



Sveučilište u Zagrebu
Fakultet kemijskog
inženjerstva i tehnologije



*15th International Scientific-Professional Conference
WITH FOOD TO HEALTH*

*Microbial Synergy for a Greener Future through PHB
Production from Sugars*

Assoc. Prof. Dajana Kučić Grgić, PhD
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Osijek, 17th – 18th September 2025



FKIT MCMXIX



bc bioPHACoMPack

Proizvodnja i razvoj kompostabilne ambalaže iz otpadne biomase za pakiranje industrijski prerađenih prehrambenih proizvoda

NPOO.C3.2.R3-II.04.0059

Nacionalni plan opravaka i otpornosti (NPOO)
Podrška transferu tehnologije

Prijavitelj projekta
Sveučilište u Zagrebu
Fakultet kemijskog inženjerstva i tehnologije
Trg Marka Marulića 19, 10 000 Zagreb

Voditelj projekta
Izv. prof. dr. sc. Dajana Kučić Grgić

Partneri projekta
Istraživačka organizacija:
Sveučilište Josipa Jurja Strossmayera u Osijeku
Prehrambeno-tehnološki fakultet Osijek
Franje Kuhaca 18, 31 000 Osijek

Poduzeća:
Podravka d.d.
Ante Starčevića 32, 48 000 Koprivnica
Rotoplast d.o.o.
Poduzetnička 7, Krenštinec, 10 431 Sveti Nedelja

Trajanje projekta: 1. 1. 2024. – 30. 6. 2026.

Ukupni prihvatljivi troškovi projekta: 1.628.689,99 €

Bespovratna sredstva: 1.488.082,51 €

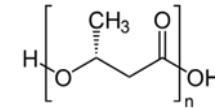
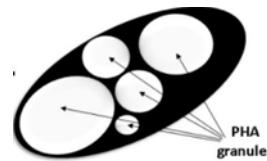
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Financira Europska unija NextGenerationEU

Projekt se finira iz Nacionalnog plana opravaka i otpornosti (NPOO), kroz poziv Podrška transferu tehnologije



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the European Union

This research was conducted as part of the project „Production and development of compostable packaging from waste biomass for the packaging of industrially processed food products“ (NPOO.C3.2.R3-II.04.0059) funded by National Recovery and Resilience Plan (funded by the European Union, NextGenerationEU).



PROJECT - Production and Development of Compostable Packaging from Waste Biomass for the Packaging of Industrially Processed Food Products

1. *Production of PHA from secondary generation biomass – agroindustrial waste using solid state fermentation*

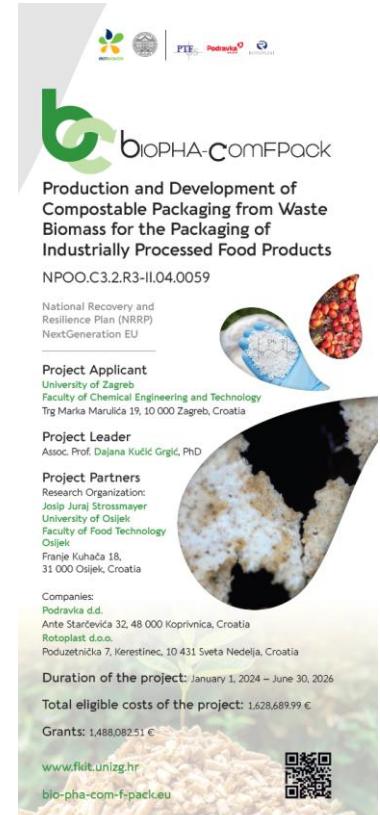
- Physical and chemical characterisation of waste
- Examine pure and mixed culture
- Examine different extractions methods
- Optimization of process via SmF and SSF

2. *Production of biodegradable and compostable packaging materials*
Development of biofilms – PHA, PLA, TPS, PBS

- Using compostable coatings
- Biodegradable additives

Examine of produced biofilms:

- biodegradability
- Ecotoxicity
- Compostability



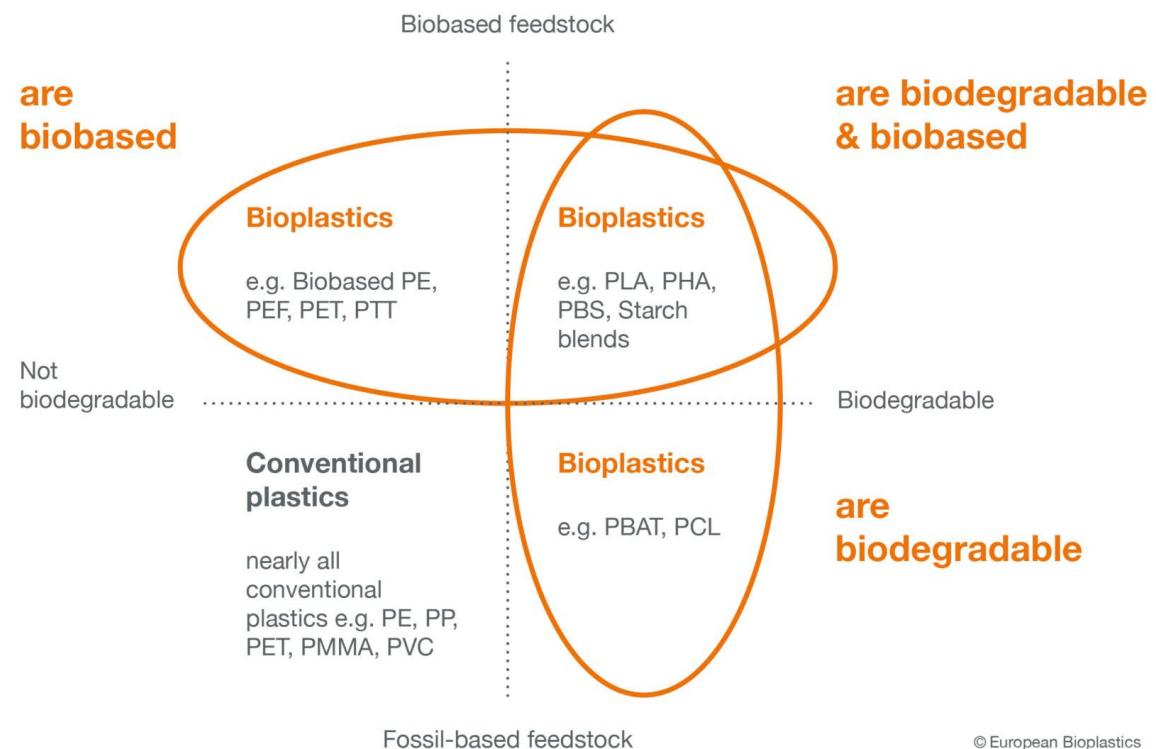
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The project is financed from the National Recovery and Resilience Plan (NRRP), through the call for Technology Transfer Support.



