Bioplastics - a new threat or industrial synthesis?

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Introduction

The EU has started to acknowledge the important role of bioplastics to drive the transition to a circular economy and in decoupling economic growth from the depletion of fossil resources. However, there is currently no EU-wide legislative framework to support the use of renewable raw materials for plastic solutions. From the other hand, it seemed that biodegradable plastics can reduce some of the environmental problems resulting from the uncontrolled disposal of plastic wastes. Unfortunately, the term "bioplastic" describes several different concepts and can cause confusion. This is because bioplastics can be made from biomass, but may have exactly the same properties as ordinary plastics. Also the plastic can be called bioplastic when it is either bio-based or biodegradable or both, even if it is derived from petrochemical industry or even if it is non-biodegradable (based on European Bioplastics). Thus, sometimes these plastics are biodegradable but not always. The knowledge about their actual decomposition during biological processes like anaerobic digestion (AD) of municipal waste treatment is very limited. Therefore, the Digest-Plast project aims to evaluate the effect of the bioplastics presence in organic fraction of municipal waste (OFMSW) subjected to anaerobic digestion (AD) and to make attempt to answer the question – is the bioplastics a new threat or industrial synthesis?

Material and methods

The Automatic Methane Potential Test System (AMPTS II) was used to determine the biogas production of different biodegradable bioplastics. Two different methods were tested to verify if increase in the biogas production rate of the organic fraction of municipal waste (OFMW) with bioplastics is possible. The first method involved thermal pre-treatment. This was done at 55ºC and 90ºC for 3h, and 12h at each temperature (4 different time-temperature conditions). The second method was mechanical pre-treatment (cuts into 0.5 and 1 cm) and again biogas potential was evaluated. Before tests, VS (volatile solids) and TS (total solids) were estimated for each substrate or mixtures as well as for inoculum (taken from the digester of municipal WWTP).

The bioplastics we considered for tests were biodegradable and commonly used in food packaging. Therefore, there is a high likelihood of them ending up in AD. These are derived from polylacid acids (PLA) and cellulose-based bioplastics. Moreover, the Polyhydroxyalkanoates (PHA), Polyhydroxybutyrate (PHB), Bioplast 120 and bran (used to manufacture edible plates) bioplastics become more and more popular on the market and they were tested too. Additionally, the test with mixture of 5% and 10% of PHBV (Poly 3-hydroxybutyrate-co-3-hydroxyvalerate) bioplastics with OFMSW was run.

Figure 1. AMPTS system for biogas potential evaluation and PLA cups cut into 1 cm and 0.5cm (mechanical pre-treatment) before addition to AD reactors.

Results and dissuasion

The results of the tests showed that exposure of PLA (widely used cold drinks cups) to AD for 25 days did not give any biogas production (SBP, specific biogas potential). Mechanical treatment as well as thermal heating before AD did not improve the gas production at all (Figure 2). No significant changes in the bioplastics structure were noticed. Similarly, in research performed by Battista et al., 2021 it was indicated that the lowest methane production was recorded for PLA, even though this material is often indicated as environmentally friendly. PLA is highly crystalline however, high crystallinity, the hydrophobicity, the presence of functional groups and different additives and plasticizers affect its biodegradability (Emadian et al., 2017).

The highest value of biogas production was recorded for PHBV, cellulose, bran and PHA varying from 265 (PHA) to 500 (PHBV) mL CH_4/gVS (Figure 2).

Due to the fact that PHA is other biomaterial which has potential to become one of the most promising to be used for the production of single use items and its biogas production was among the highest recorded

potentials additional tests for this bioplastic with thermal pre-treatment was performed. Heating in temperature of 55 and 90ºC only decreased SBM. Benn and Zitomer, 2018 conducted research on pre-treatment and AD of PHB and PLA. In this research thermal alkaline pre-treatment of PHB and PLA bioplastics increased anaerobic biodegradability (increased SBP values) and reduced lag time compared to untreated bioplastics. The average SBP values for pre-treated PHBs amounted to 360 ± 18 mL CH_4/g ThOD (theoretical oxygen demand)(35ºC), while untreated PHBs were estimated to be at 270 ± 71 mL CH_4/g ThOD. Figure 2 shows results of bio-methane production of different bioplastics during AD and no significant chances in methane production with different thermal pre-treatment options.

