The power of synergistic interactions between organisms for plastic recycling and degradation

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- Combination *Eisenia fetida* with microorganisms
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Background

Agri-food Waste Plastics

Food packaging and Agriculture consume ~44% of worldwide production of plastics

Polyethylenes (PE), Polystyrene (PS), Polyethylenthereptalate (PET)

End of life

Sorting

Waste Management Systems

Plastics

31 % recycled

Non-recyclable: Mixed or multilaminated

Incinerated
Landfiled

Organic fraction +plastics

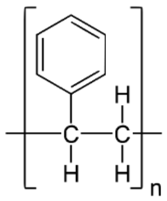
Compost contamination

Released to the environment

Soil contamination

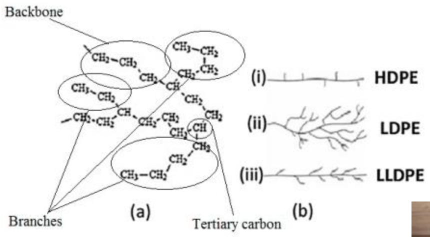
New biorecycling routes

Background



Polystyrene

– C – C –



Polyethylene

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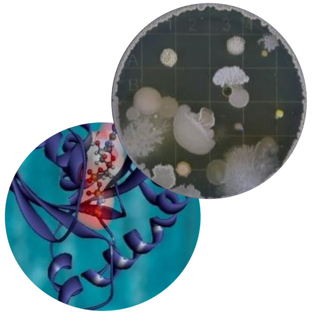
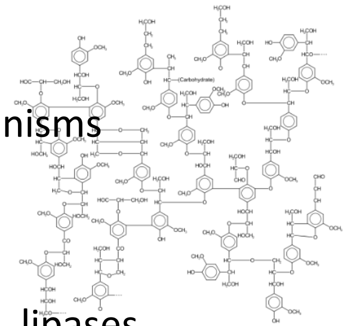




Earthworms & Insects (+microbiome)

Partial biodegradation → CO_2

AWP-adapted

Casts/faeces (microplastics)

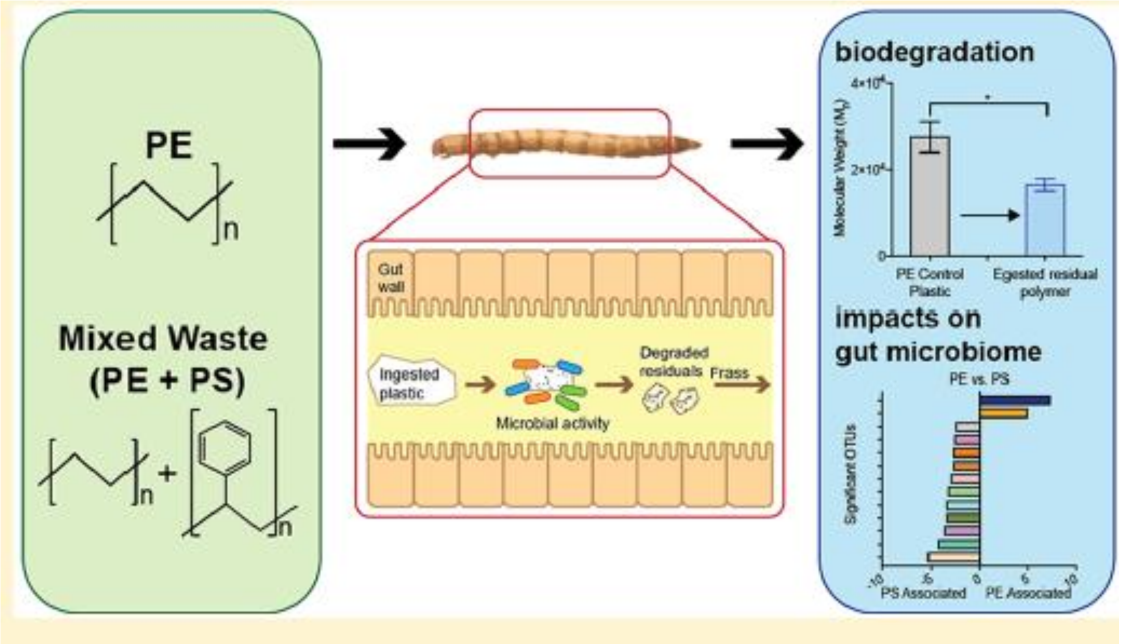
Microorganisms (Lignin)

