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Towards acceleration of environmentally relevant screening tests for biodegradable polymers

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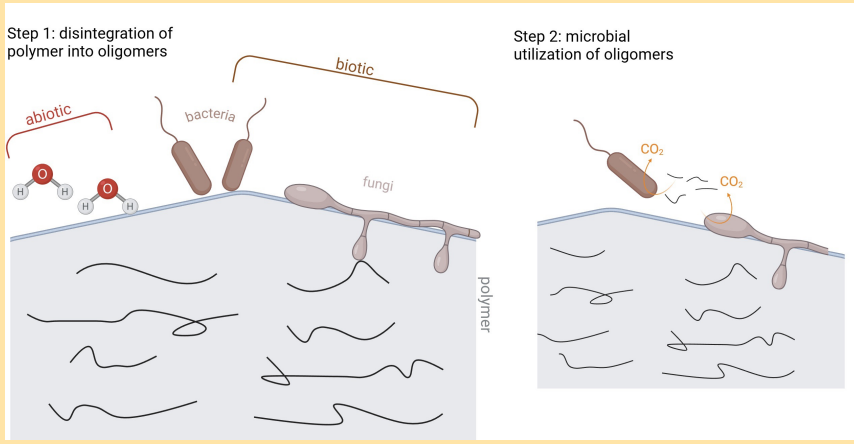
Introduction

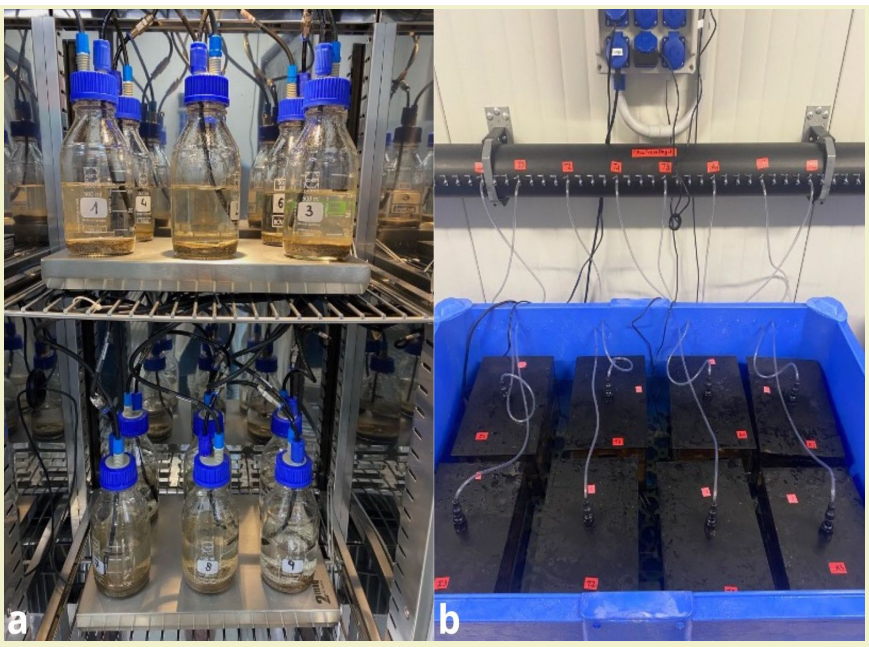
To increase crop yields while lowering the consumption of water and pesticides, agriculture heavily relies on plastics. An example are thin mulch films, which cannot be collected in their entirety after use. The European Commission is developing a legal framework for biodegradable mulch film to mitigate the accumulation of persistent plastics. Understanding their behaviour and fate in different environments is crucial because plastics may also migrate into other ecosystems like nearby waterways. Fast and environmentally relevant screening tests for biodegradation are essential to develop new biodegradable agricultural plastics. This research investigated the potential acceleration effect of 5 different treatments in established freshwater biodegradation tests. Developing more biodegradable polymers supports the agriculture to transform it into a more sustainable and circular sector.



Sequences of biodegradation. **Step 1** is the molecular breakdown of the polymer into smaller units (i.e., oligomers). This step may occur abiotically (e.g., through reactions with water causing abiotic hydrolysis) and/or biotically through the excretion of extracellular enzymes. **Step 2** is the assimilation of oligomers into microbial cells, followed by the metabolic utilisation of these molecules for energy generation, resulting in mineralization of organic carbon into CO_2 (or CO_2 and CH_4), and the synthesis of new microbial biomass.

