Anaerobic degradation of commercially available biodegradable plastics

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Abstract
Given the severe pollution caused by traditional plastics, biodegradable plastics (BPs) have received great attention because they contain chemical bonds prone to degradation that can be degraded in some bioactive environment. BPPs come in diverse types, and whether they can truly degrade is closely related to the degradation environmental conditions. Currently, aerobic composting is the arbitration method for assessing the degradability of BPs before their access to the market. Anaerobic environments are also widespread in nature and anaerobic digestion (AD) is one of the mainstream techniques to address organic waste. However, the anaerobic degradation of BPs has always been neglected. BPs can also cause environmental pollution if not degraded within a short period of time in anaerobic environment. A comprehensive literature review showed that only a few kinds of BPs have been assessed for anaerobic degradability and the anaerobic degradability reported in the literatures varied greatly (Abraham et al., 2021), which makes it almost impossible to rely on the existing degradation data of BPs. In addition, the degradation mechanism for various BPs, along with the composition and collaboration of functional microbes under mesophilic and thermophilic conditions, lack in-depth study. Therefore, a comprehensive study of the anaerobic degradation of commonly available BPs is urgently needed.

Methane production of BPs during mesophilic and thermophilic AD
As shown in Fig. 1, CDA, P34HB, PPC, and TPS possessed relatively high B_D (57.9%-84.6%) after mesophilic AD. P34HB, PCL, PLA, PPC, and TPS showed high B_D range from 53% to 95.7 after thermophilic AD. Mesophilic anaerobic degradability according to B_D values of powdered BPs could be sorted as follows: PPC > P34HB > CDA > TPS (40 days), PBSA and PVA showed partial degradation with low B_D of 21.0% and 12.5%, respectively, while no significant degradation of PLA, PCL, PBS, and PBAT was observed. Under thermophilic anaerobic condition, B_D values of powdered BPs could be sequenced as follows: PPC > PLA (120 days) > PCL > P34HB > TPS (40 days); while, PBSA and PVA still had low B_D values of 30.5% and 12.0%, respectively. PBS, PBAT, and CDA showed no significant degradation after thermophilic AD. Furthermore, there was little difference in the degradability of BPs assessed by the mass loss and B_D calculated by CMP/TMP.

Structural changes of BPs during anaerobic digestion
The morphological changes, scanning electron microscopy (SEM) and Fourier transform infrared spectrometer (FTIR) analysis of the seven pelletized BPs are displayed in Fig. 2. After 40 days of mesophilic and thermophilic AD, there was no obvious difference in the pellet size of TPS, PBAT, and PBS except the darkened colour on the surface. the visual appearance of PLA and PCL changed obviously under thermophilic condition. Furthermore, the micro-structure changes of TPS, PBSA, and PBS indicated that destruction occurred, although morphological changes were not obvious. Combined with FTIR analysis, it can be seen that the degradation of PBSA and PLA mainly depended on bulk erosion for the apparent changes of FTIR spectra, while PCL and PPC were mainly relied on surface erosion.

Microbial community of digestion of BPs
The 15 most abundant bacteria and archaea observed in the mesophilic and thermophilic digesters are displayed in Fig 3. Under mesophilic condition, *Anaerolineales*, *Bacteroidales*, *Clostridiales*, *SBR1031*, and *Synergistales* appeared to play a critical role in hydrolysis and acidogenesis. However, the bacterial community of CDA showed a significant difference with an extremely high abundance of *Synergistales*, and the reason may be the diversity of degradation mechanism. It has been reported that the anaerobic degradation of CDA proceeds by deacetylation to lower the degrees of substitution and subsequent depolymerization by breaking β-glycosidic bond (Puls et al., 2011), while P34HB, PBSA, and PPC are depolymerized by breaking ester bonds or carbonate bond. The function of the most abundant archaea during mesophilic AD, *Bathyarchaeia*, appears to include acetogenesis and methanogenesis in the degradation of BPs (Li et al., 2021). During thermophilic AD, it could be concluded that the hydrolysis, acidogenesis, and then the methanogenesis of P34HB, PBSA, PCL, PPC, and TPS was mainly conducted by the bacteria *Coprothermobacter* and the archaea *Methanothermobacter*. However, the lack of hydrolytic bacteria like *Coprothermobacter* and the high abundance of propionate degradation

bacteria of *DTU014* (Wu et al., 2020) implied that thermophilic abiotic hydrolysis seemed to play a critical role in the hydrolysis of PLA.