Enzymes (esterases, lipases, hydrolases)

Consortia “ad hoc”

$CO_2 + H_2O$

Background



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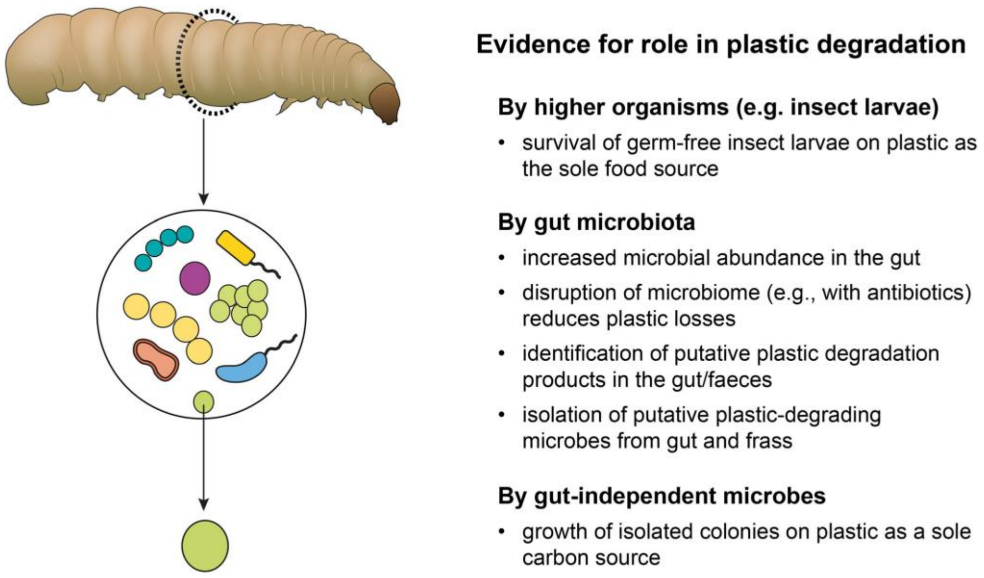

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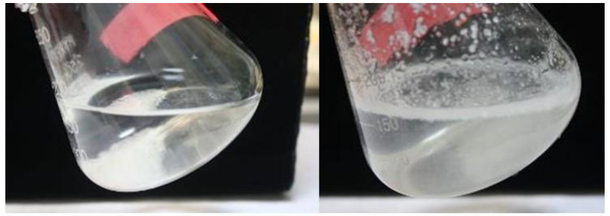
Background



Microbial Consortia

Tenebrio monitor "Gusano de la harina" (Fuente: UAL)

Galleria mellonella "Gusano de la cera"

Insects

Earthworms

Combination of biocatalytic systems (hydrolytic enzymes, microbial, insects, and earthworms)

- maximize the transformation yields
- allowing the treatment of mixed plastic waste streams
- to convert fossil fuel plastic into biodegradable counterparts in a single step.

