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Co-digestion of livestock effluents, energy crops and agro-waste: Feeding and process optimization in mesophilic and thermophilic conditions

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HIGHLIGHTS

- ▶ The co-digestion of several substrates coming from agricultural sector was studied.
- ▶ We performed both batch and continuous trials under different operating conditions.
- ▶ The partial substitution of energy crops with agro-waste increases the biogas yields.
- ▶ The greatest biogas yields were reached in thermophilic conditions.

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ABSTRACT

In this study the optimization of the biogas yield from anaerobic co-digestion of manures and energy crops was carried out using four pilot scale CSTRs under different operating conditions. The effect on biogas yield of the partial substitution of energy crops with agro-waste was also investigated. For each substrate used during the continuous trials, BMP batch assays were also carried out to verify the maximum methane yield theoretically obtainable. Continuous operation results indicated that the co-digestion of manures, energy crops and agro-waste was viable at all operating conditions tested, with the greatest specific gas production of 0.54 $m^3/kg\ VS_{fed}$ at an organic load rate of 2 kg $TVS/m^3{}_r d$ consisting of 50% manure, 25% energy crops and 25% agro-waste on VS basis. No significant differences were observed between high and low loaded reactors suggesting the possibility of either improving the OLR in existing anaerobic reactors or reducing the design volumes of new reactors.

1. Introduction

Anaerobic digestion is one of the most common practices for the management of livestock manure because of the renewable biogas energy which can be obtained. A lot of biogas plants have been built as a consequence of European incentives for renewable energies (Lindorfer et al., 2008a; Bolzonella et al., 2011). Livestock effluents are characterized by a low carbon to nitrogen ratio (C/N) due to relatively high concentration of ammonia, limiting the biogas yields (Procházka et al., 2012). A way to decrease the risk of ammonia inhibition is the co-digestion of livestock effluents with energy crops. The addition of energy crops (mainly maize silage) with high carbon content balances the C/N ratio of the feedstock (Wang et al., 2012) increasing the energy balance of the reactors (Amon et al., 2007a) and optimizing the economic revenue derived from the European subsidies received (Bolzonella et al., 2011). However, energy crops need water, energy and fertilizers (Hanegraaf et al., 1998), decreasing, at the same time, the amount of arable land surface available for food crop production with a subsequent increase in the cost of food crops. Therefore, from a Life Cycle Assessment (LCA) point of view, these substrates are penalized (see Annex V.A in Directive 2009/28/EC on renewable energies). In addition, several environmental factors negatively influence their biodegradability (Amon et al., 2007b),

Abbreviations: AD, anaerobic digestion; AV, average value; COD, chemical oxygen demand; CSTRs, continuous stirred tank reactors; GPR, gas production rate; HRT, hydraulic retention time; *K*h, hydrolysis constant; NH_3, free ammonia; $N\text{-}NH_4^+$, total ammonia; OLR, organic load rate; P, phosphorus; PA, partial alkalinity; $R1_{H37}$, high loaded mesophilic reactor; $R2_{L37}$, low loaded mesophilic reactor; $R3_{L55}$, low loaded thermophilic reactor; $R4_{H55}$, high loaded thermophilic reactor; S.D, standard deviation; SGP, specific gas production; T, temperature; TA, total alkalinity; TKN, total Kjiendhal nitrogen; TS, total solids; TVS, total volatile solids; V, volume; VFA, volatile fatty acids; w.w, wet weight; d.w, dry weight.

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