Material coordinate system for bioplastics

Bioplastics are biobased, biodegradable, or both.

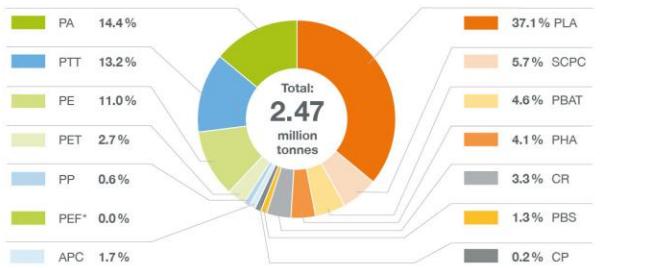


Source: Institute for Bioplastics and Biocomposites (ifBB) and European Bioplastics (EUBP)

© European Bioplastics

Global production capacities of bioplastics 2024

Biobased, non-biodegradable
43.7%



APC Aliphatic Polycarbonates
CP Casein Polymers
CR Cellulose Regenerates
PA Polyamides
PBAT Poly(Butylene Adipate-co-Terephthalate)

PBS Polybutylene Succinate and Copolymers
PE PEF Polyethylene
PET Polyethylene Furanoate
PP PET Polyethylene Terephthalate

PHA Polyhydroxyalcanoates
PLA Polylactic Acid
PP Polypropylene
PTT Polymethylene Terephthalate
SCPC Starch Containing Polymer Compounds

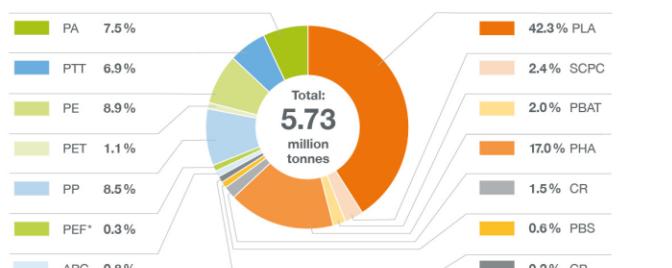
* PEF available at commercial scale as of 2024
Source: European Bioplastics, nova-Institute (2024)

Biobased, biodegradable
56.3%



Global production capacities of bioplastics 2029

Biobased, non-biodegradable
34.0%



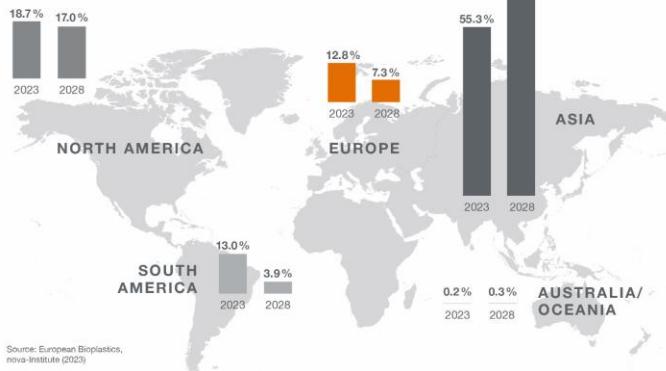
APC Aliphatic Polycarbonates
CP Casein Polymers
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PBS Polybutylene Succinate and Copolymers
PE PEF Polyethylene
PET Polyethylene Furanoate
PP PET Polyethylene Terephthalate

PHA Polyhydroxyalcanoates
PLA Polylactic Acid
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PTT Polymethylene Terephthalate
SCPC Starch Containing Polymer Compounds

* PEF available at commercial scale as of 2024
Source: European Bioplastics, nova-Institute (2024)

Global production capacities of bioplastics

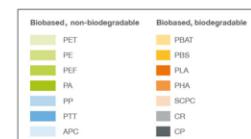


Source: European Bioplastics, nova-Institute (2023)



Global production capacities of bioplastics 2024 (market segments by polymers)

in 1,000 tonnes



Source: European Bioplastics, nova-Institute (2024)