Objectives

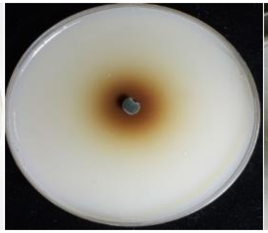
- Develop microbial consortia for multiplastic degradation
- Increase the plastic conversion efficiency of *Galleria mellonella* through the incorporation of microorganisms
- Increase the plastic conversion efficiency of *Eisenia fetida* through the incorporation of microorganisms

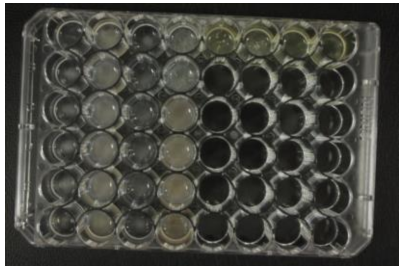
Galleria mollonella "Greater wax moth"

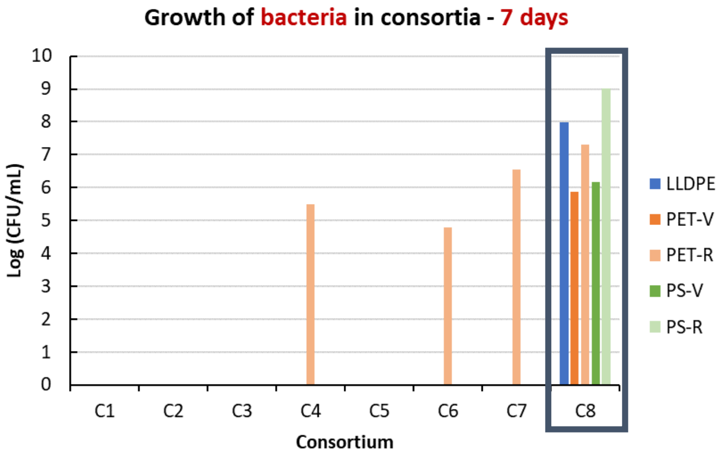
E. andrei/foetida

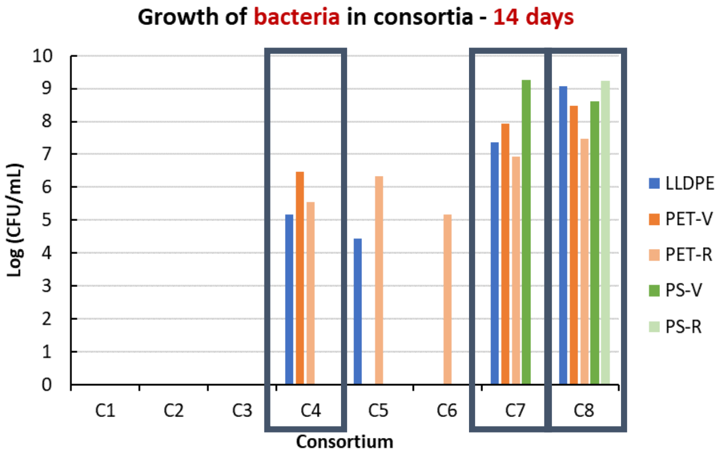
Microbial consortia for multiplastic degradation

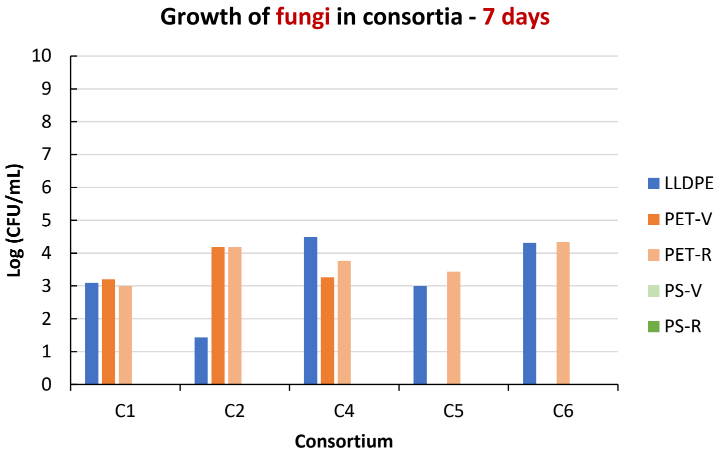
- Bacteria and fungi **screened for plastic-degrading related enzymes**: lipases, cutinases and ligninases.
- Six strains: **combined in pairs or trios to build up eight consortia**
- Plastic biodegradation: **Capability to grow in virgin or recycled LDPE, LLDPE, PET or PS as the sole carbon source.**

