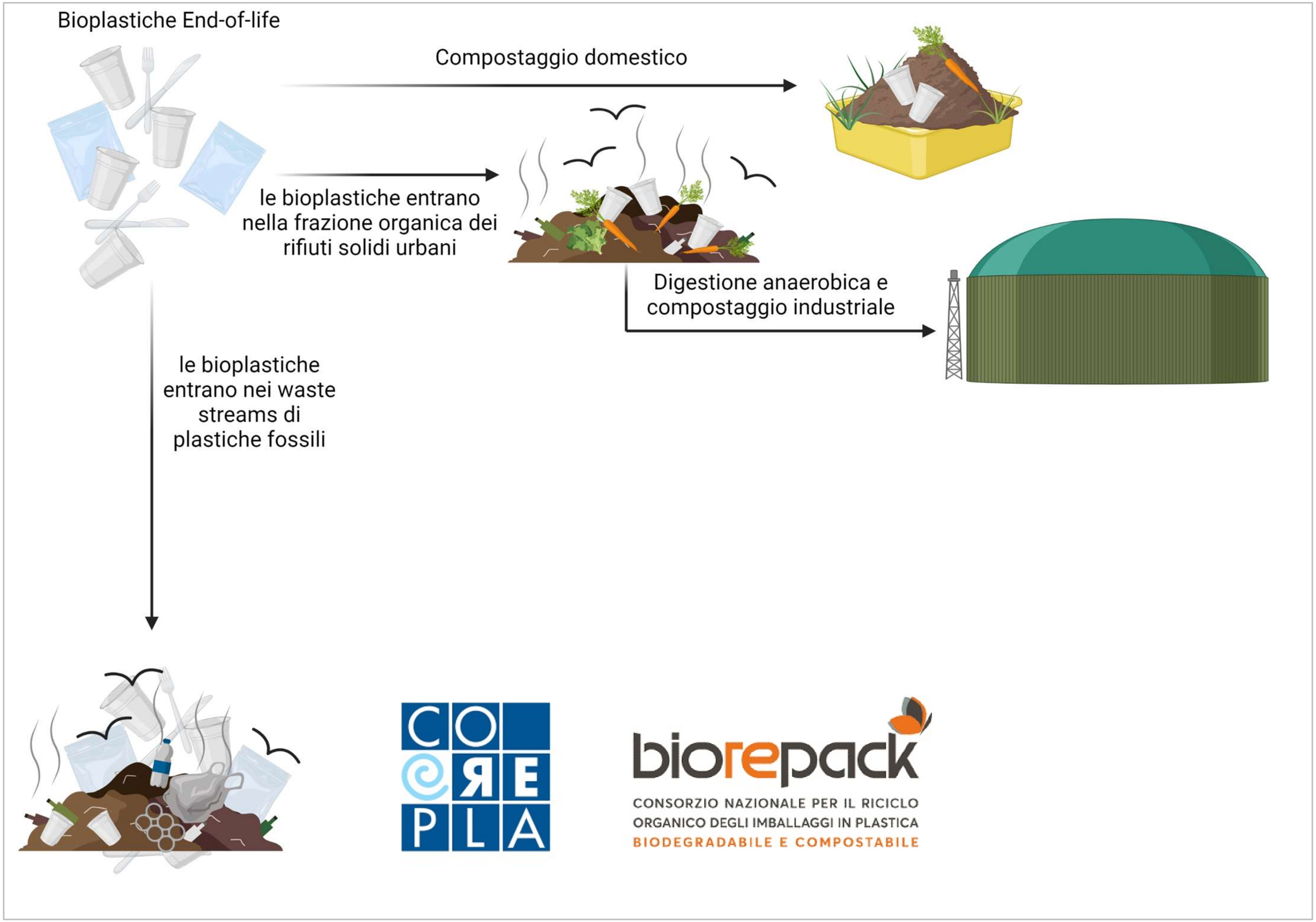
↓ *48 h of crescita esponenziale*

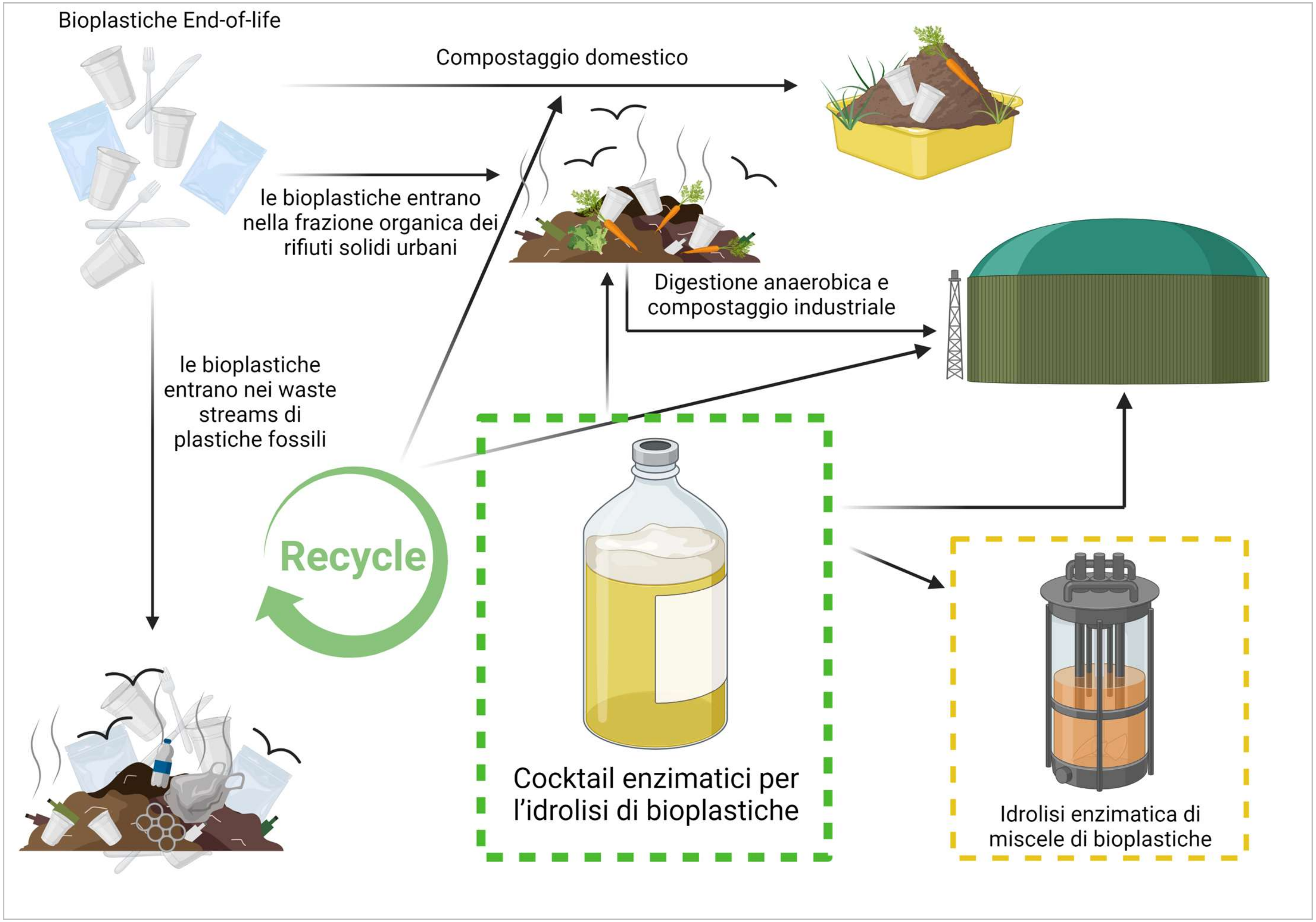
$2^{144} \sim 2.2 \times 10^{43}$

Peso di una cellula batterica ≈ 10^{-12} g

$2.2 \cdot 10^{31}$g → **quattromila volte il peso del Globo**

Qualsiasi composto di origine biologica può essere degradato ed utilizzato dai microrganismi per la loro crescita


Bioplastiche End-of-life
Compostaggio domestico
le bioplastiche entrano nella frazione organica dei rifiuti solidi urbani
Digestione anaerobica e compostaggio industriale
le bioplastiche entrano nei waste streams di plastiche fossili
CO
RE
PLA
biorepack
CONSORZIO NAZIONALE PER IL RICICLO ORGANICO DEGLI IMBALLAGGI IN PLASTICA BIODEGRADABILE E COMPOSTABILE



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Recycle
Cocktail enzimatici per l'idrolisi di bioplastiche
Idrolisi enzimatica di miscele di bioplastiche

Verso la definizione di nuove protocolli per la gestione di bioplastiche end-of-life?

Ruggero et al. (2020). *Chemosphere*, 246, 125770
Calabrò et al. (2020). *Journal of hazardous materials*, 390, 121653
Cucina et al. (2022). *Bioresource Technology*, 354, 127224

Ruggero et al. (2019). *Waste Management*, 37, 959-975
Peng et al. (2022). *Bioresource Technology*, 343, 126079
Bandini et al. (2022). *Bioresource Technology*, 351, 126934.