Production of bioplastics from biomass

First-Generation



Edible biomass

Sugar beet, wheat, corn, potatoes, canola

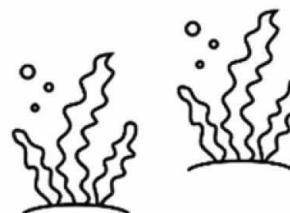
Second-Generation



Non-edible biomass

Miscanthus, switchgrass, rice straw, rice husk, saw dust, municipal waste, animal by-product streams

Third-Generation



Algal biomass

Microalgae, macroalgae

Fourth-Generation



Electrical driven

Polarized electrodes as electron source

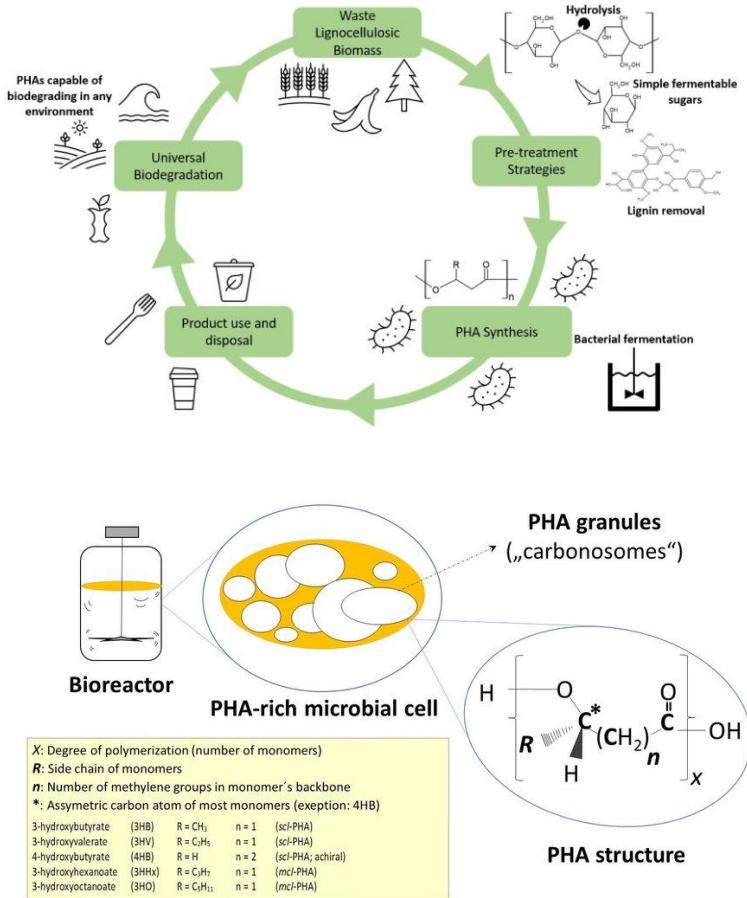


There is a clear trend in research showing a shift to second-generation feedstock usage, due to concerns about available quantities and food prices.

High abundances of second-generation feedstocks and lower market competition lead to lower prices.

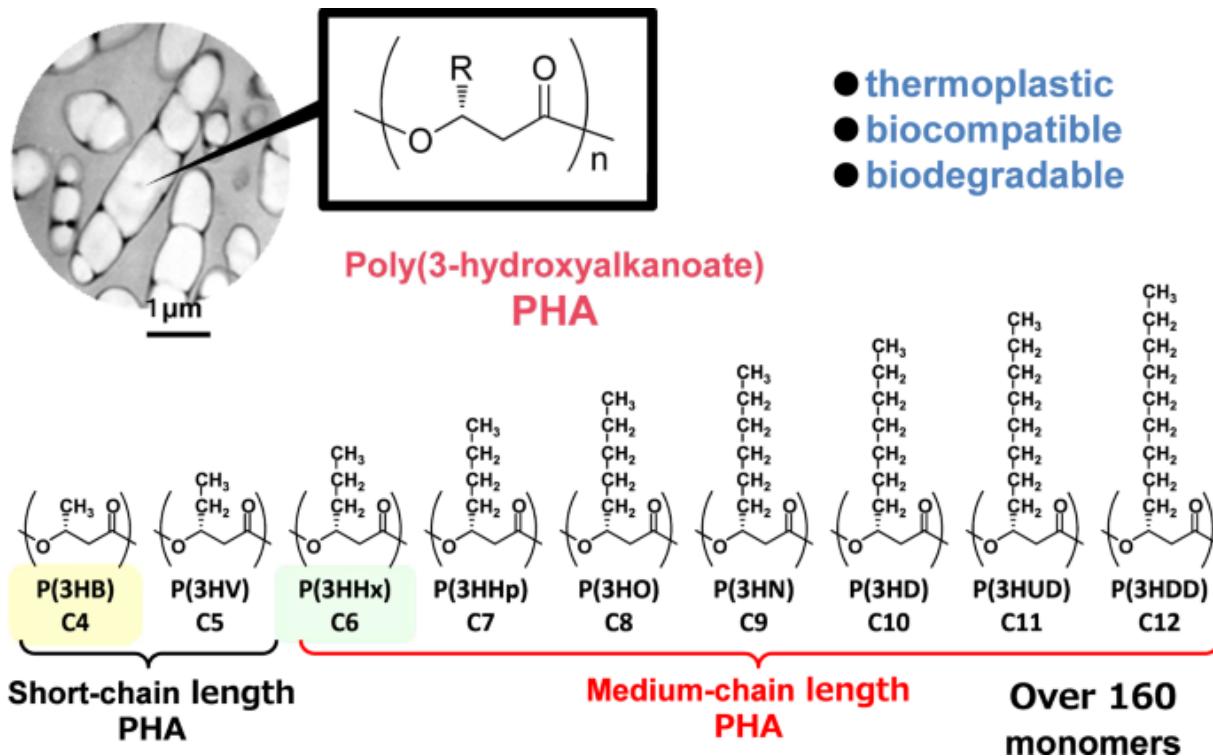
Potential problems: the economic feasibility of microalgae production, such as difficult culture conditions, high contamination risks, complex cleaning processes as well as low cell densities and productivities