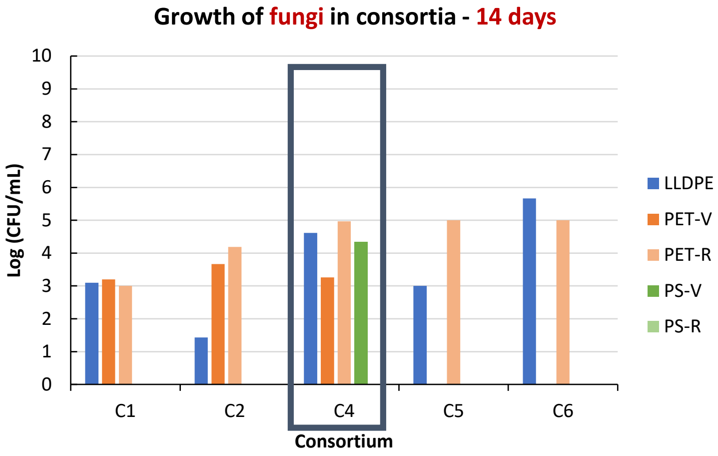





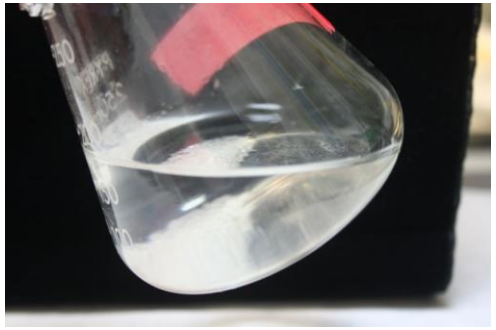


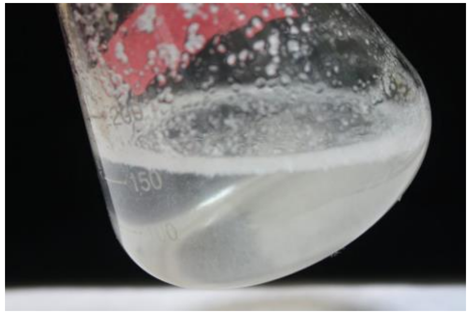






Microbial consortia for multiplastic degradation

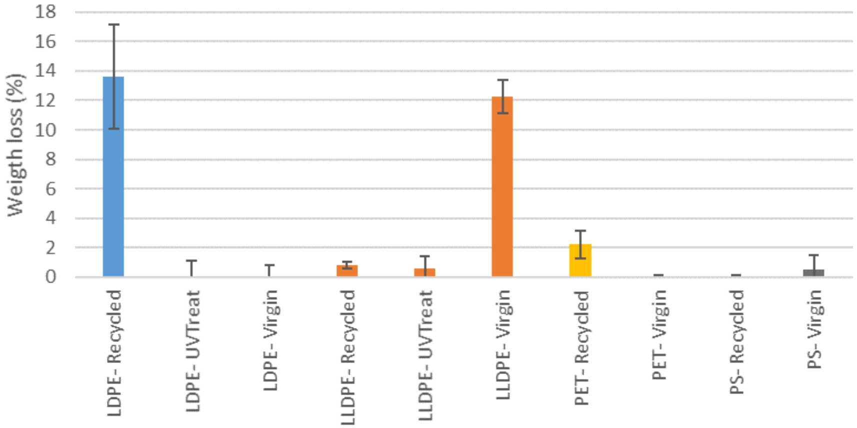




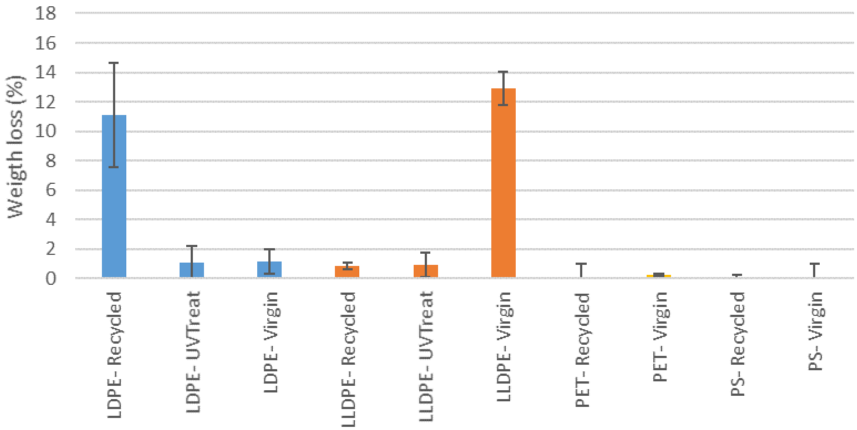
Plastic weight loss (%)

- Most - Non significant or <2%
- Consortia C2:
