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# Mechanistic understanding of plastic biodegradation in compost: how do copolymer blends and product shape influence the fragmentation behaviour?

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## Abstract

Biodegradable plastics are contributing to a circular economy as enabler for organic waste recycling to close the nutrient loop. A polymer is designated as biodegradable if microbial oxidation and hydrolysis processes result in the complete transformation of polymer carbon into biomass and CO<sub>2</sub>. Still, there are concerns that the loss of structural integrity during biodegradation might produce persistent microplastic fragments.

Biodegradable plastics are often blends whose components could show different abilities to degrade, e.g. due to inhomogeneity in the chemical structure, crystallinity and the microbial colonization. Specifically, the blend of polylactide (PLA, susceptible to hydrolysis) with aliphatic-aromatic ester copolymers (e.g. PBAT, susceptible to enzymatic cleavage) is relevant for food packaging, which can be collected and composted. The various product shapes can also lead to a change in fragmentation and degradation behaviour. To gain a mechanistic understanding of copolymer blend biodegradation we studied an aromatic-aliphatic copolymer blend in different shapes (cryomilled particles, films and polymer-coated paper cups) under industrial composting conditions, and compared them against the non-blended polymer matrix. During biodegradation (ISO 14855), CO<sub>2</sub> evolution was monitored. Using a non-destructive and efficient extraction protocol, the particle number and size distribution, and the state of copolymer degradation were assessed via fluorescence microscopy and chemically selective Raman microscopy. Staining selectivity was additionally cross-checked by an independent incubation of pre-labeled films and fragments.

Biodegradation of the polymer blend led first to fragmentation, but the previously formed fragments further degraded to complete biomineralization. The interim number of fragments per composted polymer ranked highest for film shape, lower for fragment shape, and two orders of magnitude lower for film-coated paper cups. Intermittently, up to 0.0012% of the mass of polymer was in fragments below 25  $\mu\text{m}$ , but less than  $10^{-10}$  at 90% CO<sub>2</sub>. Fragment counts dissipated with 2.5 days halftime for the realistic film shape.

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