Long-term immersion of compostable plastics in marine aquarium: Microbial biofilm evolution and polymer degradation

Delacuvellerie A.[a], Brusselman A.[b], Cyriaque V.[c], Benali S.[d], Moins S.[d], Raquez J-M.[d], Gobert S.[e,f], Wattiez R.[a]

[a] Proteomics and Microbiology department, University of Mons, 20 place du parc, 7000 Mons, Belgium, [b] Chemical oceanography unit, University of Liège, 11 Allée du 6 août, 4000 Liège, Belgium, [c] Institut national de la recherche scientifique, 385, rue Sherbrooke Est Montréal (Québec) H2X 1E3, Canada ,[d] Polymer and Composite Materials Department, University of Mons, 15 Avenue Maistriau, 7000 Mons, Belgium, [e] Oceanology department, UR FOCUS, University of Liège, 11 Allée du 6 août, 4000 Liège, Belgium, [f] STARESO, Pointe Revellata, BP33, 20260 Corse, France

Introduction

The best-selling compostable plastics, polylactic acid (PLA) and polybutylene adipate-co-terephthalate (PBAT), can accidentally end up in the marine environment due to plastic waste mismanagement. Their degradation and colonization by microbial communities are poorly documented in marine conditions. To better understand their degradation, as well as the dynamics of bacterial colonization after a long immersion time (99, 160, and 260 days), PBAT, semi-crystalline, and amorphous PLA films were immersed in a marine aquarium. Sequencing and chemical analyses were used in parallel to characterize these samples.

Material and methods

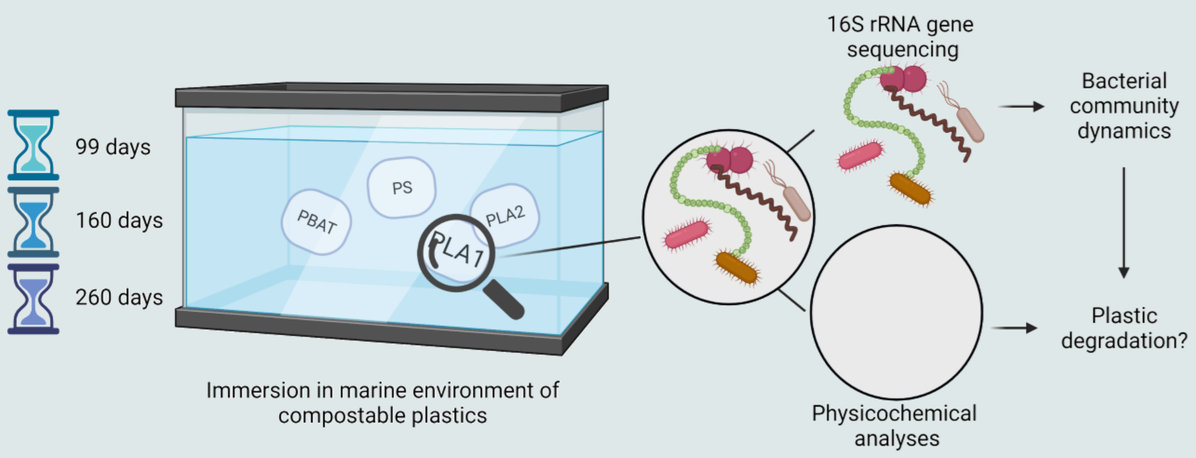

Fig.1. Compostable plastics, *i.e.*, PBAT, amorphous and semicrystalline PLA, and polystyrene (as a control for conventional thermoplastic), were submerged in a marine aquarium for 99, 160, and 260 days. Two grades of PLA were used to study the impact of crystallinity on microbial colonization and biodegradation processes. Chemical (*e.g.*, weight loss method, DSC, ATR-FTIR, and SEC) and sequencing approaches were combined.

Table 1. Characteristics of compostable plastic pellets (PLA, (PBAT, PS).

Plastic type	Density[1]	Glass transition temperature	Melting temperature	Crystallinity
PBAT	1.26 g/cm^3	- 29 °C	120 °C	13%
PLA (4060D)	1.24 g/cm^3	58 °C	/	Amorphous
PLA (4032D)	1.24 g/cm^3	62 °C	166 °C	4%

Fig.2. (A) Temperate marine water aquarium in which our samples were immersed for 99, 160, and 260 days. A frame was sampled at each time point. **(B)** Water temperature of the aquarium during the plastic immersion monitored by the HOBO ® every 6 hours.