    - LDPE - recycled 14%
    - LLDPE - virgin 12%
    - PET-recycled 2%
- Consortium C4:
    - LDPE - recycled 11%
    - LLDPE – virgin 13%

C2: RHM4+RHM1+RBM1

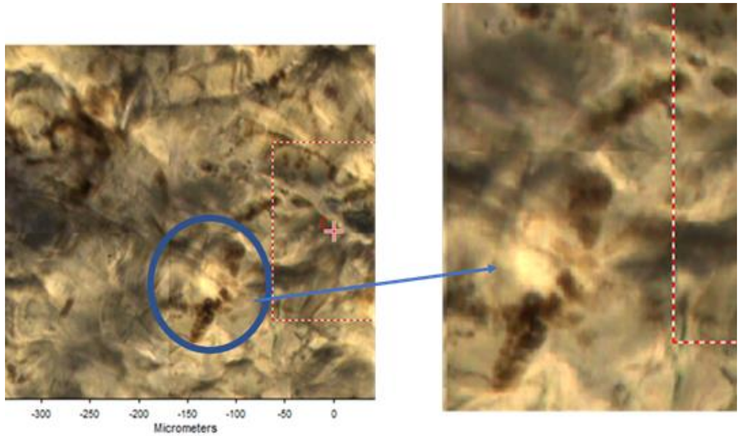


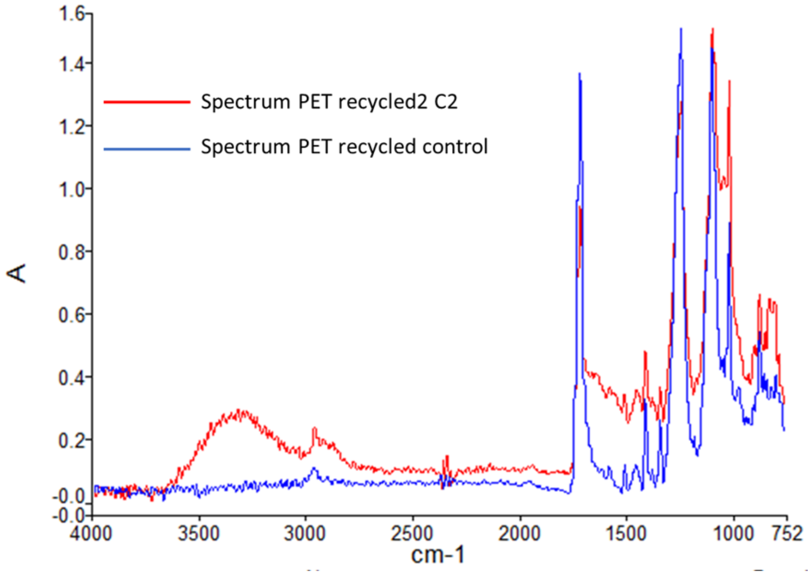
C4: RBM2+E7



PET recycled treated with Consortium C2: Chain scission through the hydrolysis of the ester bond.