Polyhydroxyalkanoate



- Polyhydroxyalkanoates polyesters are **synthesized and accumulated in various microorganisms**, usually when *entering the stationary phase of growth*.
- PHAs form **intracellular inclusions** and can be synthesized to store carbon and energy, and can reach 80% of cell weight.
- They are synthesized intracellularly as insoluble cytoplasmic inclusions in the presence of excess carbon, when other essential nutrients such as oxygen, phosphorus, or nitrogen are limited.
- These polymeric materials may be stored at high concentrations inside the cell, since it does not substantially alter its osmotic state.

Polyhydroxyalkanoate

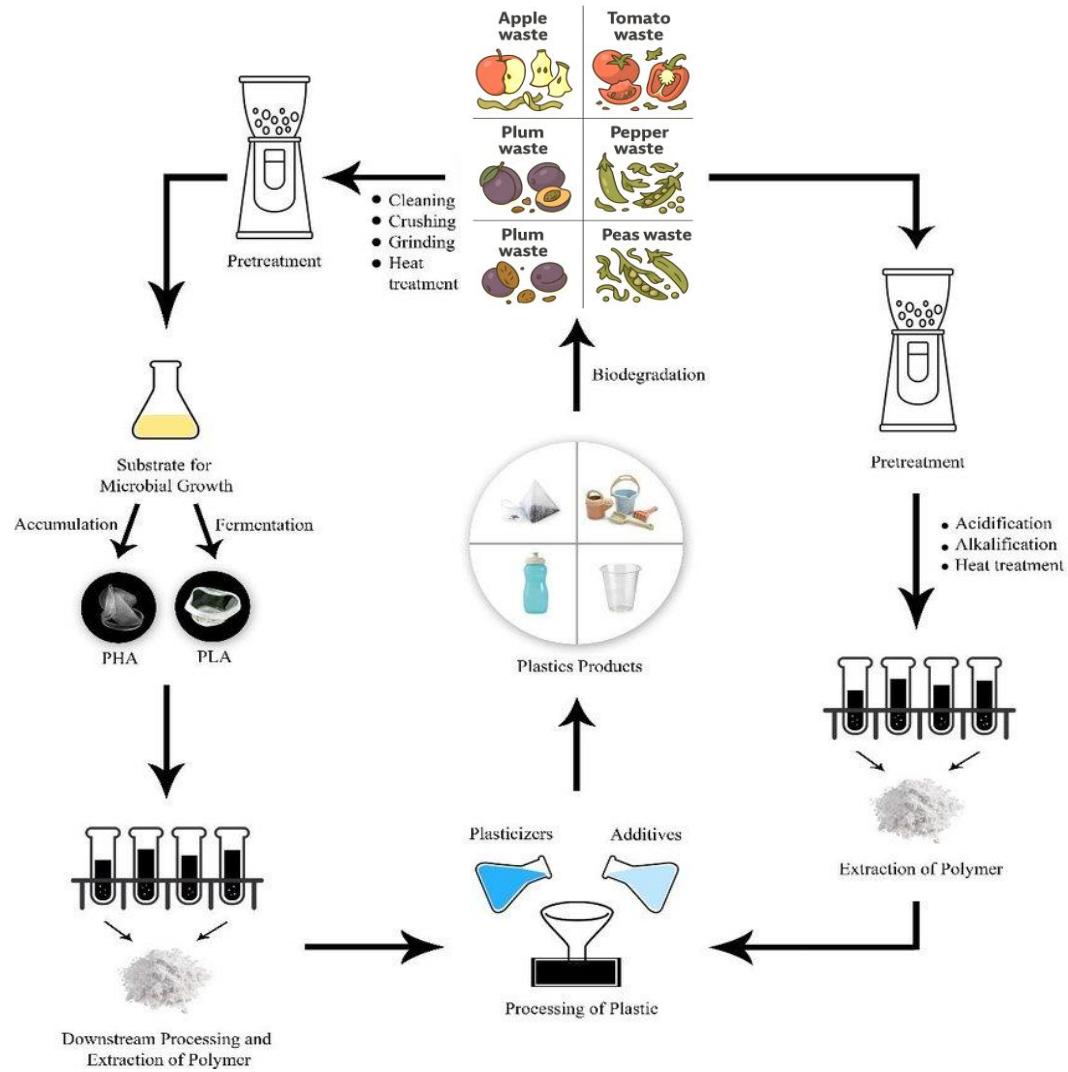


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Production of PHA by SmF

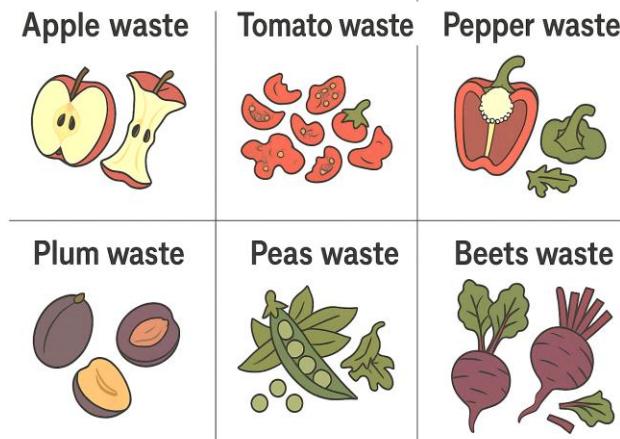


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Production of PHA by SmF



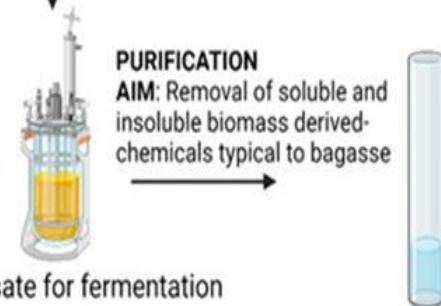
High-solid pretreatments
Combination of physical, chemical and biological agents
Chemical recycling
Use of recycled chemicals

