Anaerobic co-digestion of food waste and garden and park wastes and the process water from its hydrothermal treatment.

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Highlights

- Hydrochar fulfill the the ISO 17225-8 standard for industrial use as a solid fuel.
- Anaerobic co-digestion with process water shows synergistic effects compared to food waste mono-digestion.
- Low biodegradability of garden and park waste reduces the methane yield when used as co-substrate.

Keywords: Energy recovery, food waste, garden and park waste, methane yield, organic loading rate.

Introduction

Anaerobic digestion (AD) is a widely established biological process for energy recovery through the production of methane enriched biogas using biowaste (BW) as feedstock. However, mono-digestion of BW including garden and park waste (GPW) and food waste (FW) bears a variety of problems associated to the feedstock origin. The high biodegradability of FW can lead to the accumulation of intermediate products such as volatile fatty acids (VFA) or ammonia, which can inhibit the AD process (Bong et al. 2018). Furthermore, the high lignin content of GPW results in a low methane yield. Anaerobic co-digestion (ACoD) of biowaste (FW and GPW) balances biodegradability differences of those substrates enhancing the methane yield (Mata-Alvarez et al. 2014). Hydrothermal treatment (HTT) may also be used for BW energy recovery, being a better technology than AD for the management of lignocellulosic wastes (Suarez et al. 2022). As a result of HTT, a carbon-enriched solid product, referred to as hydrochar (HC), with diverse applications including biofuel, catalysis and soil amending is obtained while a liquid phase referred to as process water (PW) is also produced. PW is mainly composed of VFA and sugars exhibiting good characteristics for its energy recovery by AD. The aim of this study is to determine the best strategy for sustainable management of major urban biowaste (FW and GPW) combining hydrothermal and ACoD treatments. This work compares the ACoD under mesophilic range of the most important urban biowastes (FW and GPW), as well as the process water from the HTT of GPW synergistic effects and the optimal organic loading rate (OLR) for energy recovery.

Material and Methods

HTT was performed in 1 kg of GPW:H2O (20:80 (w/v)) mixture at 180 ºC for 1 h to produce HC and PW. Table 1 sums up the main characteristics of the inoculum and feedstocks. ACoD assays were carried out in 2 L digesters operating in semicontinuous mode, using an initial inoculum-to-substrate ratio of 3.0, on a volatile solid (VS) basis. The OLR of biowaste mixtures ranged from 1.5 to 3.5 g COD/L d, while a hydraulic retention time of 27 d was established. Bare FW, a blending of FW and GPW 3:1 ratio (on a VS basis), and 95% of FW and 5% of process water originated from HTT of GPW (on a COD basis) were tested. These assays are referred as 100FW, 75FW:25GPW and 95FW:5PWGP, respectively. HC was characterized evaluating elemental composition and proximate analysis (moisture, ash, volatile matter (VM), and fixed carbon (FC)) by thermogravimetric analysis following the manufacturer's recommended approach. At the steady state of each OLR studied, methane yield as well as the evolution of remarkable parameters such as pH, alkalinity, total solids (TS) and VS, total and soluble chemical oxygen demand (TCOD and SCOD), ammoniacal nitrogen and total VFA content were determined.

Table 1. Characterization of inoculum and feedstock

	TS (g/kg)	VS (g/kg)	COD (g/kg)	TKN (g/kg)	C (%)	H (%)	N (%)	S (%)	C/N ratio
FW	179 ± 4	164 ± 3	220 ± 211	0.6 ± 0.1	44.5 ± 0.1	6.2 ± 0.1	1.9 ± 0.1	0.2 ± 0.1	23.4 ± 0.1
GPW	951 ± 1	902 ± 2	1150 ± 11	0.8 ± 0.1	44.9 ± 0.1	6.1 ± 0.1	0.9 ± 0.1	0.4 ± 0.1	49.8 ± 0.1
PWGP	44 ± 1	39 ± 1	21 ± 1	0.6 ± 0.1	2.1 ± 0.1	9.7 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	14.5 ± 0.1
Inoculum	72 ± 1	63 ± 1	125 ± 1*						

