Anaerobic co-digestion of biowaste and pruning waste under mesophilic range

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The municipal solid waste (MSW) management, including bio-waste (BW) and pruning waste (PW), has become a major global concern due to the world's population growth. Around $2 \cdot 10^{12}$ tons of MSW were generated worldwide in 2017, being expected to increase up to $3.4 \cdot 10^{12}$ tons by 2050 (Kaza et al., 2018). Only a small fraction of these residues is processed as useful resource, being the majority of them landfilled, and leading to multiple environmental problems. The European Union has set an action plan for recycling 55% of MSW for 2025 as part of the struggle against climate change (Smol et al., 2020). In this context, different technologies mainly classified in biological (compost and anaerobic digestion (AD)) and thermochemical treatments (combustion, pyrolysis, torrefaction, gasification or hydrothermal carbonization) can be used to achieve that purpose.

AD is a biological process well established worldwide, with most of the biogas plants (72%) powered by agricultural residues, and the remainder using mainly MSW and sewage sludge (Torrijos, 2016). BW and PW have been considered significant renewable resources for biogas production due to their high availability. Nevertheless, the relatively low C/N ratio and high biodegradability of BW can lead to the accumulation of intermediate products such as volatile fatty acids (VFA) or ammonia which can inhibit the AD process when BW is used as sole substrate (Bong et al., 2018). On the other hand, PW reaches lower methane yields than theoretically expected due to the low biodegradability associated to the high lignin content. Anaerobic co-digestion (AcoD) of mixed substrates, such as BW and PW, can be more advantageous than single anaerobic digestion, especially for balancing C/N ratio to maintain process stability and improving methane yield (Oleszek et al., 2014). This work evaluates the viability of the co-digestion of the two most important urban residues, bio-waste and pruning waste, to achieve synergistic effects.

The inoculum employed for anaerobic co-digestion experiments was a granular anaerobic sludge obtained from an industrial digester treating brewery wastewater that operates under mesophilic conditions (35 ºC). Bio-waste was collected in a full-scale plant treating MSW, and pruning waste was collected in parks, both in the Community of Madrid (Spain). The substrates were ground and sieved to reduce the particle size (< 3 mm). Table 1 shows a representative analysis of the inoculum and substrates. Anaerobic co-digestion assays were carried out in 120 mL glass serum vials at initial inoculum concentration of 15 g volatile solids (VS)/ L and an inoculum to substrate ratio (ISR) of 2.0, on a VS basis. Mixtures of different BW to PW ratios (on a VS basis) (25, 50 and 75% BW), as well as the two bare substrates (BW and PW) were tested. These assays are referred as 25BW, 50BW, 75BW, BW and PW, respectively. Biochemical methane potential (BMP) as well as the evolution of pH, alkalinity, ammoniacal nitrogen, soluble chemical oxygen demand (SCOD) and VFA were determined.

Table 1. Characterization of inoculum and feedstock.

	TS (g/kg)	VS (g/kg)	COD (g/kg)	TKN (mg/kg)	C (%)	H (%)	N (%)	S (%)	C/N ratio
BW	130 ± 3	120 ± 1	186 ± 13	1290 ± 59	44.5 ± 0.1	6.2 ± 0.1	1.9 ± 0.1	0.2 ± 0.1	23.6 ± 0.1
PW	93 ± 1	87 ± 2	1144 ± 51	980 ± 20.3	44.9 ± 0.1	6.1 ± 0.1	0.9 ± 0.1	0.4 ± 0.1	52.2 ± 0.1
Inoculum	42 ± 2	36 ± 2	18.4 ±1.4*						

*g/L

Regarding to the process stability, a remarkable difference associated to the feedstock origin was observed. Runs based mainly on bio-waste (BW and 75BW) reached a significant reduction of SCOD due to its higher biodegradability. These trials also showed an initial significant decrease in pH while those with higher percentage of PW (PW and 25BW) maintained pH stable around 7 – 7.5. Concerning the ammoniacal nitrogen, none of the runs reached a critical content that could lead to a process inhibition. The high biodegradability of BW promoted the rapid hydrolysis-acidogenesis and the consequent early VFA accumulation, as can be seen in Figure 1, and the drop of alkalinity resulting ultimately in a pH decrease. Under these acidified conditions, methanogenic Archaea were inhibited and the methane production did not increase until this microbial population grew and was able to degrade and transform the VFA into methane.

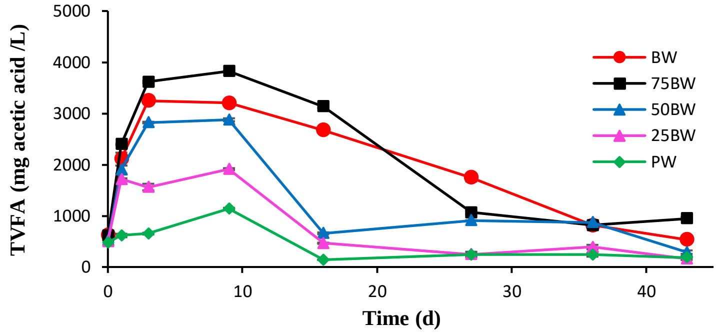

Fig 1. Time course of volatile fatty acid content along the anaerobic co-digestion of BW and PW.

The cumulative methane yield of the mixtures tested is shown in Figure 2. Significant different results, associated to the feedstock origin, were observed. Trial based exclusively on bio-waste reached the highest value, 426 ± 16 mL CH_4/g VS_{added}, while an increase in the concentration of pruning waste led to lower methane yield. 50BW showed the fastest start-up of methane production due to the balance between higher biodegradability and process stability. 75BW reached the highest methane yield among co-digestion trials (345 ± 4 mL CH_4/g VS_{added}), being 33 and 50% higher than those for 50BW and 25BW, respectively.

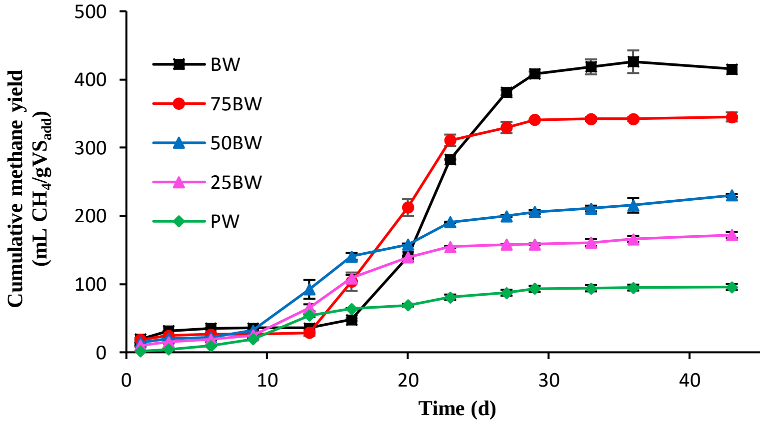

Fig 2. Cumulative methane yield along the anaerobic co-digestion of BW and PW.

As conclusion, a mixture of 75% of bio-waste and 25% of pruning waste (on a VS basis) reached promising results, not only for showing a synergistic effect on methane production, but also for reporting a faster recovering of the process stability and consequently a quicker start-up of biogas production than trial based exclusively on bio-waste.

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