PRETREATMENT
AIM: To break structural integrity of bagasse and produce fermentable sugar



Cellulase and auxiliary enzymes with high re-usability

ENZYMATIC SACCHARIFICATION
AIM: To generate concentrate sugar solution by degradation of cellulose



Optimal fermentation parameters, improved one-step feeding, substrate detoxification, selection of high-yield microbes



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Production of PHA by SmF



Peas waste



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Initial conditions (duration 6,5 days) _Experiment 1

$\gamma_{initial}$ (reducing sugars (fructose, glucose, and sucrose) / g/L	15.0
pH-value / -	6.9
Culture	Mixed culture of <i>C. necator</i> and <i>P. putida</i>
Optical density _{600nm} / -	0.9
T / °C	30.0
rpm	250.0
Air / mL/min	300.0

Initial conditions (duration 2,5 days) _Experiment 2

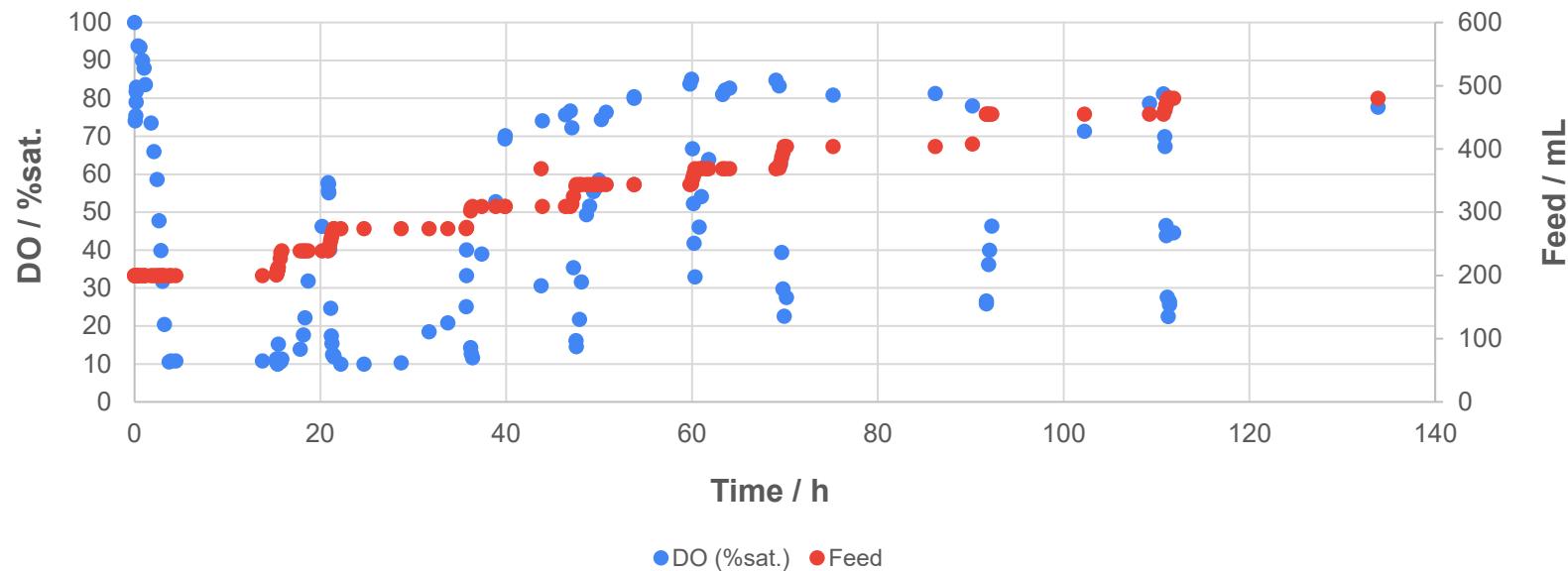
$\gamma_{initial}$ (reducing sugars (agroindustrial waste - peas) / g/L	15.0
pH-value / -	6.9
Culture	<i>C. necator</i>
Optical density _{600nm} / -	0.9
T / °C	30.0
rpm	350.0
Air / mL/min	400.0