This study provides critical data including morphological changes, digestibility, degradation mechanisms, and composition and collaboration of microbes for BPs anaerobic degradation, which will lay the foundation for BP application. **The anaerobic degradation of various biodegradable plastic products such as packaging bags and tableware had also been analyzed and the results will also be presented in detail in the full paper.**

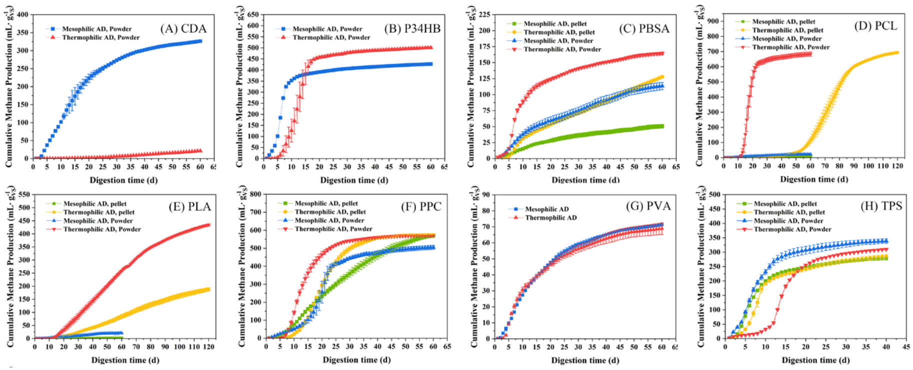

Figure 1 Cumulative methane production of ten BPs under mesophilic and thermophilic conditions.

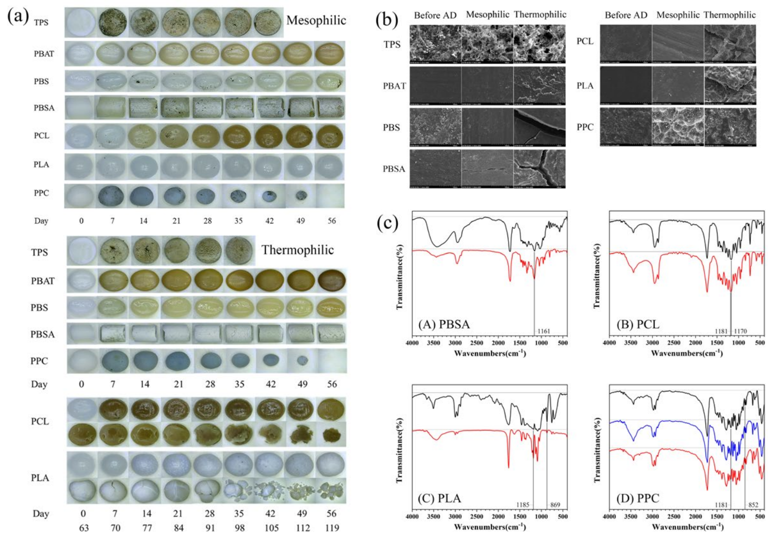

Figure 2 (a) Morphological change, (b) SEM and (c) FTIR of BPs.

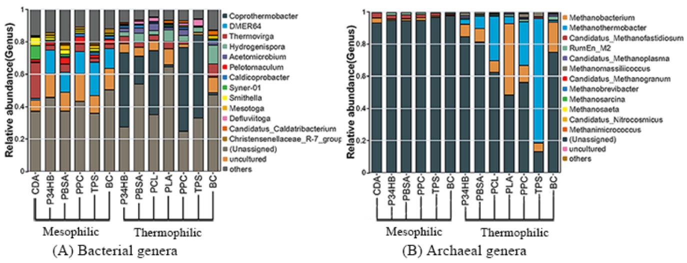

Figure 3 The 15 most abundant bacteria and archaea.

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