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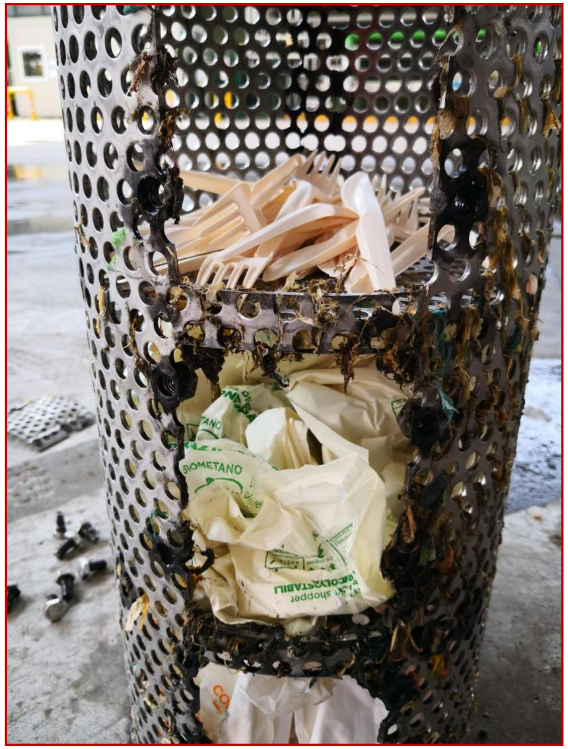
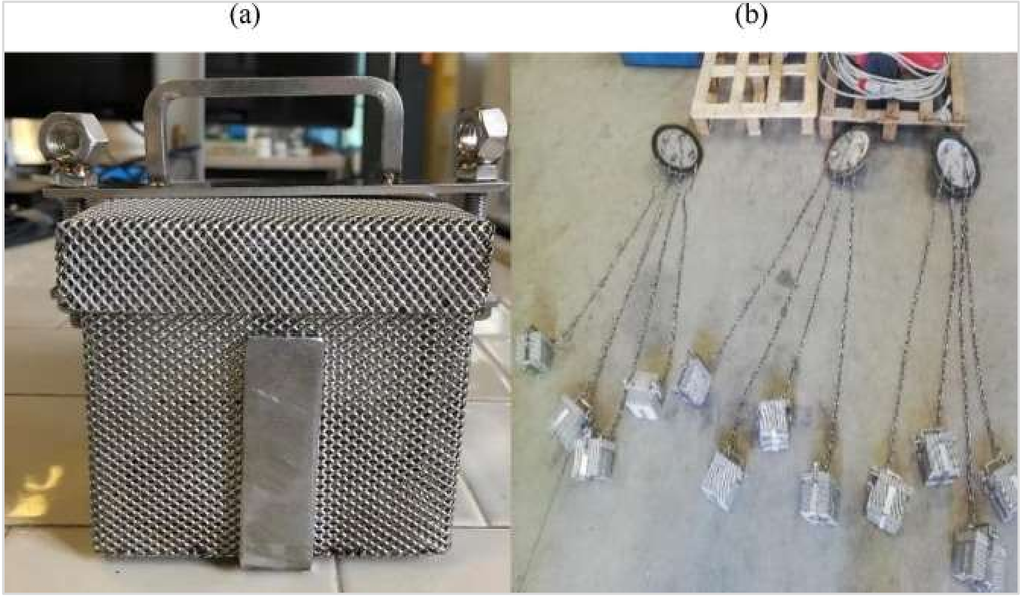


digestione anaerobica, impianto pilota

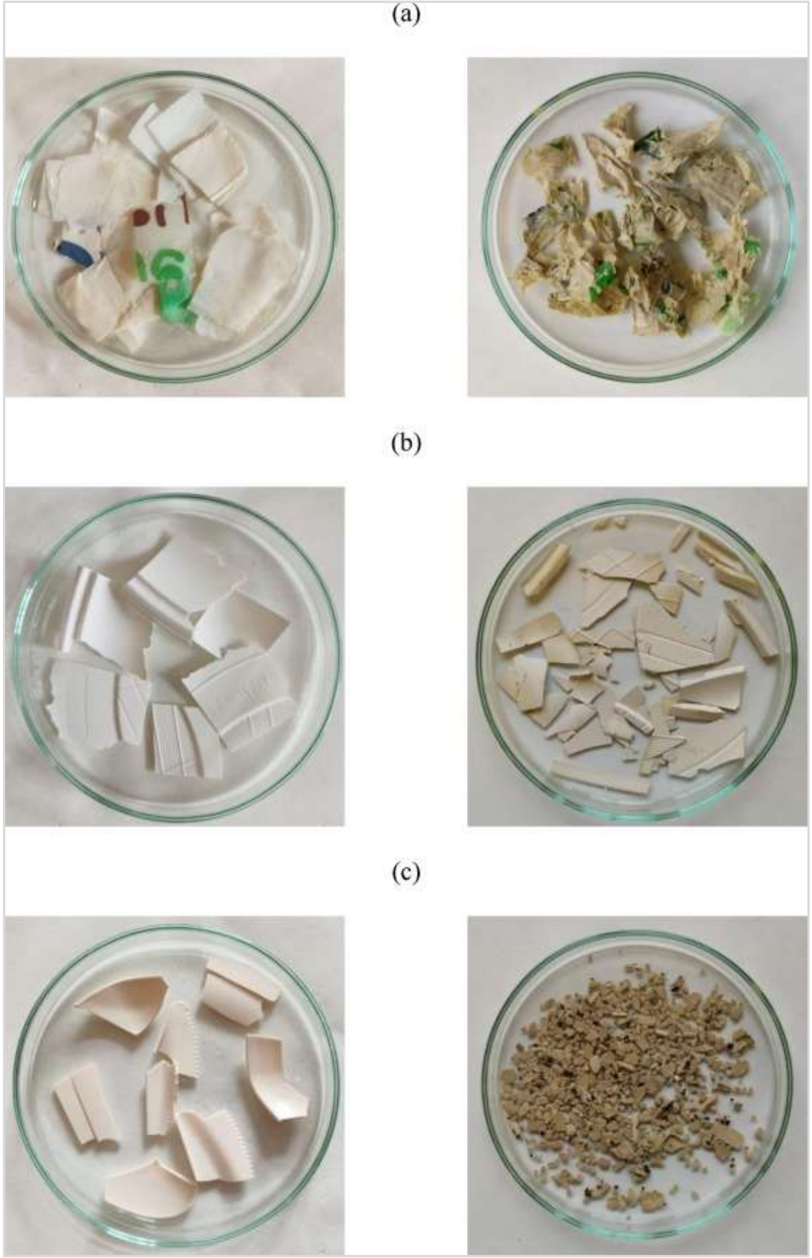
42°C, 32 gg

Verso la definizione di nuove protocolli per la gestione di bioplastiche end-of-life?



digestione anaerobica full-scale

55° C, 90 gg



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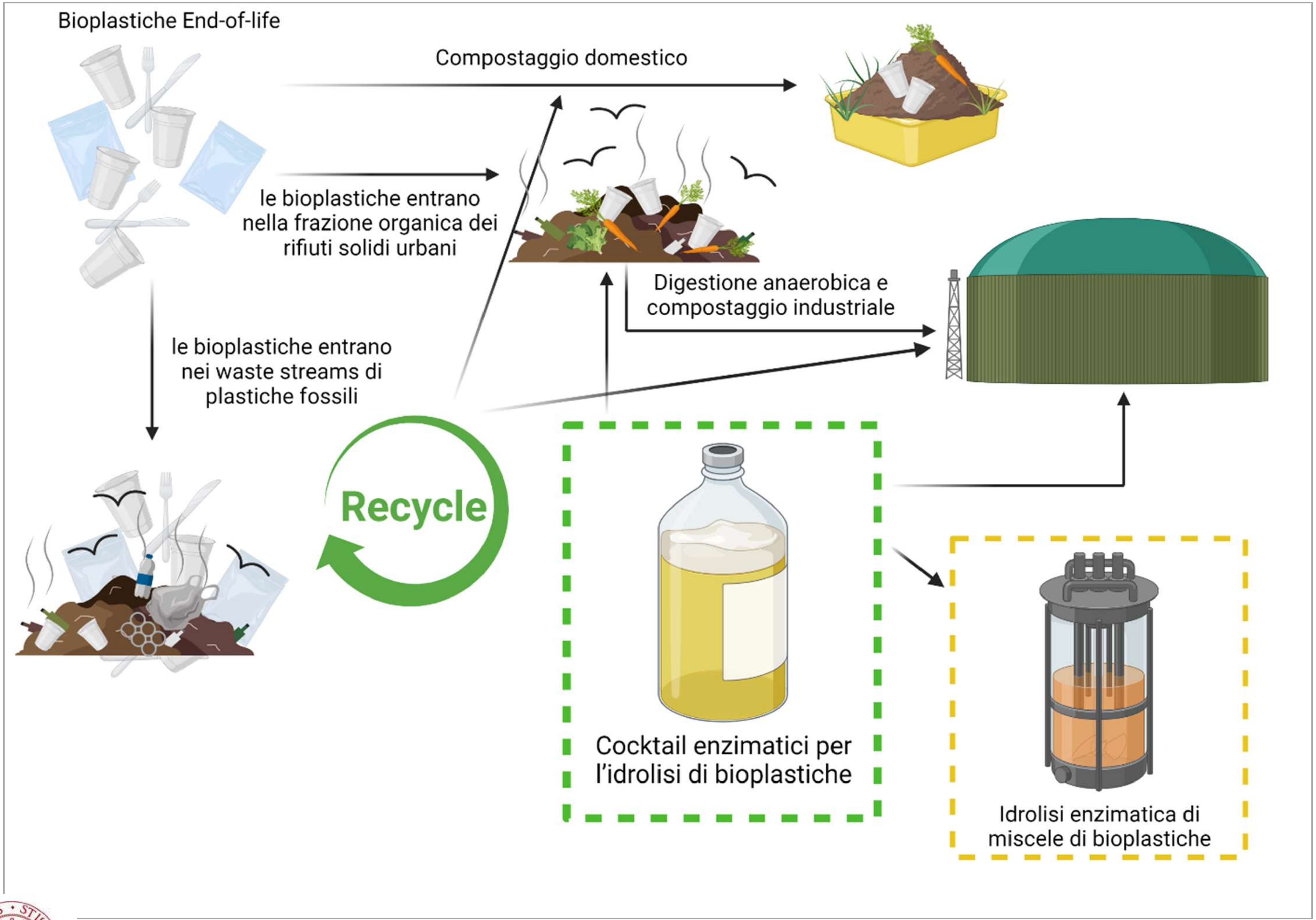
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Sviluppo di enzimi e microbi per il **riciclo BIOTECH**