*g/L

Results and Discussion

All digesters maintained an adequate pH (7.1 – 7.4) and values of total alkalinity above 2.5 g $CaCO_3$/L indicating a good buffer capacity of the system. Concerning the ammoniacal nitrogen content, none of the assays reached a critical value that could lead to process inhibition. As the OLR raised, TS and VS increased as well as TCOD that resulted higher in the ACoD with PW of GPW (95FW:5PWGP) due to the accumulation of less biodegradable species resulted for PW addition (De la Rubia et al. 2018). 95FW:5PWGP also showed the highest SCOD for the ORLs studied, providing more soluble organic matter (VFA and sugars) to the microorganisms. Regarding to VFA pool they were mainly composed of acetic, propionic, and butyric acids. 100FW showed similar content of VFA (500 mg acetic acid/L) at OLRs ≥ 2.5 g COD/L d, in the same range as that obtained in 75FW:25GPW (200 – 600 mg acetic acid/L). While 95FW:5PWGP showed the content in the range 600-1200 mg acetic acid/L as OLR raised. The highest proportion of acetic acid at VFA pool correlates with the highest methane yield reported at OLR 2.5 g COD/L d.

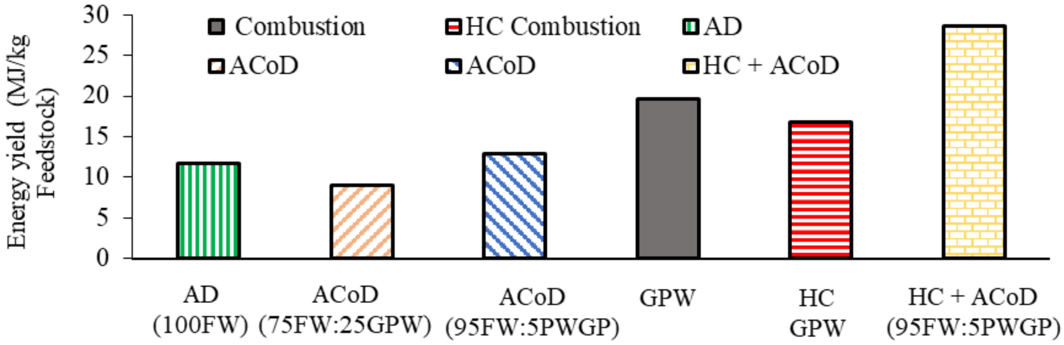

Figure 1. Energy recovery at steady state at optimal organic loading rate of 2.5 g COD/L d.

At optimal OLR (2.5 g COD/L d), the ACoD of 95FW:5PWGP showed the highest methane and thus, energy recovery (Figure 1) pointing out synergistic effects (+10% over 100FW), while the presence of GPW led to lower methane yield decreasing the energy recovery (-23% compared to 100FW) due to the structural complexity and lower biodegradability. Direct combustion of GPW for industrial purposes is not allowed due to excessive VM content (76.5%) but HTT improved the fuel characteristics of GPW (higher FC and lower VM) and HC fulfilled the quality standards for T2 solid fuels produced from thermally treated biomass (higher heating value (HHV) > 18 MJ/kg; VM content < 75%; sulphur and nitrogen content < 0.3% and < 2.5%, respectively). Integration of both technologies (HTT and ACoD) maximized the energy yield.

The different approaches for the integral valorization of biowastes via AD and ACoD have been evaluated and the OLR of 2.5 g COD/L d was determined as optimal for all digesters. ACoD of 95% FW and 5% PW from the HTT of GPW showed synergistic effects compared to FW mono-digestion resulting in the best strategy to maximize the energy recovery from the main urban bio-wastes.

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