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Experiment 1



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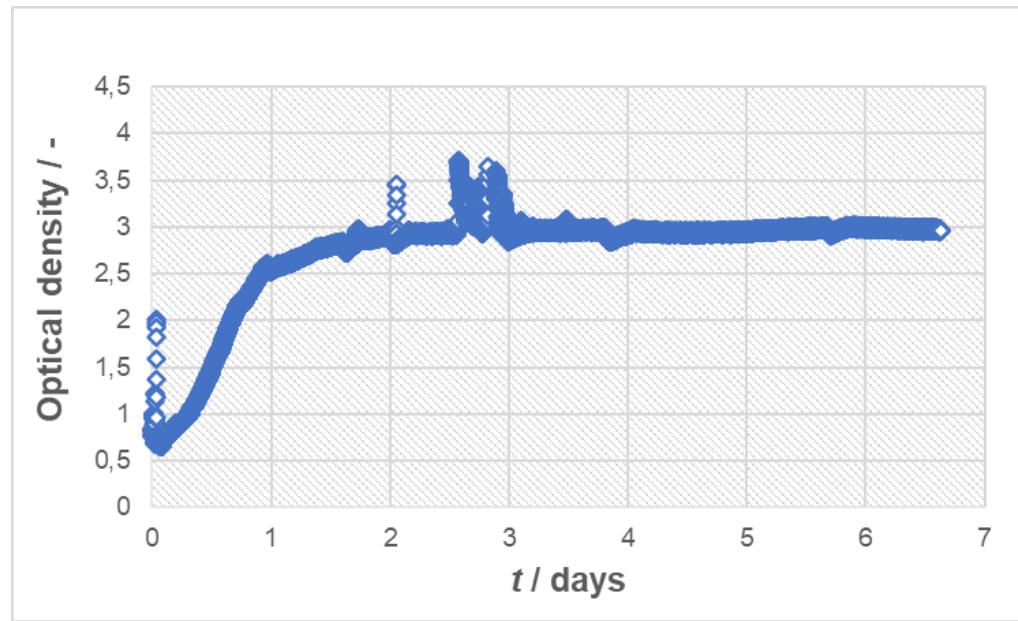
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Production of PHA by SmF



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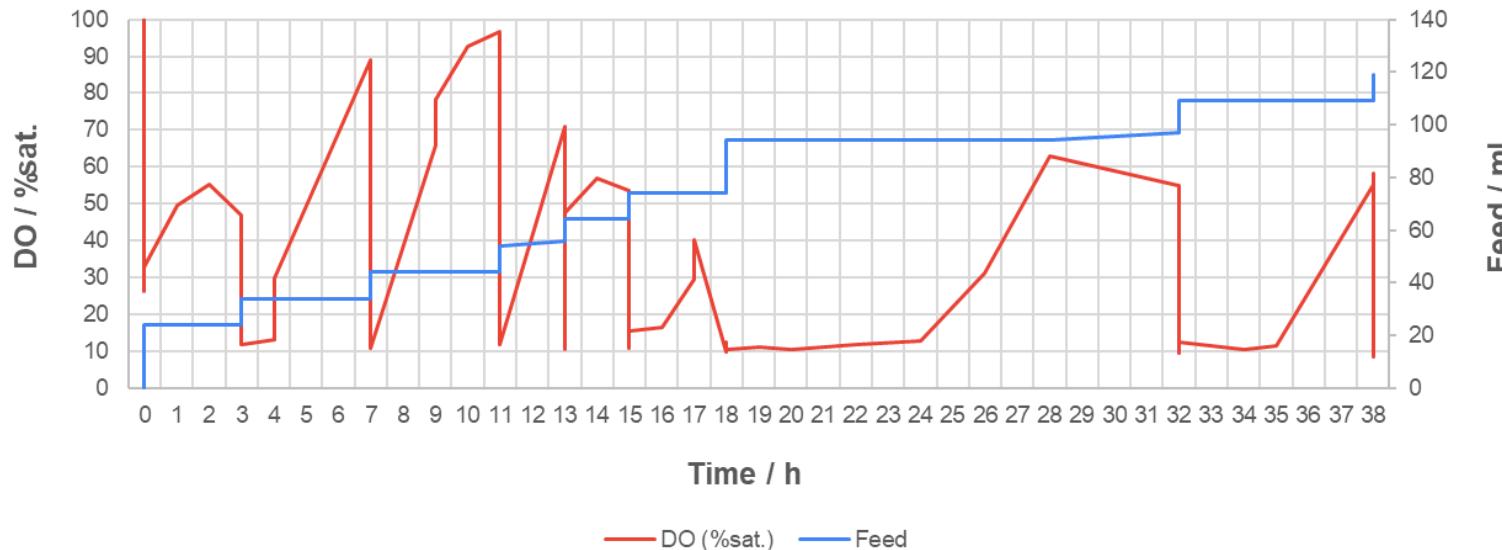
Production of PHA by SmF



Peas waste



Experiment 2



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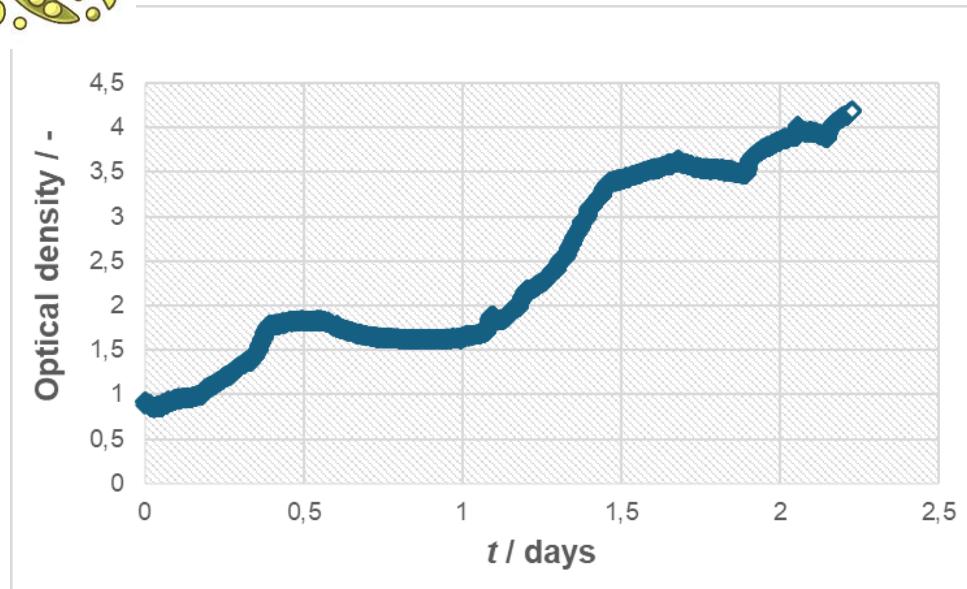
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Production of PHA by SmF