Bioprospecting

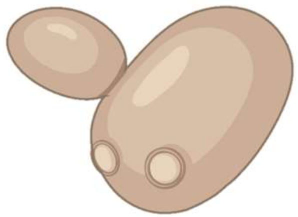
Isolamento/Selezione sequenze geniche

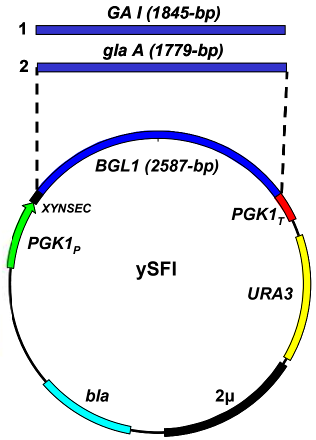
***Clonaggio in S. cerevisiae* Y294**

Studi di *codon-optimization* e *promotori*

Segnali di secrezione (*Trichoderma* sp., *Aspergillus* sp.)

pH, temperatura, concentrazione di substrato





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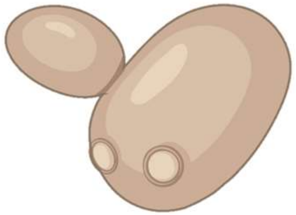
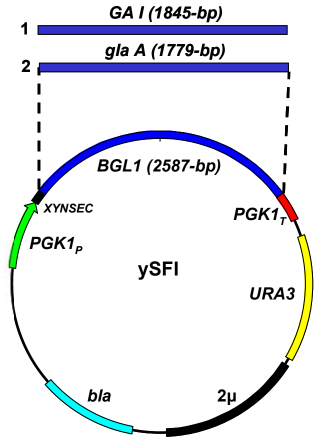
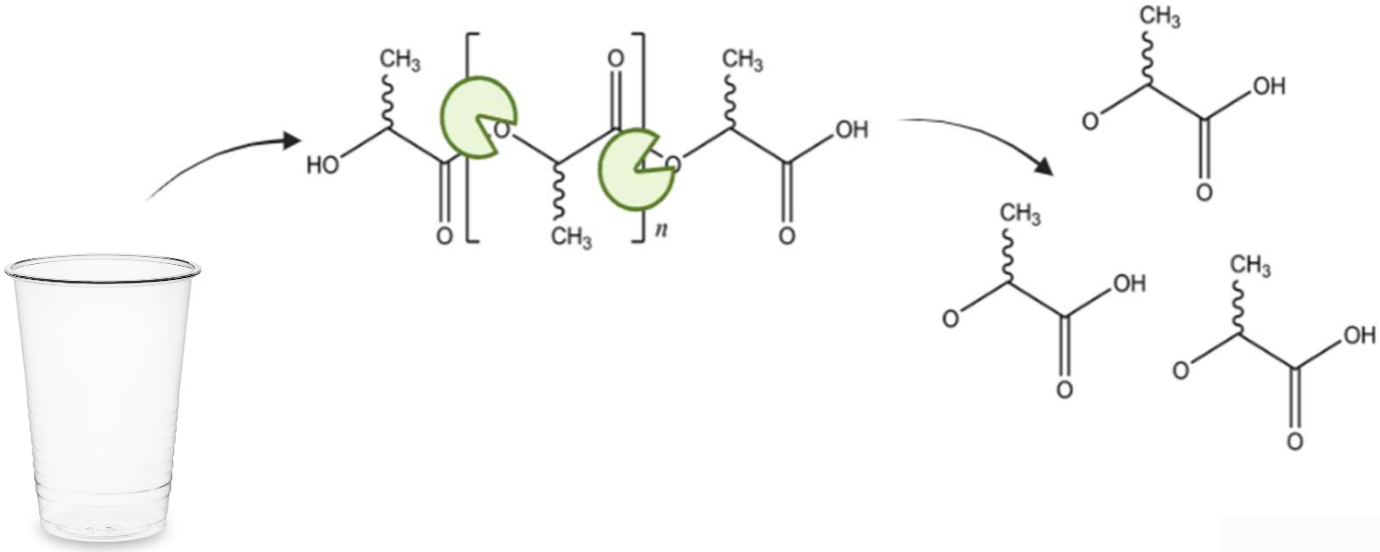
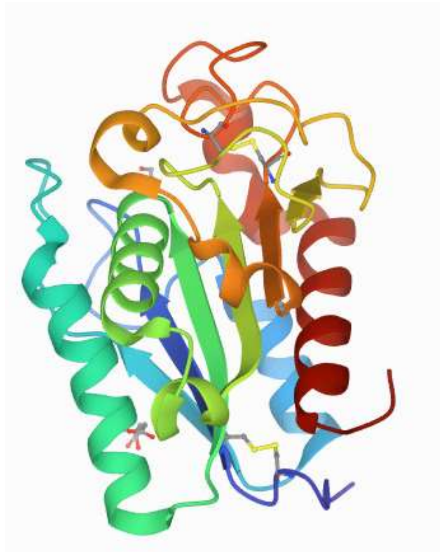
Piccola scala e scala di fermentatore (1-5 L)





