# Improved anaerobic digestion of organic fraction of municipal solid waste pre-treated by thermal hydrolysis

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Moving towards a circular economy, the implementation of separate biowaste collection in the member states of the European Union represents a critical approach to improve municipal waste management (European Parliament, 2018). This strategy seeks to harness the biodegradable organic fraction of municipal solid waste (OFMSW) as a valuable resource, reducing the volume of waste disposal in landfills. Anaerobic digestion provides a sustainable solution for the treatment of OFMSW, enabling energy recovery while addressing the challenges associated with population growth and waste generation. Considering hydrolysis as the rate-limiting step in the anaerobic degradation of organic solid waste, thermal hydrolysis is proposed as an effective pre-treatment method. This technology has already demonstrated potential as a kinetic and methane yield enhancer in the treatment of sewage sludge. The aim of this work is to optimize the operating conditions of thermal hydrolysis on a pilot-scale for the pre-treatment of OFMSW to evaluate its impact on enhancing methane production during anaerobic digestion.

Organic fraction of municipal solid waste, collected from a waste treatment plant near Madrid, Spain, was used as raw material. Thermal hydrolysis of OFMSW was conducted using the Econward pilot-scale plant (Econward Tech, S.L.) under three pressure conditions: 2.5, 3.2, and 4 bar (130 °C, 140 °C and 150 °C, respectively). Wet feedstock (90 kg, 67% moisture content) was treated for 20 min at 100% rotation. After hydrolysis, the biomass was screened through a 90 mm light sieve. The resulting biomass (B) was labelled according to each reaction pressure (e.g., B-2.5, hydrolyzed biomass at 2.5 bar). The substrates for determining biochemical methane potential (BMP) included raw OFMSW, B-2.5, B-3.2, and B-4.0. Anaerobic digestate, collected from a mesophilic reactor at a municipal wastewater treatment plant (Madrid, Spain), was used as inoculum. Batch anaerobic digestion tests were performed at 35 (1) °C at 130 rpm, using an inoculum concentration of 15 g volatile solids (VS)/L and an inoculum-to-substrate ratio of 2, on a VS basis (De la Rubia et al., 2018). The tests were carried out in 120 mL glass vials, including a nutrient solution after which the vials were made up to volume (60 mL) with deionized water. Initially, the headspace of the vials was gassed with $N_2$ for 3 min to ensure anaerobic conditions. Biogas volume and composition were measured seven times through the experiment, every day for the first three days of the trial, twice a week for the next two weeks, and weekly until the end of the experiment. At the same time as the biogas measurement, seven samples from the glass vials were sacrificed for each substrate in order to monitor the evolution of the process control variables. Triplicate tests were carried out for the four substrates, and duplicate tests for the blank runs (samples establishing the biogas volume that the inoculum can produce), and the control runs, (samples determining the inoculum activity). The methane yield was calculated by subtracting the amount of methane produced by the blank experiments and relating it to the amount of total chemical oxygen demand (TCOD). The trial was extended for 30 days. All initial substrates were analyzed for pH, total solids (TS), VS, TCOD, total Kjeldahl nitrogen (TKN), and elemental analysis (C, N, S, and H). The soluble chemical oxygen demand (SCOD), total organic carbon (TOC), alkalinity, ammonium determination and volatile fatty acids (VFA) were determined to characterize the inoculum and the sacrificed samples.

The four substrates presented a VS/TS ratio of 80. However, an increase in the C/N ratio from 17 for OFMSW to 21 for hydrolysed substrates were observed. **Figure 1a** shows the cumulative methane potential per g of added TCOD of the non-pre-treated OFMSW feedstock and B-2.5, B-3.2 and B-4 samples. The highest methane production was observed for the sample obtained at the highest hydrolysis pressure, B-4, 197 (10) mL STP $CH_4$/g $TCOD_{added}$, which was 16% higher than that determined for OFMSW. The test carried out with B-2.5 and B-3.2 samples improved the methane yield by 5% and 2%, respectively, compared to the untreated waste. In addition, the sample obtained at 4 bar, yielded 10% to 14% more methane than the generated at 2.5 and 3.2 bar, respectively.