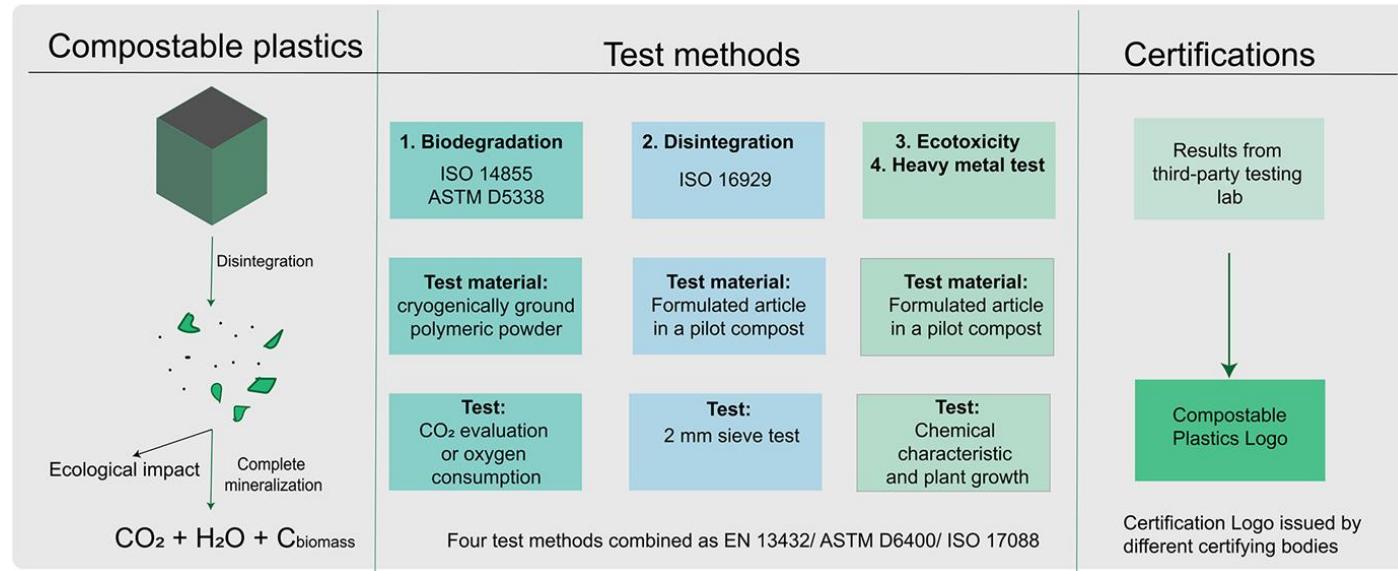
Peas waste



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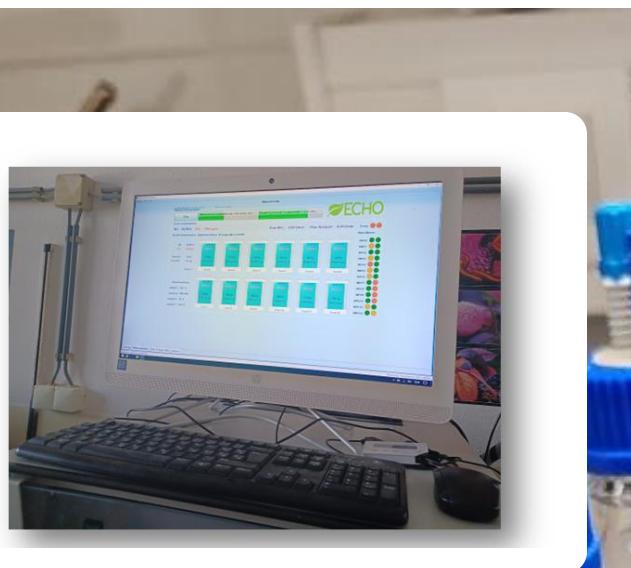


ISO 17556:2019

Plastics — Determination of the ultimate aerobic biodegradability of plastic materials in soil by measuring the oxygen demand in a respirometer or the amount of carbon dioxide evolved

ISO 14852:2021

Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium — Method by analysis of evolved carbon dioxide





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University of Zagreb
Faculty of Chemical
Engineering and Technology