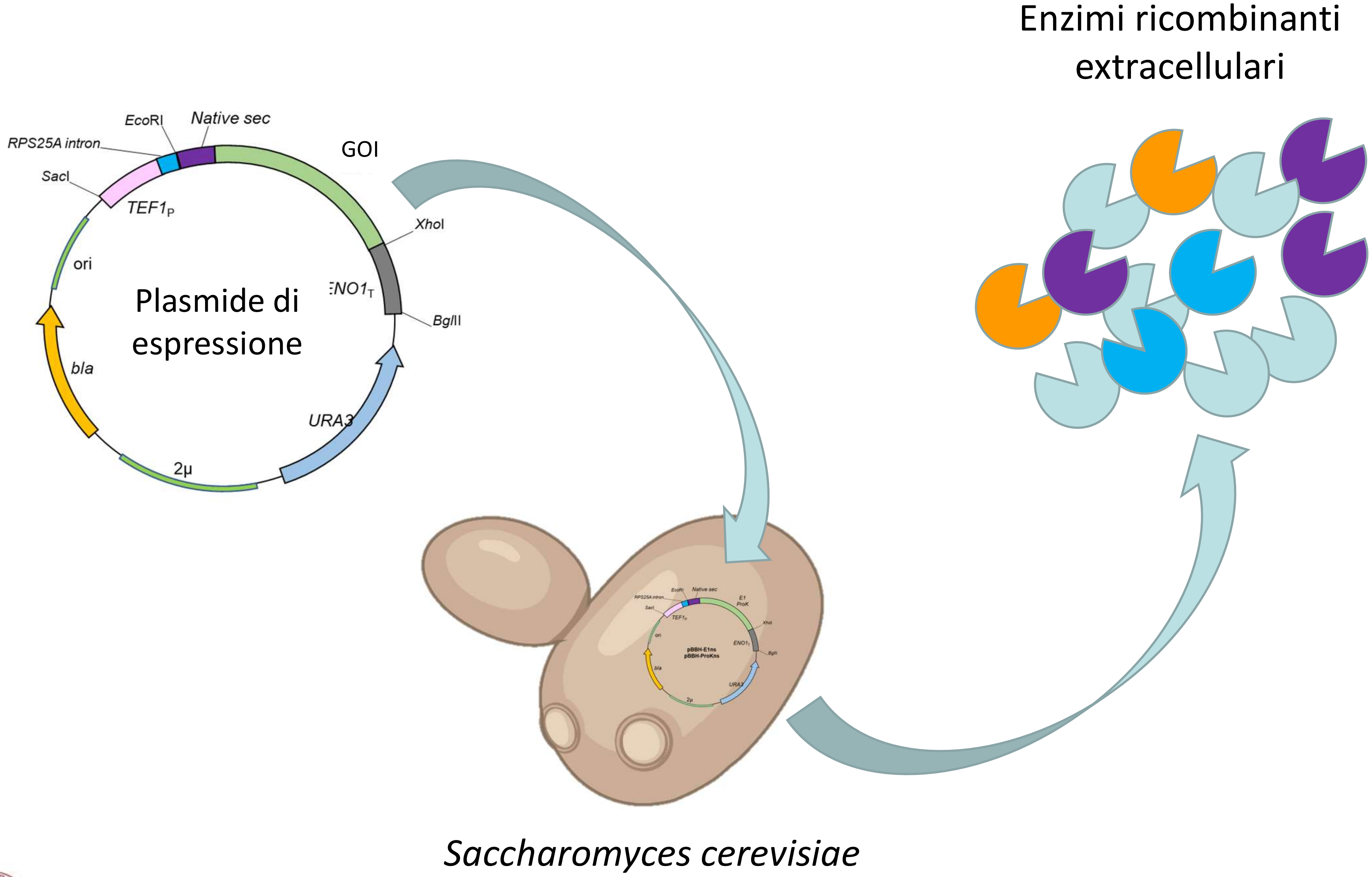
L’esempio di materiali a base di PLA





- Sono state identificati enzimi *ad hoc*
  - principalmente batterici (in particolare *Actinomycetes*)
  - alcuni fungini
  - proteasi preferibilmente a carico di PLLA
  - cutinasi, lipasi ed esterasi preferibilmente a carico di PDLA

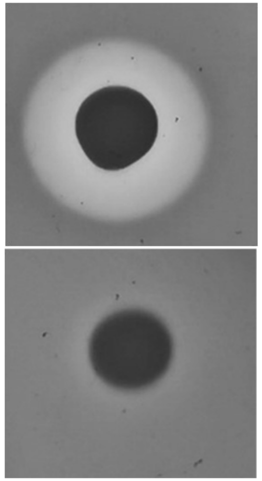
Idrolasi per materiali a base di PLA

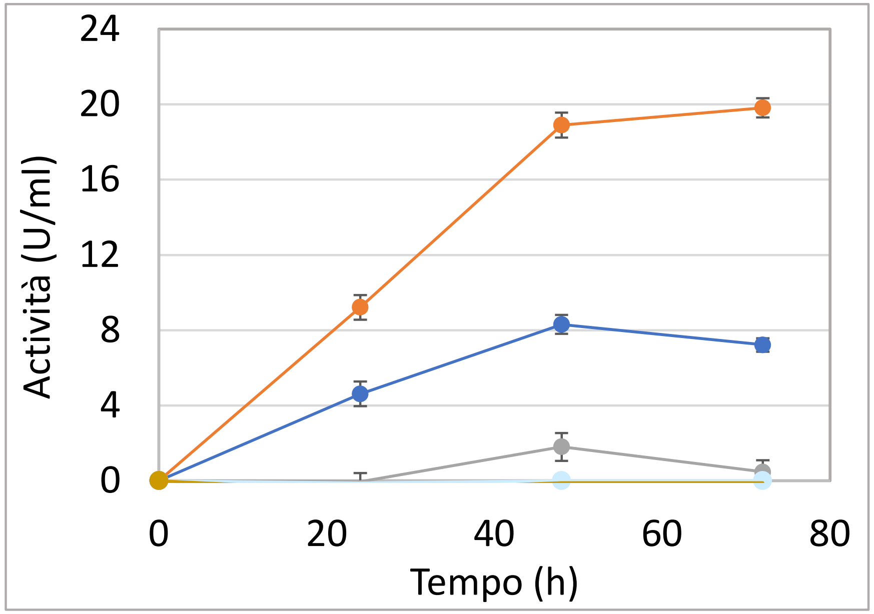


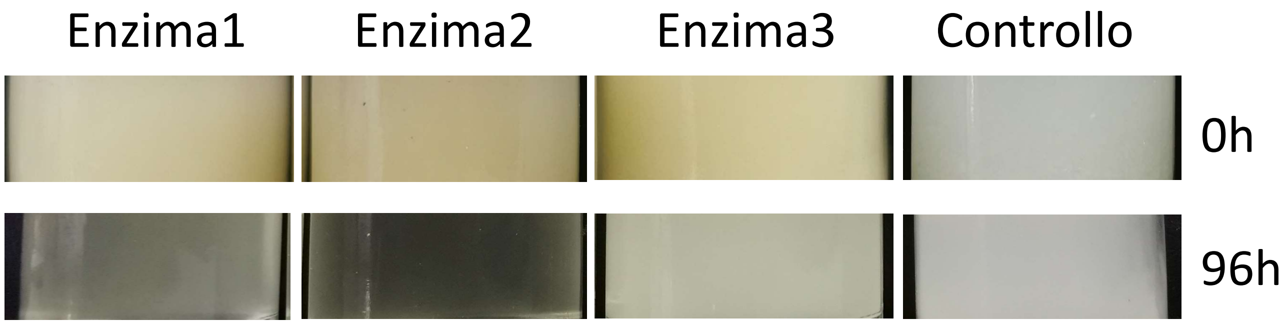
Idrolasi enzimatica di PLA: lab-scale

Lievito ricombinante

Lievito controllo







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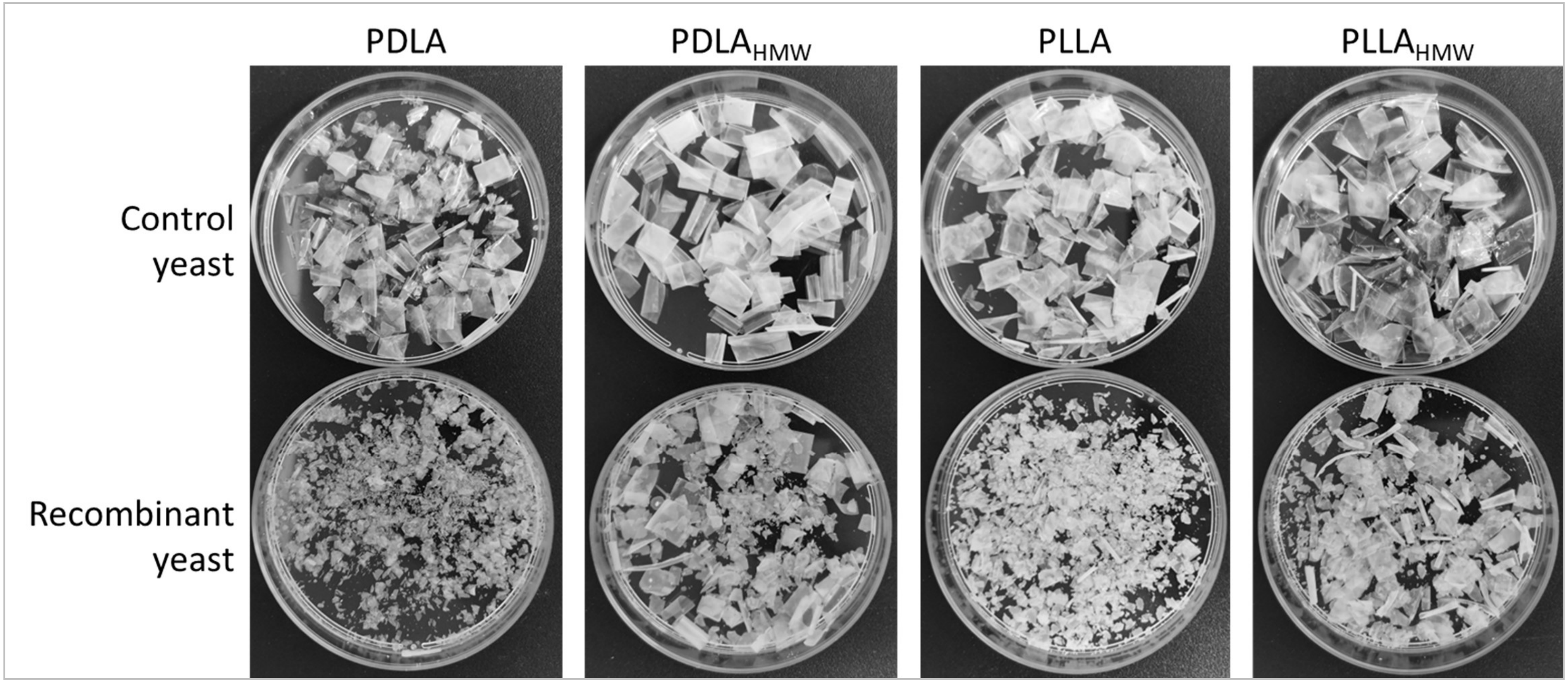
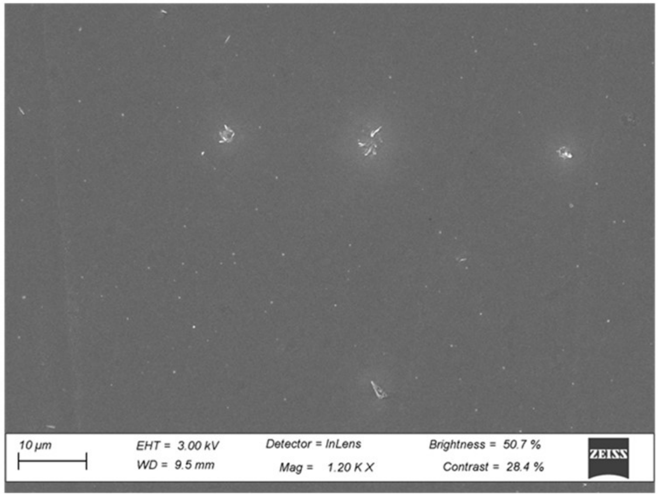
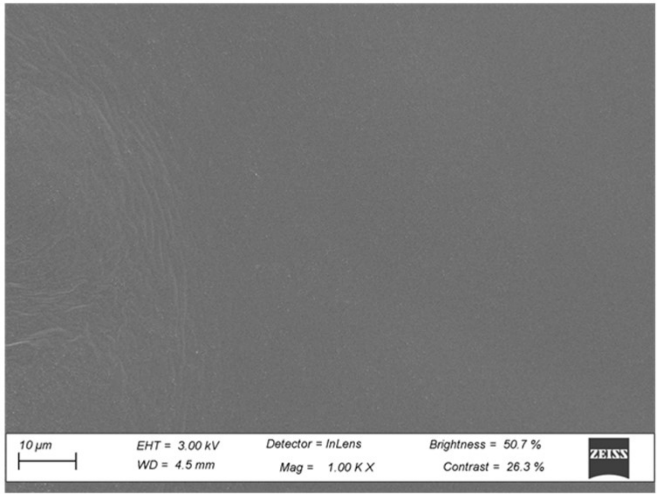


