Abstract

Bioplastics that are of biological origin and/or biodegradable are an alternative to plastics produced from non-renewable raw materials, such as petroleum or natural gas. As bioplastics are labelled biodegradable, the priorities of the municipal waste management hierarchy indicated that bioplastic waste should be selectively collected with biowaste and processed via organic recycling processes (composting or methane fermentation). Currently, anaerobic organic recycling of biowaste by methane fermentation is widely employed. However, the literature lacks a holistic assessment of the effectiveness of anaerobic biodegradation of bioplastics, which would allow determination of the effect of bioplastics on the biodegradation of biowaste under anaerobic conditions. Therefore, in this dissertation, a multi-faceted analysis was used to determine the effect of temperature and pre-treatment of bioplastics on their anaerobic biodegradation. The analysis included i) determination of the yield of biogas and methane, the kinetics of biogas (BP) and methane (MP) production, and the suitability of bioplastics for biogas production and co-digestion with biowaste, ii) surface changes on bioplastics (macro- and microscopic or topographic) and their mechanical (tensile strength, elongation at break) and thermal (differential scanning calorimetry) properties, iii) identification of functional groups using Fourier infrared spectroscopy (FTIR), and iv) assessment of the degree of bioplastic biodegradation (based on theoretical methane production (TMP)).

Five types of commercially available bioplastics were tested: foils (F), based on starch (F_S), cellulose (F_Cel), polylactide (F_PLA) and polybutylene succinate (F_PBS), as well as rigid (S) disposable PLA-based beverage cups (S_PLA). Biodegradation was carried out under anaerobic mesophilic (M) and/or thermophilic (T) conditions and after pre-treatment of the bioplastics via chemical (0.1 M KOH, 2 h, room temperature) or hydrothermal methods (H_2O, 2 h, 90°C).

The temperature conditions affected the biodegradability of the bioplastics. Based on the biogas or methane yield under mesophilic conditions, the bioplastics were ranked from the most to the least biodegradable: $F_Cel_M > > F_PBS_M > F_S_M \geq F_PLA_M$.

Under mesophilic conditions, the time of anaerobic biodegradation exceeded 30 days for all the bioplastics except F_Cel_M. This indicates that all of them (except F_Cel_M) are unsuitable for anaerobic co-digestion with biowaste under the conditions commonly applied at technical scale.

The yield and rate of MP from F_PBS were higher under thermophilic than under mesophilic conditions. The biodegradability of the bioplastics was different under thermophilic

than under mesophilic conditions and decreased in the following order: $S_PLA_T > F_Cel_T > F_PBS_T > F_PLA_T \geq F_S_T$.

As under mesophilic conditions, the bioplastics, except for F_Cel_T and F_PBS_T, were unsuitable for methane production under thermophilic conditions at technical scale due to the long time necessary for anaerobic biodegradation. S_PLA_T, F_PLA_T, and F_S_T should not be subjected to thermophilic methane fermentation or co-digestion with biowaste.

A relationship between the biological and physical indicators of biodegradability was found. The yield of biogas or methane under mesophilic and thermophilic conditions was associated with the elongation at break of the bioplastics: biogas or methane yield from bioplastics with high values of elongation at break (F_S, F_PLA) was several times lower than the yield from those with low values (F_Cel, F_PBS). The additives used to improve the properties foils, including its flexibility (high value of elongation at break), may reduce biodegradability and biogas or methane yield.

Thermophilic conditions enhanced the fragmentation of the bioplastics. However, the fragments of the bioplastics (except for F_Cel_M, F_Cel_T, and F_PBS_T) remained visible in the inoculum up to the 66th day of anaerobic degradation or longer. This means that with an HRT of about 20-30 days, as commonly used in the digestion of biowaste, fragments of bioplastics (*microbioplastics)* would contaminate digestate.

Pre-treatment of bioplastics prior to anaerobic, mesophilic, or thermophilic biodegradation did not affect biodegradability as assessed by biological indicators, but it did affect the changes in surface and mechanical properties. After pre-treatment, bioplastics lost their mechanical properties in a shorter time. Regardless of the use of pre-treatment, the time of biodegradation of bioplastics was several times longer than that of biowaste, indicating not effective co-digestion with biowaste. Regardless of the temperature conditions and the use of a pre-treatment, the results of the FTIR spectrophotometric analysis showed an increase in the intensity of the peaks corresponding to the functional groups that indicated progressive biodegradation of bioplastics, while the formation of new functional groups was not observed.

This dissertation has demonstrated the utility of a multi-faceted assessment of the effectiveness of anaerobic biodegradation of bioplastics based on indicators of biodegradability. The results on the anaerobic biodegradation of the tested bioplastics can be used to design guidelines and instructions for the organic recycling of bioplastics, which are needed to plan management of biowaste with bioplastics.