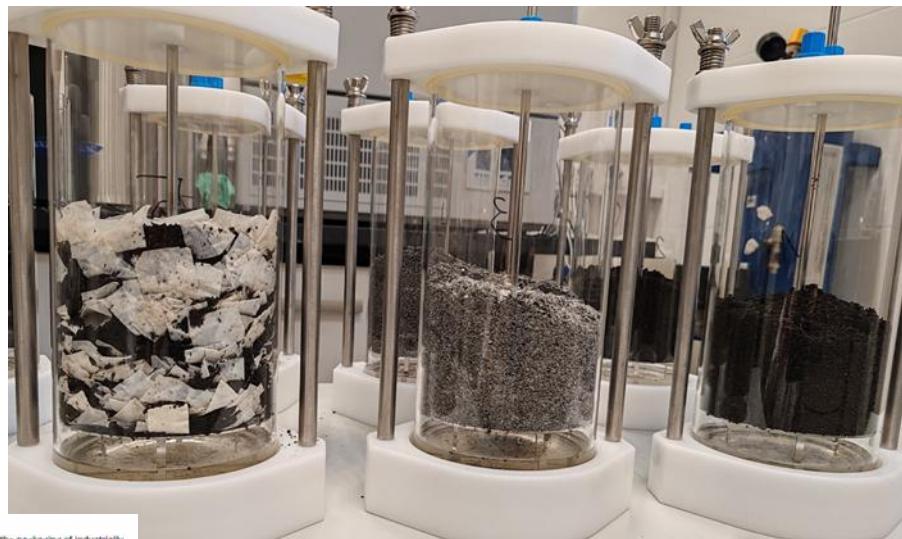
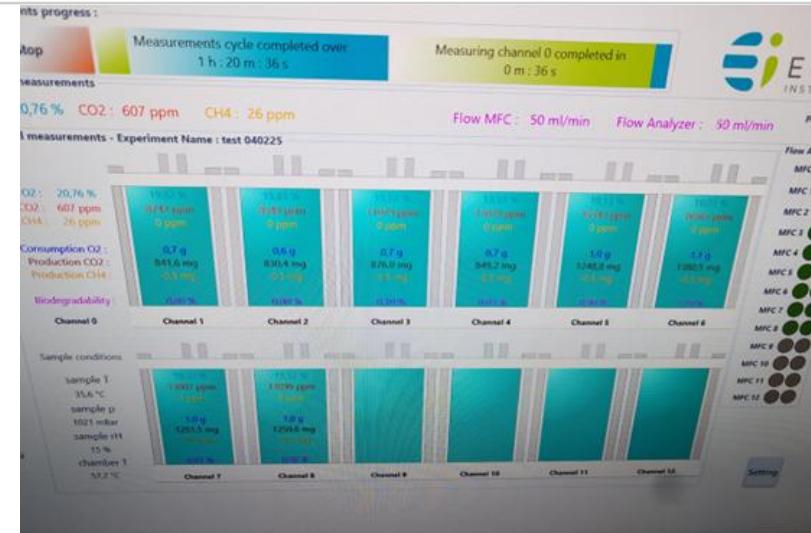


PTF

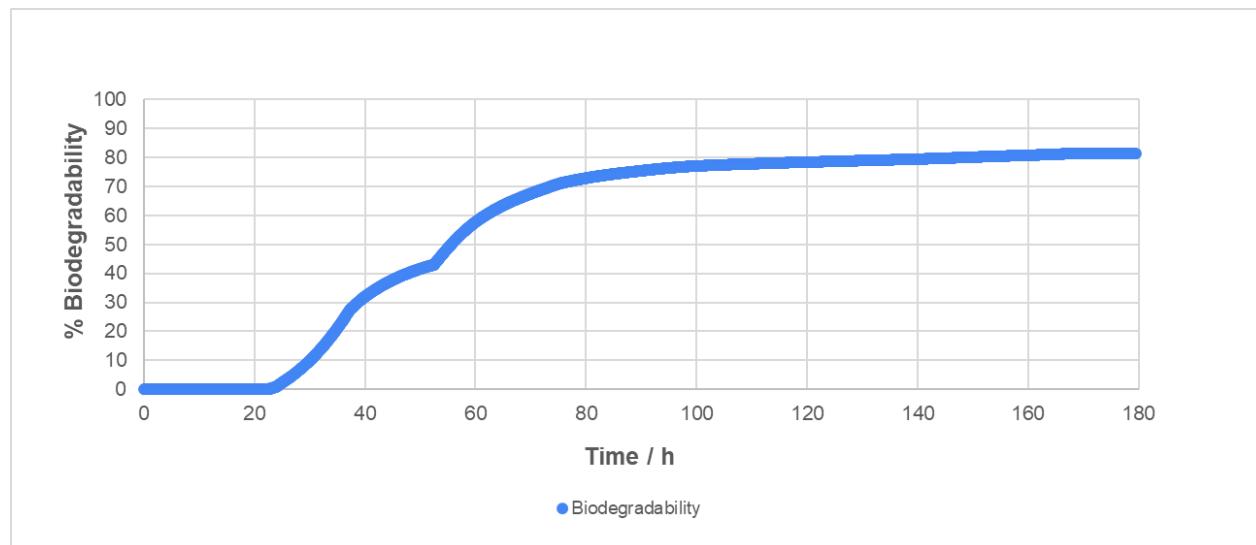
Podravka

ROTOPLAST

Determination of biodegradability of bioplastics



Determination of biodegradability of bioplastics



RESEARCH TEAM FROM FCET AND PTFOS

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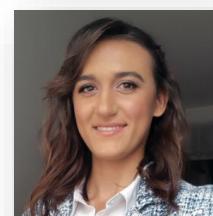
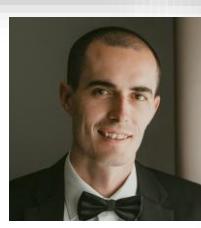
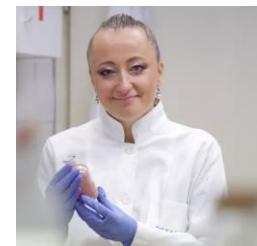
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