Idrolasi enzimatica di PLA: lab-scale

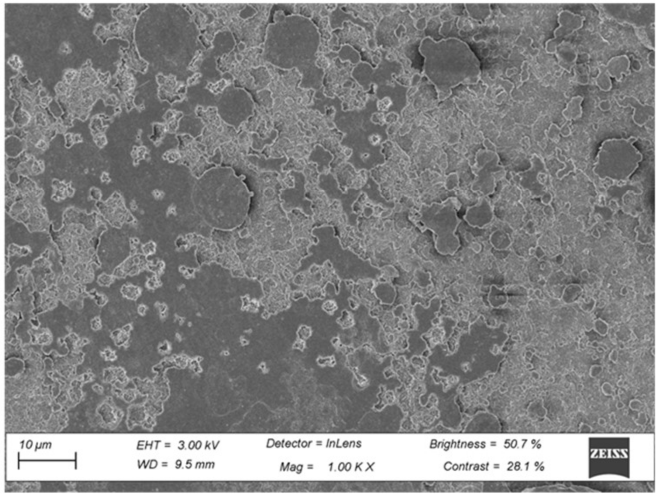
Prior to hydrolysis
0h

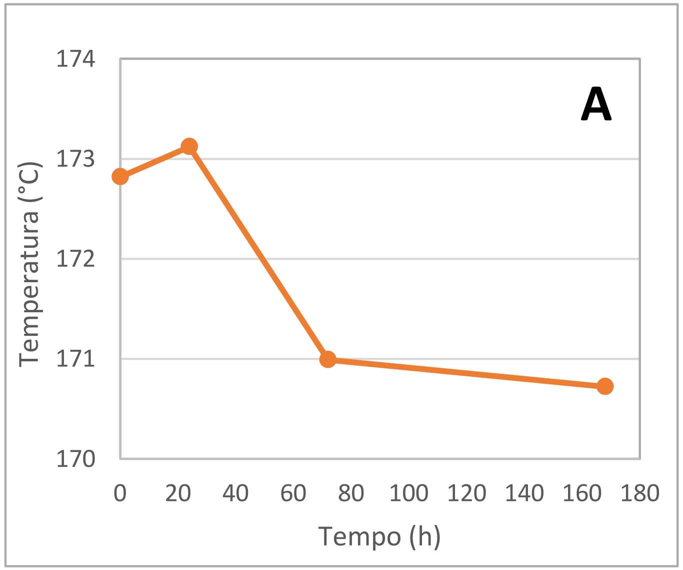


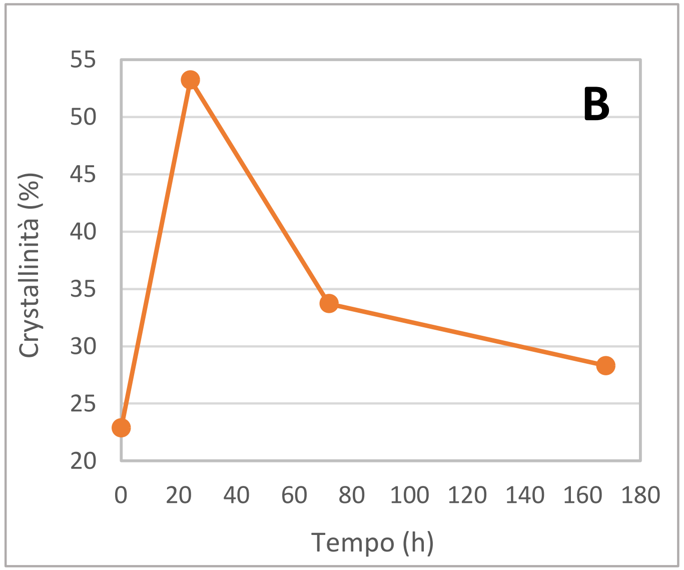
Control yeast
168h



Recombinant yeast
168h



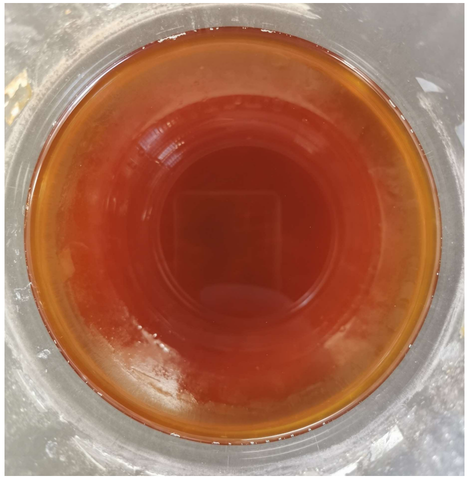


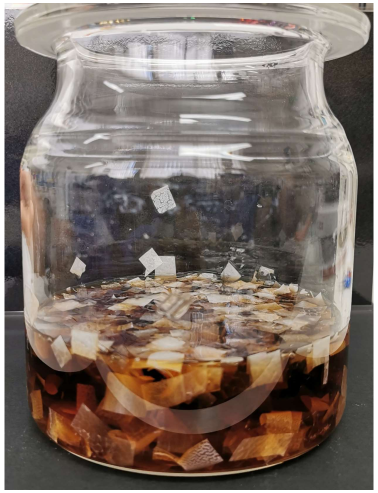


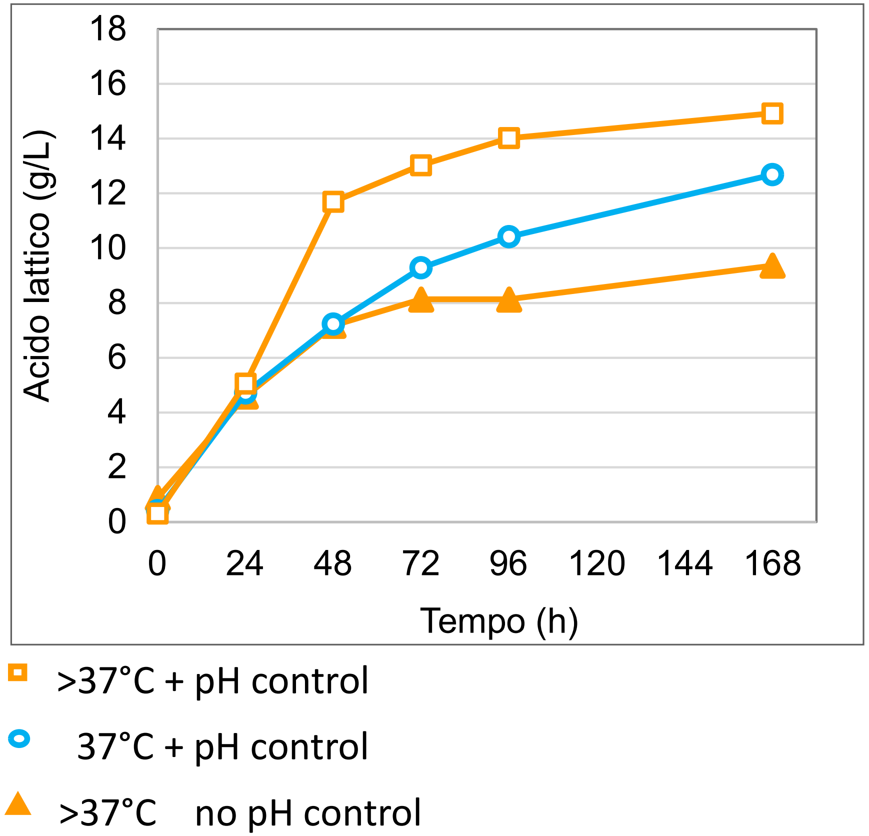
La Tm aumenta all'inizio dell'idrolisi (A) indicando un'aumento della cristallinità (B) per poi diminuire sensibilmente con il passare dell'idrolisi a carico di entrambe le regioni amorfe e crystalline del film di PLLA