- Changes in chemical composition in the surface area
- A band at 3500-3100 cm^{-1} (-OH)
- Decrease of bands in the range where the ester bond of PET resonates: 1712 cm^{-1} (carbonyl stretching) and 1240 cm^{-1}
- Spectrum modification 1700–1500 cm^{-1} (carboxyl or carboxylate groups) spectral range, likely related to microbial degradation.





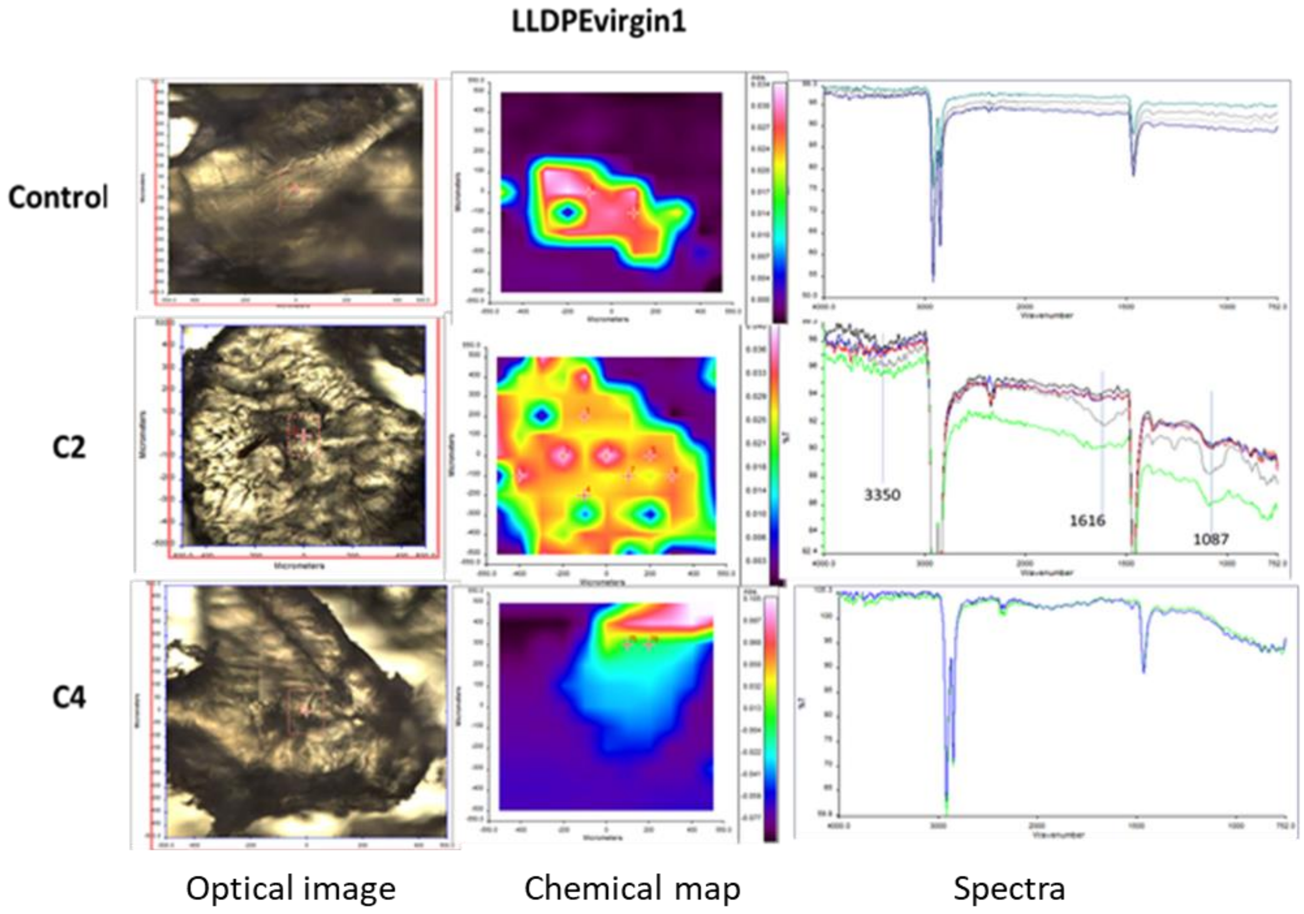
FTIR Chemical Imaging analysis