A similar final degradation was achieved for TCOD (38 (1)% removal), SCOD (88 (4)% removal), TOC (84 (3)% removal) and VS (27 (1)% removal) for each substrate studied. The results of the evolution of both SCOD and VFA, expressed as COD, showed that hydrolysis does not occur simultaneously in all experiments (**Figure 1b**). Thus, in the experiments with OFMSW, B-2.5 and B-3.2, acidogenesis began one day later than B-4 run, which was evidenced by a significant accumulation of VFA during the first day, combined with a higher decrease in pH. On the other hand, B-4 run presented a lower and constant accumulation of VFA during the first three days.

Thermal hydrolysis improved the bioavailability of the organic matter, which was evident in the enhancement of methane production and COD degradability. Further confirmation was provided by the presence of higher TOC content in B-2.5, B-3.2 and B-4 runs (15%, 18%, and 21%, respectively) than in OFMSW one. The degradation of VS was also faster in three first days for B-4 run (13% removal) than for OFMSW, B-2.5 and B-3.2 runs (8% 11% and 10% removal, respectively).

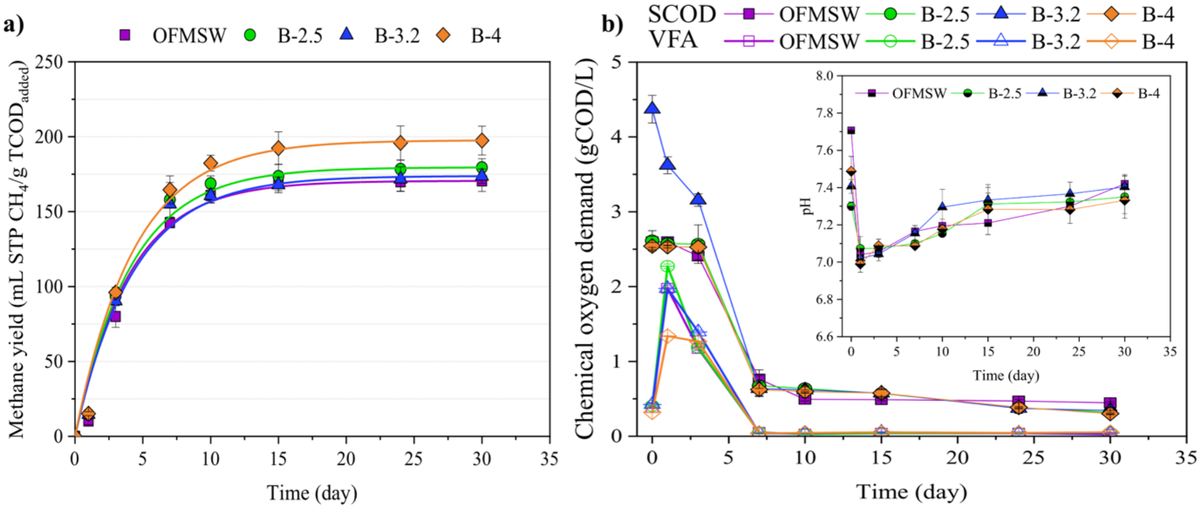


**Figure 1.** Methane production per g $TCOD_{added}$ (a); SCOD, VFA and pH evolution (b).

The initial TKN concentration for each substrate (2.0 (0.1) g TKN/L), lead up to 0.8 (0.1) g $N\text{-}NH_3$/L, below the inhibitory threshold, did not affect bacterial growth and acted as a buffer, stabilizing the pH and preventing acidification by VFA. No significant alkalinity reduction was determined indicating effective VFA control and avoiding methanogenic inhibition. After 30 days, substrates B-2.5, B-3.2 and B-4 showed a 27 (1) % lower alkalinity than the OFMSW substrate, demonstrating greater stability and resistance to pH fluctuations. These findings highlight the robustness of hydrolyzed substrates in maintaining process stability and preventing inhibitory conditions during anaerobic digestion.

Thermal hydrolysis of OFMSW as a pre-treatment for anaerobic digestion was very effective to achieve efficient VS and COD degradation, due to the improvement in the bioavailability of the substrates, which led to a high degree of methanization. The best results were obtained with the OFMSW hydrolyzed at 4 bar.


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**References**


Econward Tech, S.L. https://econward.com

European Parliament, (2018). Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste. http://data.europa.eu/eli/dir/2018/851/oj

De la Rubia, M.A., Villamil, J.A., Rodriguez, J.J., & Mohedano, A.F., (2018). Effect of inoculum source and initial concentration on the anaerobic digestion of the liquid fraction from hydrothermal carbonisation of sewage sludge. *Renewable Energy*, 127, 697–704. https://doi.org/10.1016/j.renene.2018.05.002