Idrolasi enzimatica di PLA: ottimizzazione e bioreattore

>37°C, 7 gg







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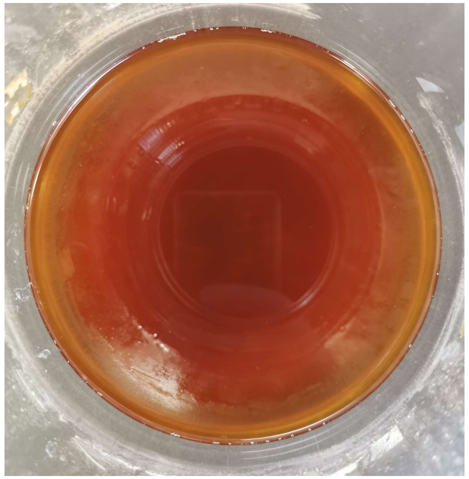
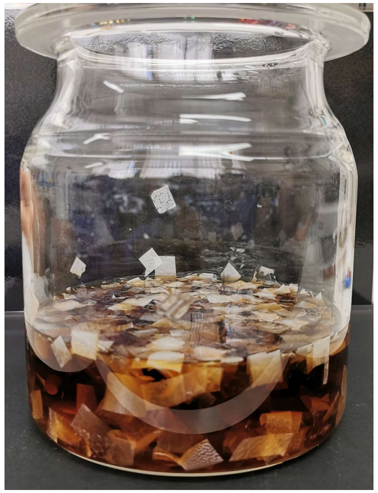
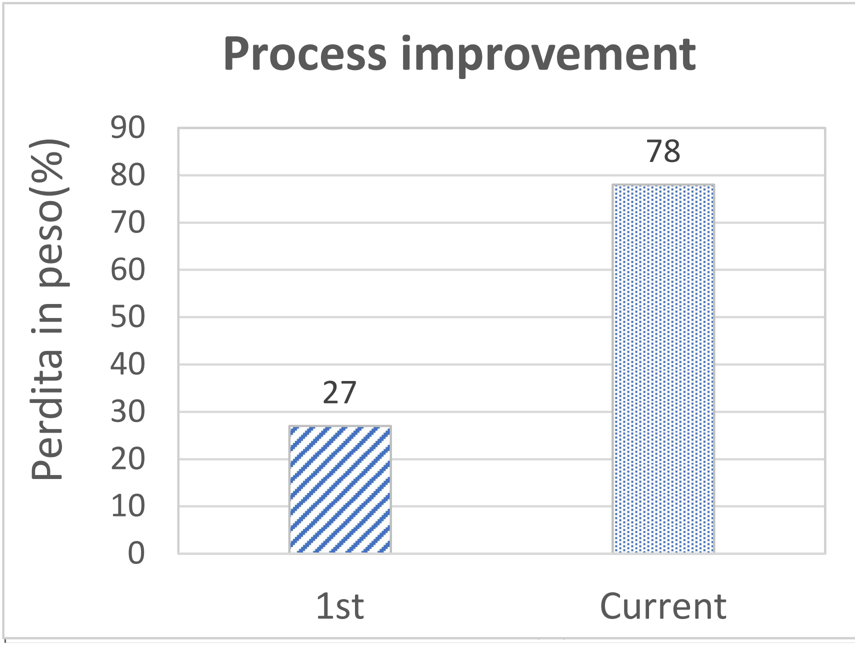
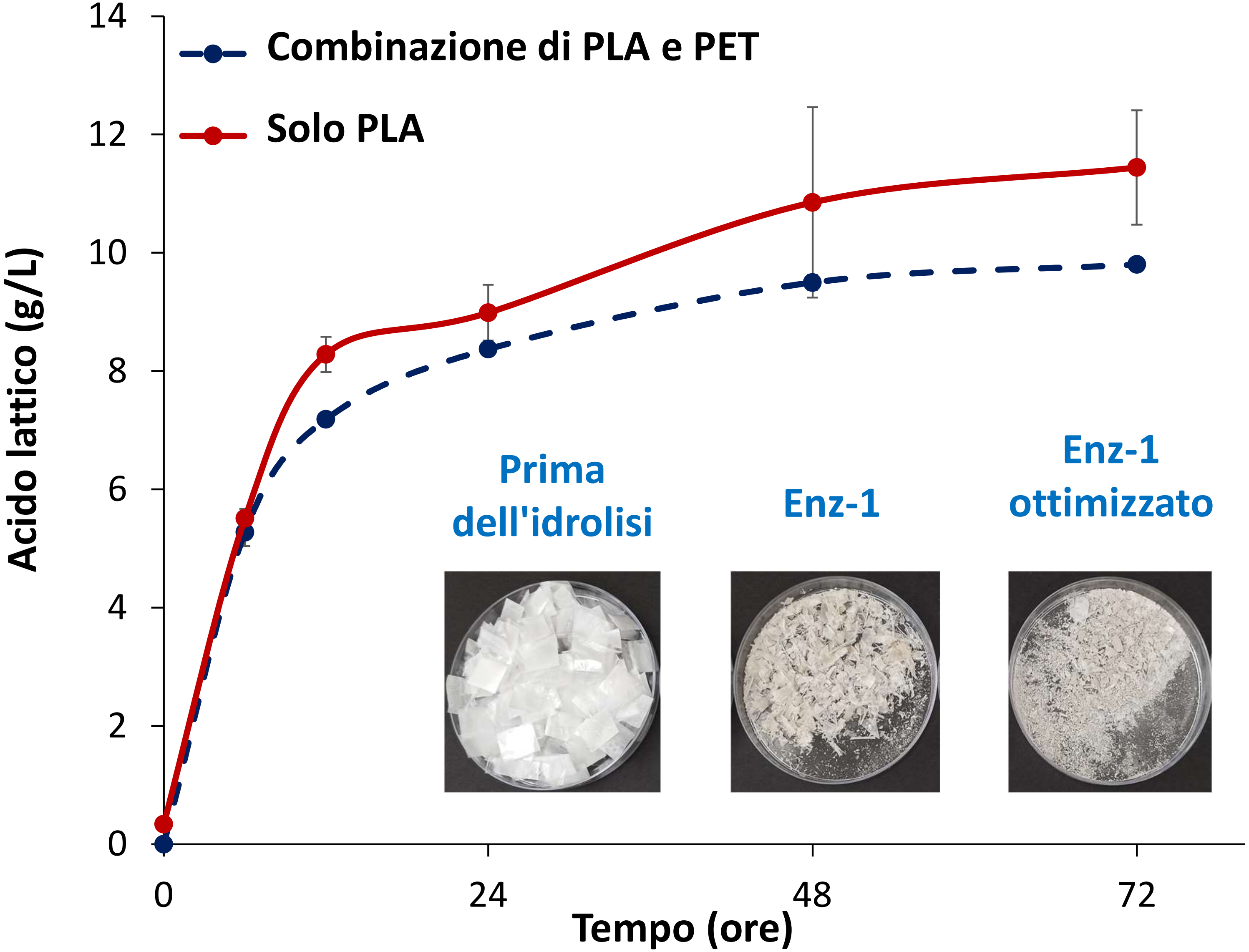