Microbial consortia for multiplastic degradation

Small changes in chemical composition in the surface area of LLDPE virgin after C2 treatment were observed

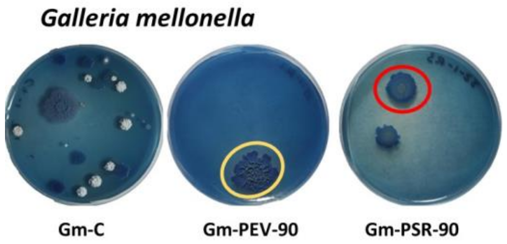
Incorporated oxygen functional groups was observed at 3500-3100 cm^{-1}(-OH) and 1800–1500 cm^{-1}(C=O).

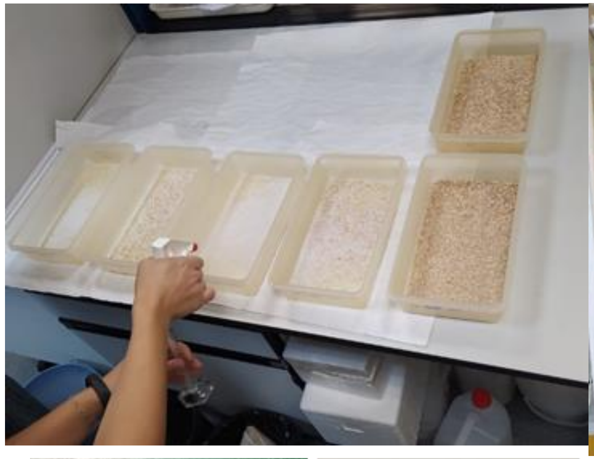
A broad adsorption band centered at 1087 cm^{-1} related to C-O was evident.