This study was conducted during an internship at the Research & Test Center of HYDRA Marine Sciences GmbH

Method

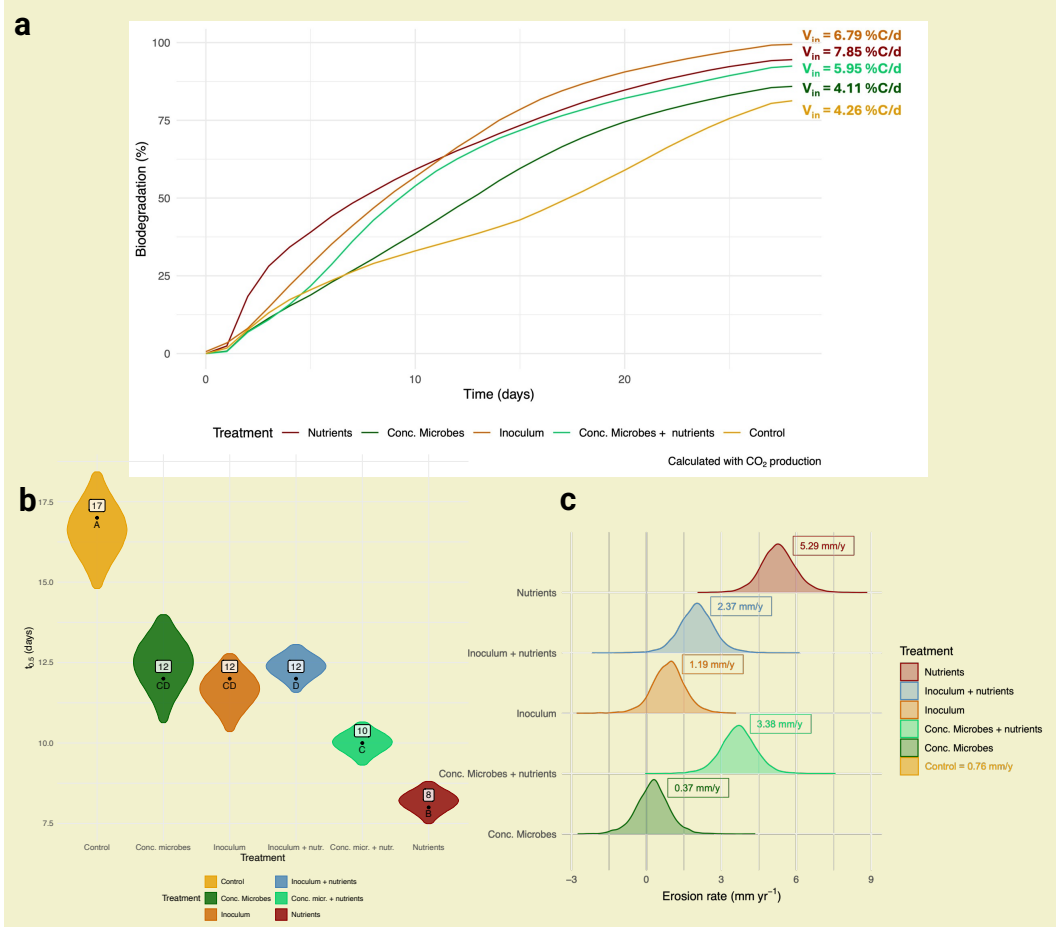


Experiment: 1 freshwater sediment as matrix (Sandbach sediment – small creek in Southern Germany), 1 material type (PHBH) considered as fast biodegrading, 1 positive control (PHB/PHV).
Laboratory incubation in a flow-through respirometer (ECHO instrument) measuring evolved CO_2 (**a**) and mesocosm incubation in aquaria assessing disintegration as a proxy for biodegradation (**b**). The five adopted treatments were nutrient enrichment, concentrated microbes extracted from sediment via sonication, inoculum pre-grown on tested materials, concentrated microbes + nutrients, inoculum + nutrients. In the lab incubation, only 4 treatments were tested due to the limited number of incubation vessels available.

Conclusion & Outlook

- 4 out of 5 treatments accelerated the biodegradation of the material
- Results consistent between lab and mesocosm (nutrient treatment fastest one, probably because more microbes → more competition for nutrients → lower biological activity)
- Study design, strategy, and implementation suited to accelerate environmentally relevant biodegradability and disintegration screening tests
- Testing is continued with different material types and different matrices. Aim: understand if these outcomes are reproducible or if the acceleration treatment is related to material type and/or matrix

Results



Biodegradation (%) over incubation time (days), calculated on the bases of the CO_2 measurement in the respirometer (**a**). The biodegradation rate in the initial phase (i.e., in the linear phase), was modeled considering the exposure between day 1 and 7. The rate is expressed as the percentage of organic carbon biodegraded per day. All treatments except for the "concentrated microbes", showed an acceleration of the biodegradation of the material, with the biodegradation in the presence of nutrient-enrichment being almost twice as fast as the non-accelerated treatment (i.e., control). Results modelled from the mesocosm test disintegration data. 95 percentile of the half-life simulations of the positive control. A dot represents the estimated half-life of the test material, which is shown as a number above the dot. Next to the dot for the estimated half-life is plotted the letter code used to indicate significant differences between treatments (**b**). Annual erosion rate (mm/year) of PHBH exposed to 5 different treatments modeled with a Bayesian Mixed Effects Model (**c**).

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