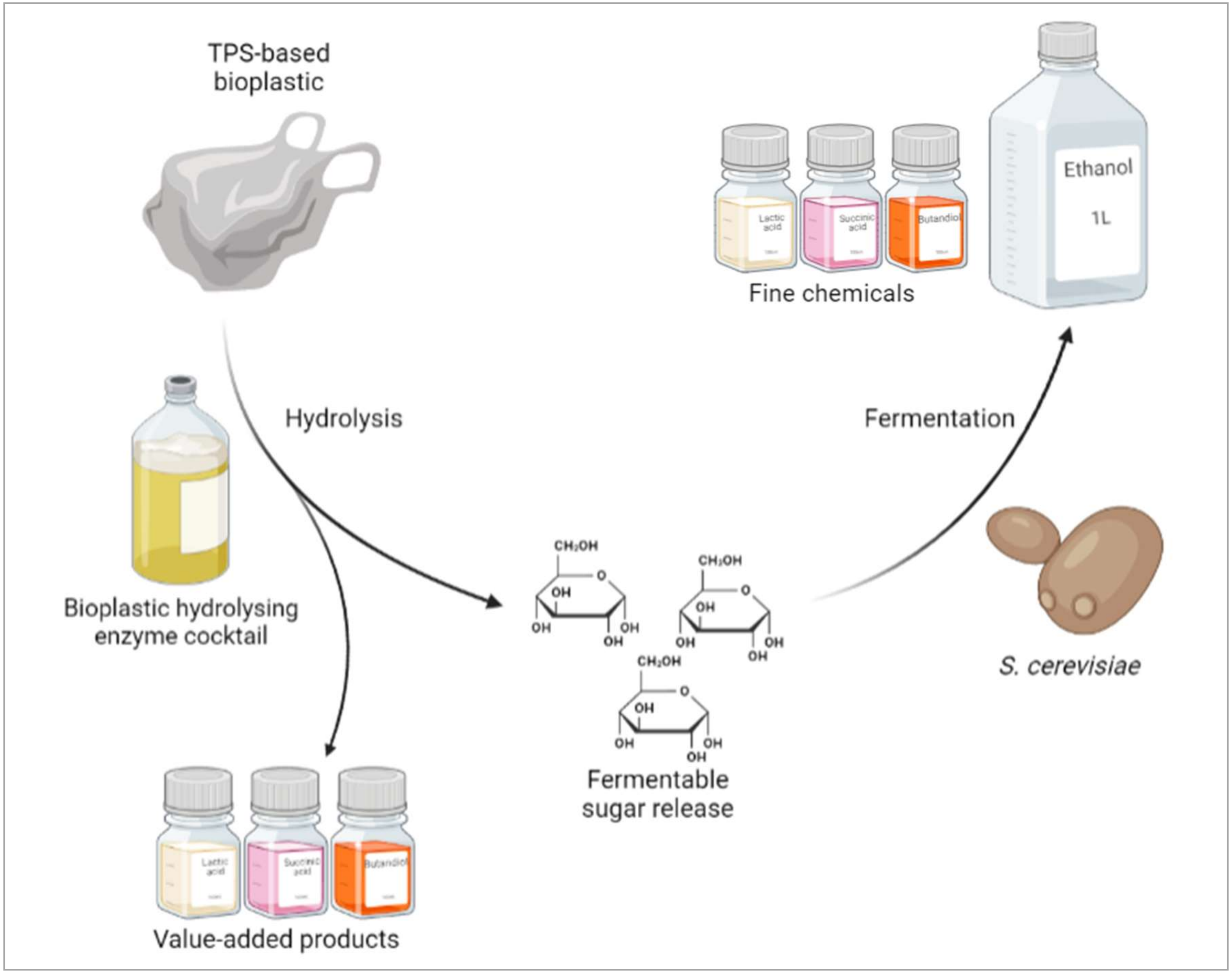




Idrolasi enzimatica di PLA in contesti di riciclo delle plastiche fossili: il caso di PLA & PET



TPS: cocktail enzimatici e lieviti per la bioraffineria



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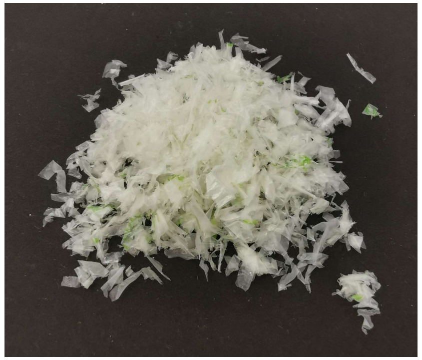
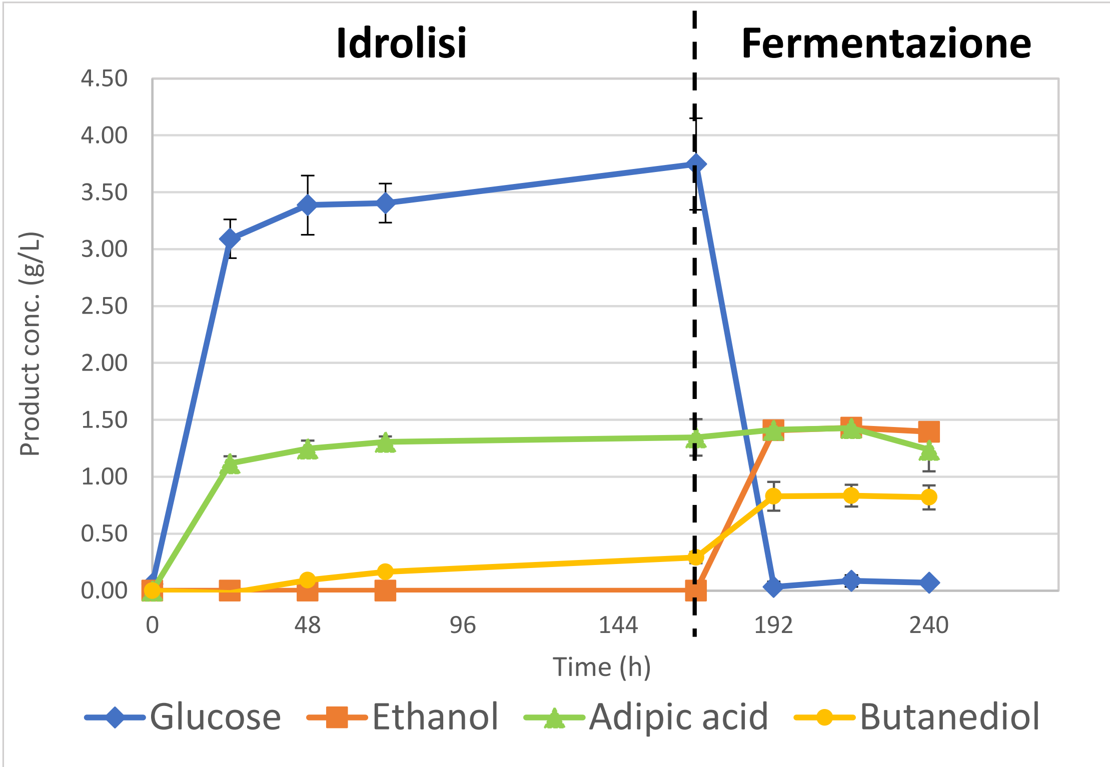
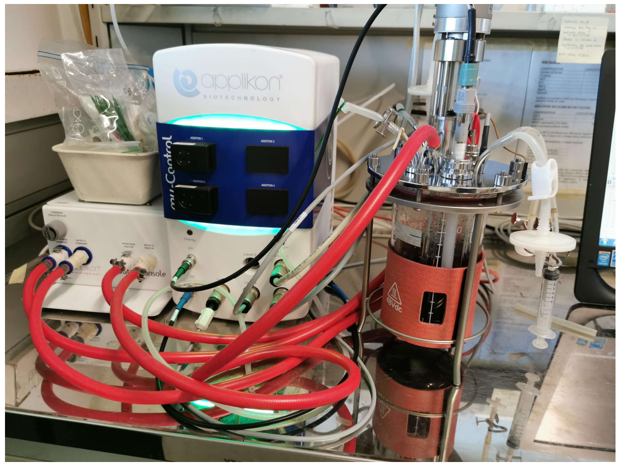
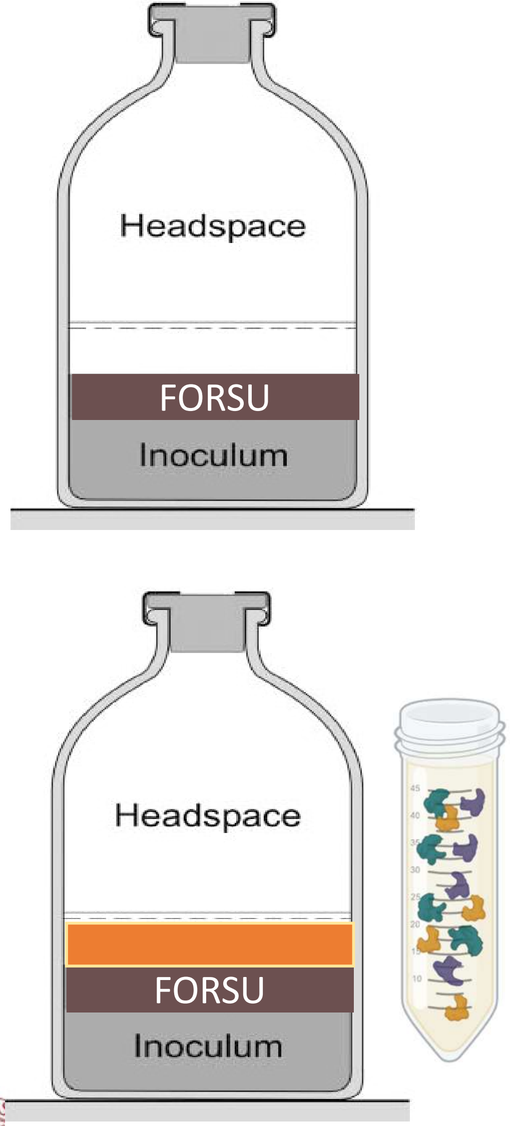
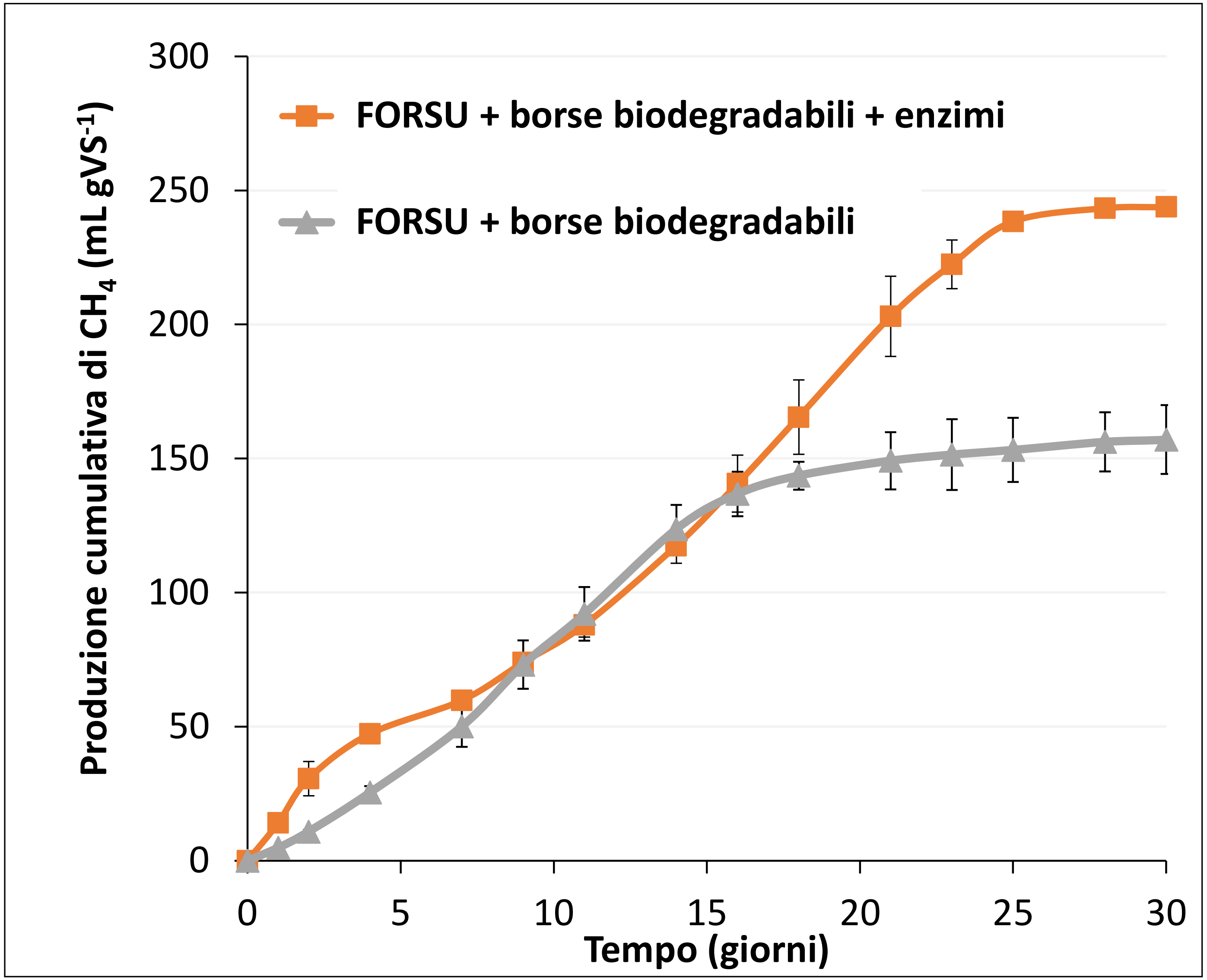