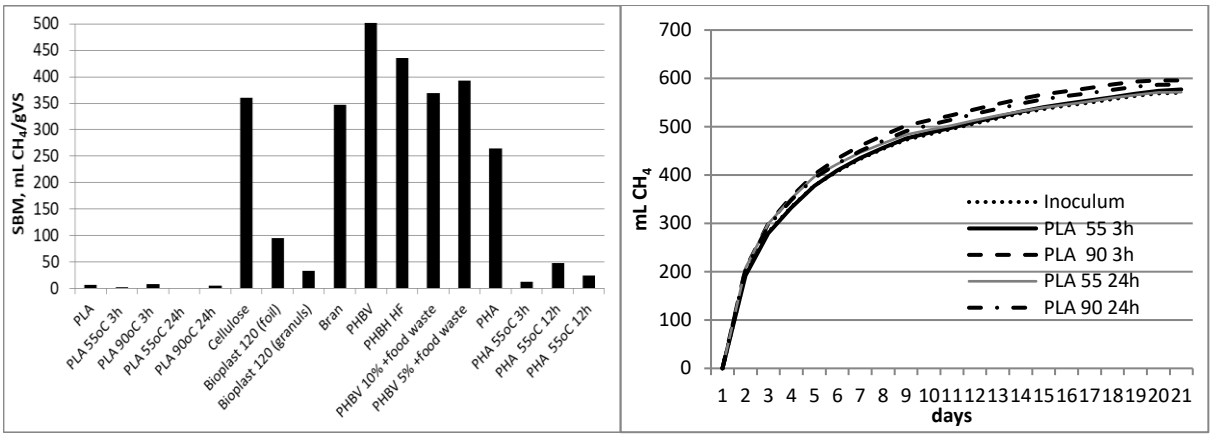

Figure 2. Specific bio-methane production (SBP) of bioplastics and accumulated CH_4 production during AD after thermal pre-treatment of PLA.

Conclusions

Bioplastics are relatively new products which are increasingly used in various areas of life. Meanwhile, the knowledge about their actual decomposition during biological processes of municipal waste treatment is very limited. Biodegradable plastics can reduce some of the environmental problems resulting from the uncontrolled disposal of plastics wastes. They are particularly suited to recycling alongside organic wastes, as long as the plastics are 'biodegradable/compostable'.

The main advantage of bio-based plastic products compared to conventional plastics, is that they lower the use of fossil resources by using biomass while this biomass provides potential for carbon neutrality, contributing to a reduction in greenhouse gas emissions. They can contribute to improved resource efficiency, as they are suitable for recycling and energy recovery after any possible reuse and recycling option. Secondly, they can avoid some of the environmental problems resulting from uncontrolled land spreading and disposal at sea. However, one must remember that not all bioplastics are bio-based and not all are biodegradable!

Therefore despite their many obvious advantages, the problems associated with the use of plastics on such a large scale should not be forgotten. First of all, one of their most important drawbacks is often the lack of biodegradability. In addition, they are produced from crude oil, a non-renewable resource whose resources may run out in the near future.

The answer to the question from the topic –threat or synthesis - is ambiguous. It varies from bioplastic to bioplastic. The conducted research showed that commonly used PLA (known as biodegradable) under anaerobic condition does not decompose at all. The highest value of methane production was achieved for PHB, cellulose and bran. None of the applied methods: mechanical and thermal gave any significant increased biogas production for PLA while thermal pre-treatment decreased the biogas production in case of PHA. The research will be continued and aerobic decomposition and compostable properties of bioplastics will be evaluated.

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