Results

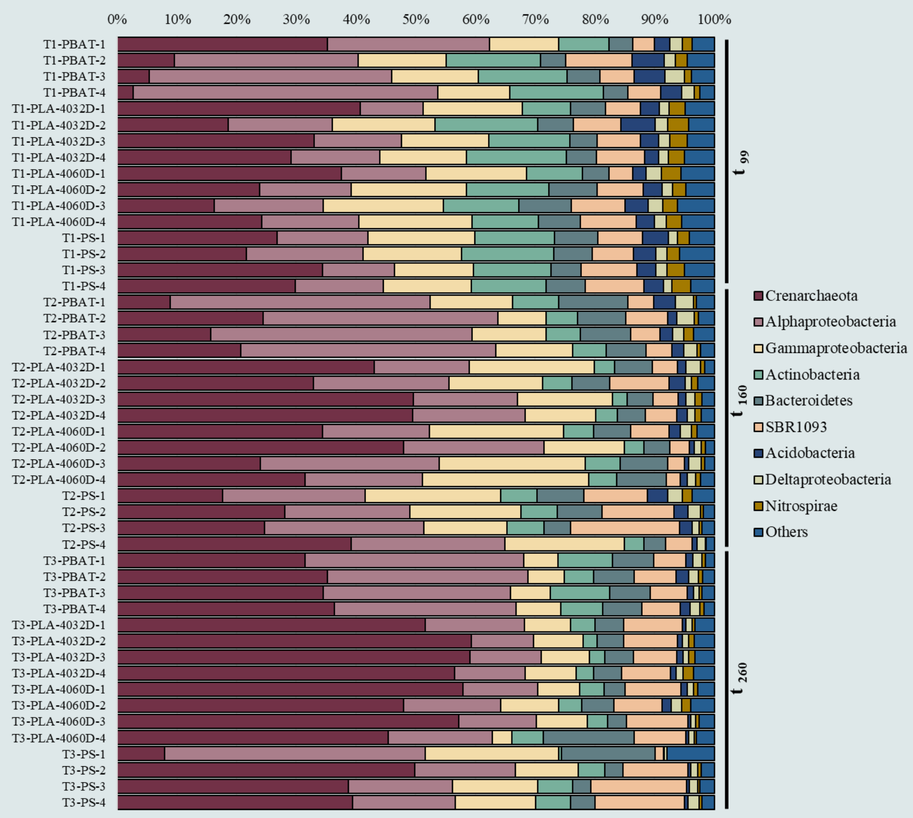

Fig.3. Phylogenetic profiles based on 16S rRNA amplicon sequencing for plastic films (PBAT, amorphous PLA (4060D), semicrystalline PLA (4032D), and PS) after 99, 160, and 260 days (t99, t160 and t260, respectively) of immersion in the marine aquarium (polylactic acid (PLA), polybutylene adipate-co-terephthalate (PBAT), polystyrene (PS)).

