Biodegradable plastics, a sustainable solution for the environment?

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Introduction

5 trillion plastic pieces into oceans (Geyer et al., 2017)
Introduction

Biodegradable plastics

90% into CO₂ in compost at 70°C in 180 days

PLA: excellent oxygen and water barrier properties, replacement for PS and PP
PBAT: similar properties than LDPE
Introduction

What about degradation into environmental conditions?
What about bacterial community?

(Hasler et al., 2019)
Strategy

Degradation analysis

Weight Loss
DSC (Differential Scanning Calorimetry)
GPC (Gel Permeation Chromatography)
ATR-FTIR

(Benali et al., 2015)

Bacterial community analysis

DNA extraction (DGGE, 16S rRNA amplicon sequencing)
Methods

Biobased

- Semi-crystalline PLA (4032D)
- Amorphous PLA (4060D)

Biodegradable

Non-biodegradable

- PET
- LDPE

Petro-based

- PS
- PVC
- PBAT
Methods
Methods

Water column (4.5 m)
Methods

Plastics on sediment (8 m)
Methods

Plastics on sediment

Plastics in the water column
Degradation analysis

Water column plastics

![Graph showing weight loss for PBAT, PS, PVC, PET, and LDPE in water column plastics.]

Sediment plastics

![Graph showing weight loss for PBAT, PS, PVC, PET, LDPE, PLA 4060D, and PLA 4032D in sediment plastics.]

Around 1% of weight loss for PBAT
Degradation analysis: DSC

Semi-crystalline PLA (4032D)

\[ \chi_c = \left( \frac{\Delta H_{m(t)} - \Delta H_{c(t)}}{\Delta H_m^0} \right) \times 100 \]

\( \Delta H_m = \) Melting enthalpy
\( \Delta H_c = \) Enthalpy of cold crystallisation
\( \Delta H_0 = \) Melting enthalpy of the 100% crystalline polymer

T_g = Glass transition temperature
T_c = Cold crystallisation temperature
T_m = Melting temperature
Degradation analysis: DSC

Semi-crystalline PLA (4032D)

\[ T_g \] = Glass transition temperature
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\[ \Delta H_m \] = Melting enthalpy
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\[ \chi_c = \left[ \frac{\Delta H_{m(t)} - \Delta H_{c(t)}}{\Delta H_m^0} \right] \times 100 \]
Degradation analysis: GPC

Semi-crystalline PLA (4032D)

Detector response

Elution volume (ml)

Mn = Number average molar mass
Mw = Mass average molar mass
Mz = Z average molar mass
D = Dispersity (Mw/Mn)
Mp = peak molecular weight

PLA 4032D T0
SP-PLA-4032D-1
FP-PLA-4032D-1

All polymers are not soluble into chloroform
Degradation analysis: ATR-FTIR

Semi-crystalline PLA (4032D)

Transmittance

Wavenumber (cm⁻¹)

Degradation analysis: ATR-FTIR
Degradation analysis: ATR-FTIR

Semi-crystalline PLA (4032D)

Wavenumber (cm⁻¹)

Transmittance
# Degradation analysis

<table>
<thead>
<tr>
<th>Samples</th>
<th>Visible aspect</th>
<th>Weight loss</th>
<th>GPC</th>
<th>DSC</th>
<th>ATR-FTIR</th>
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</thead>
<tbody>
<tr>
<td>SP-PLA-4032D</td>
<td>NA*</td>
<td>Mw, Mz</td>
<td>ΔHcc</td>
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<tr>
<td>FP-PLA-4032D</td>
<td>NA*</td>
<td>Mw, Mz</td>
<td>ΔHcc</td>
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<tr>
<td>SP-PLA4060D</td>
<td>0.2%</td>
<td>Mw, Mz and Mp</td>
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<td>FP-PLA-4060D</td>
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<tr>
<td>SP-PBAT</td>
<td>1.5%</td>
<td>Mw, Mz</td>
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<tr>
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*NA: Not acquired (lost samples)
**ND: Not determined (polymer not soluble into chlorofom)

FP= « Floating plastic » (4.5 m under the water surface)
SP= « Sediment plastic » (8 m under the water surface, on the sediment)

- No difference in comparison with the initial time ($T_0$)
- One or more parameters are different in comparison with $T_0$
- All parameters are different in comparison with $T_0$
Degradation analysis

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No visible degradation of biodegradable plastics
Bacterial community analysis

SP-PBAT

FP-PBAT

SP-PS

FP-PS
Bacterial community analysis

Difference in the bacterial composition (water column vs sediment)
Bacterial community analysis in water column plastics

No difference according to the plastic nature
Bacterial community analysis on sediment plastics

No difference according to the plastic nature
Conclusion & perspectives

➢ No visible degradation after 80 days

➢ Difference in microbial composition of biofilm: water column vs sediment

➢ No difference in microbial composition biofilm depending on the polymer nature

The concept of « biodegradable plastics » is relative

Perspectives

➢ 16S rRNA amplicon sequencing analysis

➢ Immersion for a long time (2, 4 and 6 months) into Mediterranean sea
Acknowledgments

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