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Performances and Agronomic Assessment of Bio-Waste and Biodegradable Plastic Co-Digestion in Semi-Continuous Reactors

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ABSTRACT

The majority of European nations' adoption of selective bio-waste collection offers new potential for the anaerobic digestion industry. Parallel to this, during the past 10 years, significant progress has been made in the creation of biodegradable plastics such polylactic acid and poly hydroxy-butyrate, which make it easier to replace traditional plastics. This study looked into anaerobic co-digestion of bio-waste and biodegradable polymers in semi-continuous reactors. According to estimates, phb completely biodegraded in the reactors. In contrast, pla accumulated in the reactor, and at the third hydraulic retention time, an average biodegradation was predicted. The biodegradation yield of pla was boosted by thermo-alkaline hydrolysis pretreatment. Finally, it was made clear that adding pla or phb to the feed had no further impact on the digestate's agronomic characteristics.

Keywords: Bio-wastes, Agronomy, Biodegradable

INTRODUCTION

By diversifying their feedstock, the anaerobic digestion industry will benefit from the advancement of source separation of bio-wastes. According to the European waste directive, sorting bio-waste at the source will be required starting in 2024. This has only applied to large producers in France thus far. However, the anti-waste law extends it to all producers by transposing the directive. Given that households view plastic bags as practical and hygienically secure, the introduction of biodegradable plastic collecting bags could be a helpful strategy for increasing food waste collection. Biodegradable plastic bags must currently be removed prior to anaerobic digestion treatment, especially when wet or semi-dry technologies are used. Plastic bags that are biodegradable and those that are not cannot be distinguished from one another. Additionally, the treatment of these materials might result in hydraulic issues in the plant, and biodegradable plastic bags often degrade much more slowly than bio-waste. However, the removal of plastic bags could result in the loss of a sizeable amount of the organic waste they contained, which would reduce the biogas plant's profitability. It would be ideal to use products made of biodegradable plastic that can be digested simultaneously with other bio-wastes, as this would avoid the need for pricey deconditioning procedures and increase the amount of bio-waste that can be recovered.

Among the most researched polymers to replace plastics derived from petroleum are poly Hydroxy-butyrate and poly lactic acid. In 2018, the manufacture of biodegradable plastics is made up of about 25% PLA. The biodegradation rate of PLA under Mesophilic AD is so poor that extremely extended digesting times are necessary to attain a biodegradation level in batch AD tests between 29% and 66%. In comparison to mesophilic circumstances, thermo-philic conditions allow for much faster anaerobic digestion of PLA, which leads to a high conversion of methane in a mean digestion time of 90 days. However, thermal or thermo-alkaline pretreatments can be used to accelerate PLA's biodegradation. During an alkaline pretreatment, two PLA products almost completely dissolved, but this pretreatment time is too long for use in industrial settings. Similar to this, thermal or thermo-alkaline pre-treatment increased the kinetics of PLA's biodegradation. Under mesophilic conditions, it was seen that pretreatment PLA granules converted to methane at a rate of 75% in 20 days, whereas untreated PLA took more than 500 days to reach the same level. On the other hand, PHB only makes up a small percentage of the market for biodegradable plastics, but due to its superior biodegradability capability, production capabilities are anticipated to more than triple in the following five years. PHB has a lot of potential to turn into methane quickly, whether under therm-ophilic or mesophilic conditions.

The majority of investigations looking into the anaerobic digestion of biodegradable plastics to date have been batch-mode, laboratory-scale operations, typically without a co-digestion procedure To get a better understanding of the biodegradation kinetics, the interaction between the co-substrates, and the process stability over time, experiments at a pilot scale that involve co-digestion with semi-continuous or continuous feeding are preferable. The co-digestion of biodegradable plastics with other wastes, particularly bio-wastes or food wastes is a crucial consideration. The low carbon to nitrogen ratio of bio-wastes makes anaerobic digestion difficult; however co-digestion with greater C/N biodegradable polymers can easily increase the stability of the biogas plant and the system's ability to produce biogas. Additionally, the inclusion of biodegradable plastics can aid in lowering the percentage of highly biodegradable material that can cause acidification. According to Tonanzi, even at modest organic loading rates, mono-digestion of food wastes displayed gradual system instability brought on by methanogen suppression, which led to the formation of volatile fatty acids and process failure. Anaerobic digestion or co-digestion of biodegradable polymers has received relatively little attention in the literature up to this point. Anaerobic digestion of Mater-biodegradable bags was recently examined by Dolci at bench scale and full scale, respectively. Under therm-ophilic conditions, Dolci carried out semi-continuous co-digestion with synthetic food waste. Using a 20-day hydrolytic retention time, Mater-Bio bags demonstrated reasonably low biodegradation. In four dry anaerobic digestion plants in Germany—a batch therm-ophilic and mesophilic plant, as well as two plug-flow therm-ophilic plants, Kern studied the biodegradation of Mater-biodegradable bags.

Numerous pretreatment procedures can be used to speed up the decomposition of biodegradable plastics due to the low biodegradability of the majority of biodegradable plastics and the normal hydraulic retention period of biogas plants processing bio-waste. To date, mechanical, thermal, and thermo-chemical techniques have dominated pretreatment of biodegradable plastics. Batch testing has shown how pretreatment affects the methane production of biodegradable polymers, but there is little data on semi-continuous pilot-scale biodegradation. For instance, Venkiteshwaran performed co-digestion of untreated and pretreated PHBs with synthetic municipal primary sludge under mesophilic conditions. At steady-state, co-digesters converted 86% and 91% of untreated and pretreated phb to methane.

The scientific literature is currently lacking information on the co-digestion of biodegradable plastics and bio-wastes. New sources of biomass for anaerobic digestion will be produced when various European countries gradually implement selective bio-waste collection. For this reason, it's critical to gather more data on the stability and effectiveness of bio-waste anaerobic digestion using biodegradable polymers performed at a semi-continuous scale, which is more typical of future industrial biogas facilities than batch testing. This study examined the stability and effectiveness of co-digesting two chosen biodegradable polymers with semi-continuous feedings of bio-waste under mesophilic conditions. The effect of a thermo-alkaline pretreatment on Pla to increase its biodegradation rate was also looked at concurrently.

MATERIALS AND METHOD

Properties of soil and feedstock

Pellets made of PHB and PLA were bought from businesses. After a brief submersion in liquid nitrogen, biodegradable plastic sample were pulverized with a filter of 1 mm in a centrifugal mill. During the PLA thermo-alkaline pretreatment, unground PLA pellets were utilized. In 35 mL Pyrex® glass tubes, 2.5% w/v calcium hydroxide, distilled water, and 50 g of PLA pellets were introduced.

Reactors in the cstr are stable

In the supplemental materials, the primary physicochemical characteristics of the various biomasses used are displayed. High carbon content and negligibly low nitrogen content define biodegradable plastics. The PLA and PHB samples' theoretical methane potentials were calculated to be 522 L and 552 L.

CONCLUSION

There were no indications that the anaerobic digestion process was negatively impacted by the co-digestion of biodegradable plastics and bio-waste. When compared to a reactor that exclusively treated bio-wastes, the co-digestion reactors showed greater stability. According to estimates, PHB was completely turned into methane, whereas PLA was only partially converted and stored in the reactor.