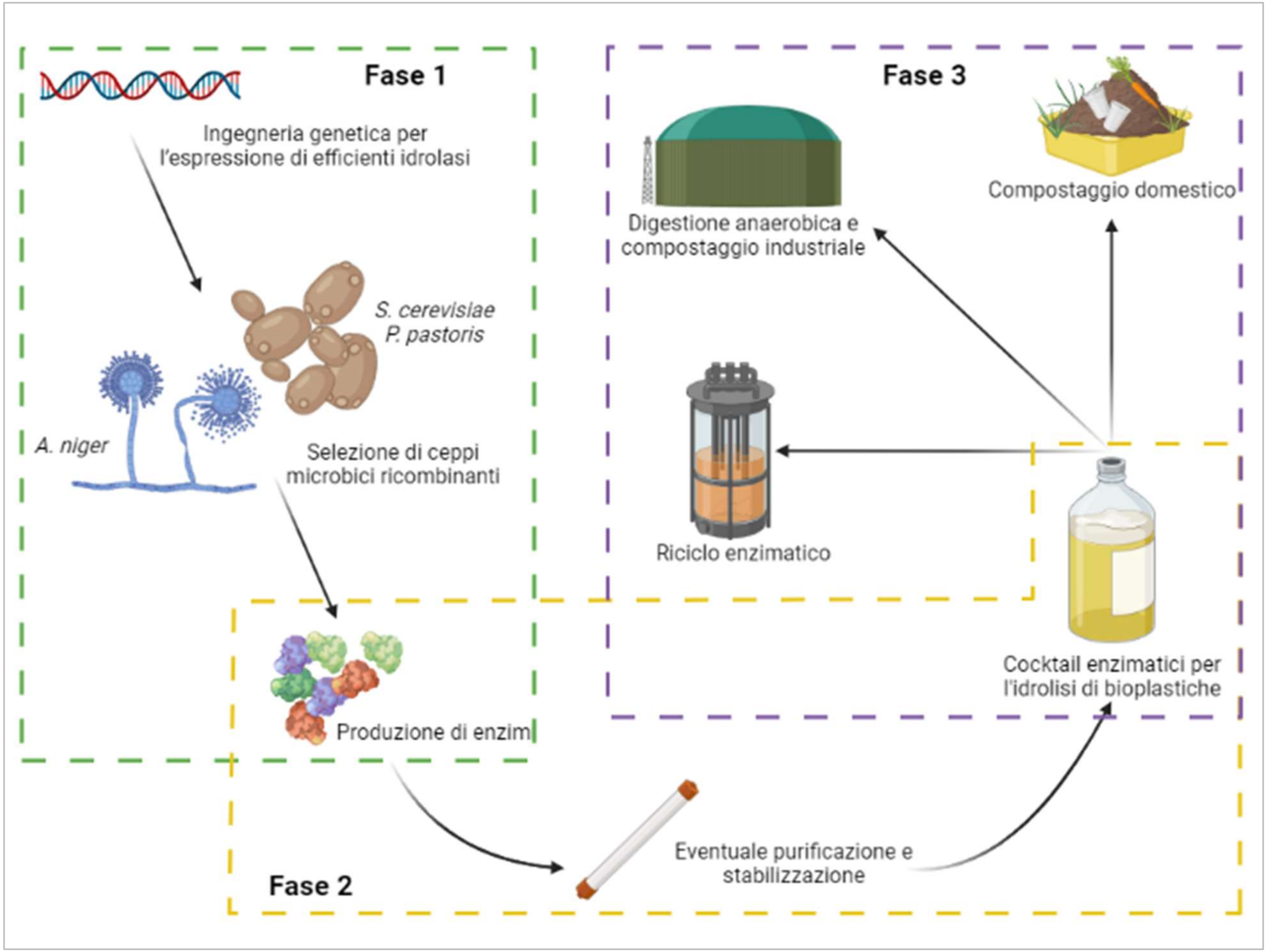


TPS: cocktail enzimatici per supportare la digestione anaerobica di FORSU e borse biodegradabili





Prospettive future



InnoDAbio: biotecnologie per la digestione anaerobica delle bioplastiche a fine vita

FONDAZIONE *Cariverona*

ETRA

BTS®

Ringraziamenti

Dott. Marthinus Wessel Myburgh
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Dott.ssa Sara Agostini
Dott. Leonardo Faggian

Prof. Michele Modesti
Prof. Alessandra Lorenzetti
Dott.ssa Silvia Zanatta
Dott. Diego Penzo

Prof. Marinda Bloom
Prof. Willem van Zyl
Dott.ssa Hannah L. Fosterb

Dott. Leigh Loots

Università degli Studi di Padova

UniSMART Fondazione Università di Padova

Enzyme treatment for bioplastic recycling

Applicant	Università degli Studi Padova; University of Stellenbosch
Inventors	Lorenzo Favaro, Marthinus Wessel Myburgh, Marinda Viljoen-Bloom, Willem Heber Van Zyl
Priority Date	27/10/2021
Protection	UK2115470.3

What we are looking for

We are looking for a suitable partner to enter into license deal/co-development partnership

What it is needed for?

This technology aims at improving the hydrolysis of bioplastics through the use of microbial enzymes that efficiently hydrolyze polyesters in bioplastic materials. In contrast to cellulosic sugar cane-based materials, starch-based bioplastics and polylactic acid (PLA) items can remain undegraded even after prolonged anaerobic digestion and/or composting treatment, with huge technological and economic issues for treatment plant owners.

In terms of waste management, enzyme-based systems could serve as a recycling approach to obtain single monomers whilst improving composting. These patented engineered Saccharomyces cerevisiae strains produce enzymes with high efficiency in hydrolyzing polyesters such as those in starch-based bioplastics. The use of enzymes in the degradation process has the advantage of requiring moderate process parameters and delivering valuable monomers at the end of the hydrolysis reaction.

This would allow for cradle-to-cradle recycling of bioplastics that could limit waste in polymer production and bioplastic manufacturing facilities.

Advantages

- Saves energy – Enzymatic recycling and hydrolysis is a mild temperature process;
- Monomer recovery for re-polymerisation;
- Improvement of bioplastic degradation in industrial or domestic composting and anaerobic digestion.

Applications

- Bioplastic Polymer Industry;
- Cradle-to-cradle (C2C) recycling;
- Recycling and waste management facilities;
- Organic waste treatment facilities and home composting.

TRL scale

1 2 3 4 5 6 7 8 9

Biotechnology, Chemistry, New Materials

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Patent@unismart.it