Organic Solid Waste Mechanical Pretreatment for the Optimization of Anaerobic Digestion Processes

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Abstract
Anaerobic digestion has been recognized as the most demanding process for the valorization of organic solid waste towards the generation of valuable intermediates, that can be converted into a methane rich-gas to meet the current needs for renewable energy. In this regard, press-extrusion has raised as a promising mechanical pretreatment to enhance methane production by increasing the organic loading rate to the digester as well as by adequately mixing the liquid and the solid fractions from this pretreatment. This study aimed at verifying the significance of both the organic loading rate and the mixing ratio between the liquid and solid fraction from press-extrusion by using a factorial design of experiment. Results were discussed and statistically elaborated to identify the operating conditions to be further tested for the optimization of the integrated process.
Keywords: biological process; hydrolysis; organic load; press-extrusion.

1. Introduction

Anaerobic digestion represents an attractive treatment method for the organic fraction of municipal solid waste (OFMSW). This process allows indeed the biological stabilization of organic waste and the consequent recovery of energy, through the production of methane. The yields of the process, in terms of methane production, are strongly influenced by the mass transfer in each biological step, that can be enhanced by applying suitable pre-treatments (Cesaro and Belgiorno, 2014), such as the press-extrusion.

During the process solid organic waste is squeezed at very high pressure and separated in a more liquid fraction, characterized by moisture content of 80-85%, which is suitable to be treated through wet digestion processes, and a solid fraction, that can be sent to other recovery processes,.

The technical interest towards this technology is related to the possibility of increasing the organic loading rate to the digester fed with the liquid fraction from the press-extrusion (Novarino and Zanetti, 2012). More recent studies also pointed out that the solid fraction can be adequately mixed with the liquid one so as to enhance anaerobic digestion yields (Mu et al., 2018).

The aim of this study was in verifying the significance of both the organic load and the mixing ration between the liquid and solid fraction from press-extrusion, in order to identify the operating conditions to be further tested for the optimization of the integrated process.

2. Materials and Methods

2.1. Substrate

The samples of the organic fraction of municipal solid waste (OFMSW) were prepared on the basis of scientific literature (MTT Agrifood Research Finland, 2010).

The extruded substrate was obtained by blending the organic waste sample with water, so as to reach the consistency described in scientific literature (Novarino and Zanetti, 2012).

2.2. Anaerobic digestion tests

The strategy of the design of experiments was adopted to investigate the operating factors, namely the organic loading rate and the mixing ratio, affecting the anaerobic digestion response.
These factors were varied in a 2^3 factorial design between a “low” (-) and a “high” (+) level (Table 1), selected according to previous investigations (Haider et al., 2015; Mu et al., 2018), so as to test four combinations.

Table 1. Investigated parameters and selected values

Parameters	Value [%SV]	
	Low	High
OFMSW/LF	25 %	75%
S/I	0.5	2

Anaerobic digestion tests were carried out in batch, for 21 days, under mesophilic conditions. Substrate samples were added together with the digested sludge used as inoculum, so as to fulfill the designed experimental conditions. Tap water was added as well, in order to ensure a working volume of 450 mL in each flask.

Each test was performed in triplicates and average values were considered for discussion.

2.3. Analytical methods

Total solid (TS), volatile solid (VS), and pH of substrate and inoculum were performed in accordance with Standard Methods (AWWA-APHA-WEF, 1998).

Daily methane production was monitored through a displacement method, using an alkaline solution (2% NaOH), as described byEsposito et al. (2012) and the

results were used for the analysis of variance.

3. Results and Discussion

The main aim of this study was to assess the statistical significance of both the organic load and the mixing ratio between the liquid and the solid fraction from OFMSW press-extrusion on the methane production from anaerobic digestion.

For this reason, the performances of the anaerobic digestion tests were evaluated in terms of methane production under the different operating conditions.
The methane production increased over time, under all the applied experimental conditions. The best performances were obtained from the batch operated with a S/I ratio of 0.5 and OFMSW/LF ratio of 25%, resulting in 442.6 NL/kg_{VS} of methane.

The lowest methane production was obtained when both the S/I ratio and the OFMSW/LF ratio had the highest values.
At the same S/I ratio, the specific production of methane was observed to decrease as the quantity of the liquid fraction in the mixture increases, in accordance with the greater bioavailability of the press-extruded waste over the OFMSW. For this reason, when the organic load was mainly provided in the form of solid substrate, the methane production is lower than when provided as a liquid fraction.
The effects of both the OFMSW/LF and S/I ratios were statistically analyzed through the analysis of variance, showing that there is a not significant interaction between the chosen factors and that the S/I ratio is more statistically significant than the OFMSW/LF ratio in the definition of the biogas production.

4. Conclusions

Experimental tests showed that the co-digestion of OFMSW with the liquid fraction deriving from the extrusion process had a higher methane production when the S/I ratio was 0.5. Increasing this ratio, much lower methane production was observed. At the optimal S/I ratio, increasing the amount of liquid fraction towards that of organic solid waste (OFMSW/LF = 25%), greater methane yields were obtained.
These outcomes highlight that the mass transfer efficiencies in the digester is improved by the higher amount of the extruded substrate, which is more easily bioavailable and that the stability of the digestion process should be better achieved by operating with low S/I ratio. Further tests should be then addressed to identify, at larger scale, the optimum organic load to maximize the methane production from press-extruded waste.

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