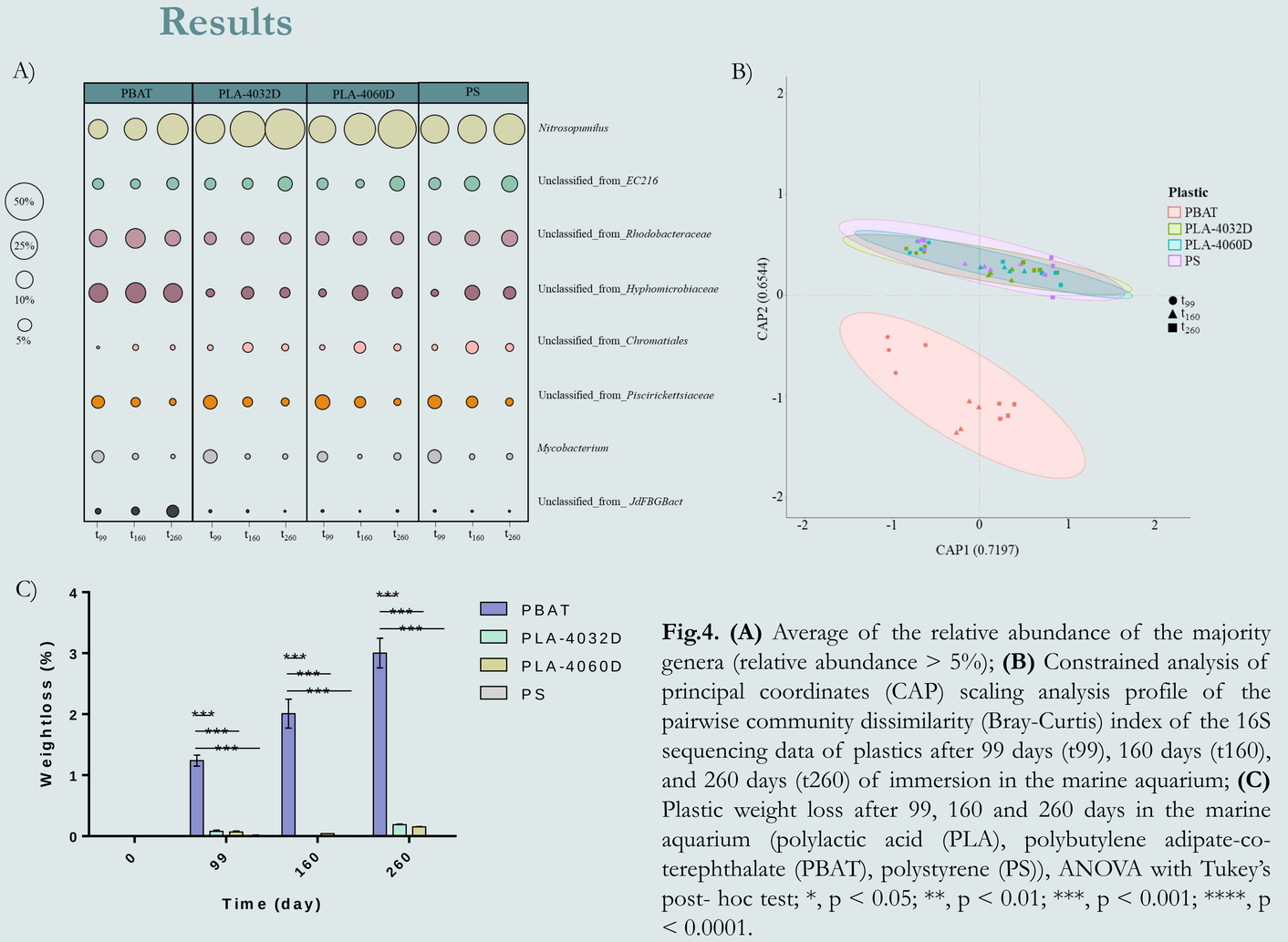

Fig.4. (A) Average of the relative abundance of the majority genera (relative abundance > 5%); **(B)** Constrained analysis of principal coordinates (CAP) scaling analysis profile of the pairwise community dissimilarity (Bray-Curtis) index of the 16S sequencing data of plastics after 99 days (t99), 160 days (t160), and 260 days (t260) of immersion in the marine aquarium; **(C)** Plastic weight loss after 99, 160 and 260 days in the marine aquarium (polylactic acid (PLA), polybutylene adipate-co-terephthalate (PBAT), polystyrene (PS)), ANOVA with Tukey's post- hoc test; *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$; ****, $p < 0.0001$.

Take-home message

Despite the variation in the chemical intrinsic parameters of these plastics, their degradation remains very slow after 260 days of immersion. Microbial community structure varied according to the immersion time with a high proportion of Archaea. Moreover, the plastisphere structure of PBAT was specific. A better understanding of compostable plastic degradability is crucial to evaluate their impact on ecosystems and to eco-design new recyclable plastics with optimal degradation properties.

If you would like more information about this study, see: Delacuvellerie A., Brusselman A., Cyriaque V., Benali S., Moins S., Raquez J-M, Gobert S., Wattiez R. (2023) Long-term immersion of compostable plastics in marine aquarium: microbial biofilm evolution and polymer degradation, *Marine Pollution Bulletin*, 189, 114711.

Acknowledgement: This study was funded by the Fund for Scientific Research (F.R.S.- FNRS) FC 23347. We thank the Aquarium-Museum of Liège and particularly Marie Bournonville and her colleagues. Samira Benali acknowledges support from the - European Regional Development Fund (ERDF-FEDER) for general support in the frame of LCFM-BIOMAT. Jean- Marie Raquez is an F.R.S.-FNRS Research Associate, and Valentine Cyriaque is a F.R.S.-FNRS scientific collaborator.

Contact: alice.delacuvellerie@umons.ac.be