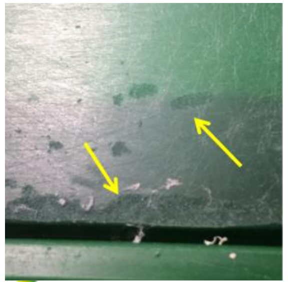


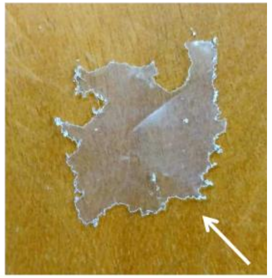
FTIR Chemical Imaging analysis

G. mellonella with microorganisms

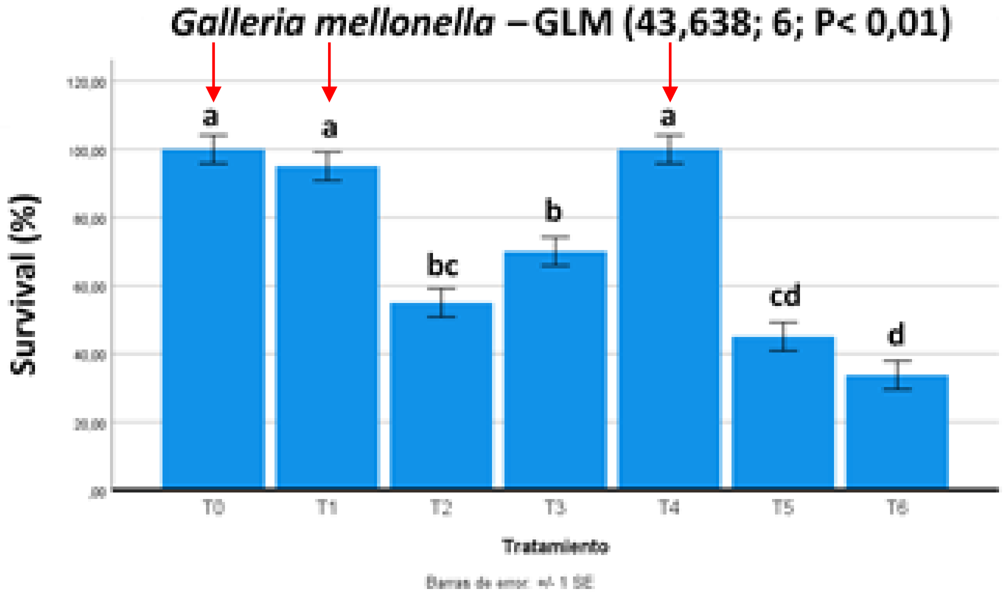








Galleria mollonella “Greater wax moth”



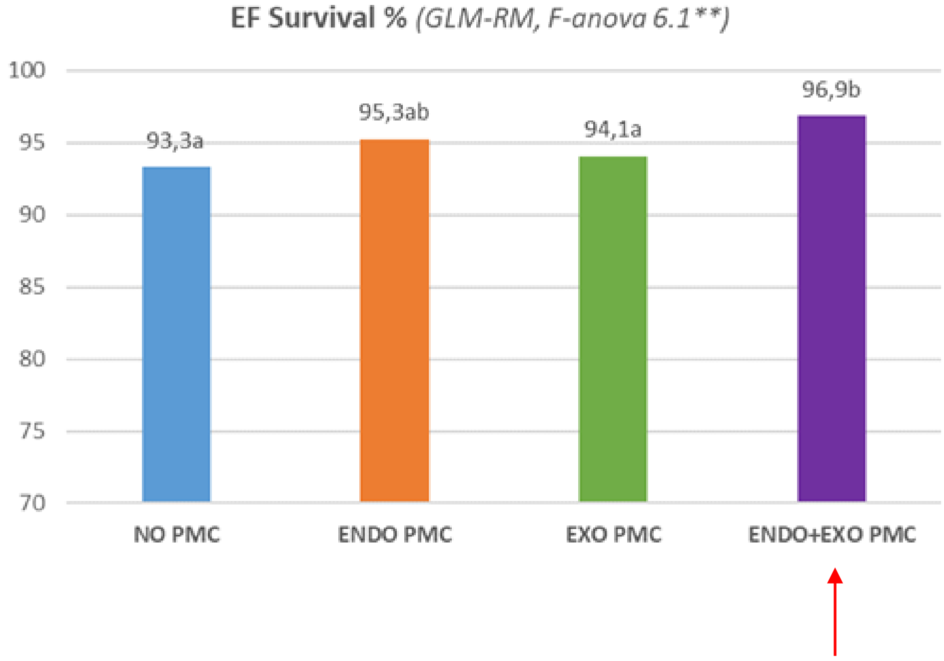
T0: Standard diet (no plastic)

T1: Bacteria 1 – LLDPE 100%

T4: Bacteria 2 – LLDPE 100%

Eisenia fetida with microorganisms

E. andrei/foetida



Conclusions

- The microbial consortia selected in this work are very promising tools for the treatment of heterogeneous mixtures of plastic wastes.
- The combination of microorganisms and *G. mellonella* or *E. fetida* allows higher survival when feeding on plastic, which can be used for plastic biological recycling.
- Further analyses are required to determine the fate of plastic bioconversion by the combinations insect or earthworm with microorganisms

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RECOV3R

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