Acidogenic fermentation of process water from hydrothermal carbonization of sewage sludge: volatile fatty acids production

L. Martinez-Sanchez[1], C. Díaz-Padilla[1], J.F. Hernández[1], A.F. Mohedano[1]; E.Diaz[1], M.A. de la Rubia[1], M. Tobajas[1]

[1] Department of Chemical Engineering, Universidad Autónoma de Madrid, 28049 Madrid, Spain
E-mail contact: lydia.martinez@uam.es

Keywords: waste valorisation, hydrothermal carbonization, chain elongation, acidogenic fermentation

Abstract

Sewage-sludge valorisation using hydrothermal carbonization (HTC) results in the production of a solid product called hydrochar, with many application as a soil amendment or energy resource, and a liquid phase subproduct, process water (PW). The main aim of this work is to evaluate the production of volatile fatty acids (VFAs) from process water of secondary sewage sludge using acidogenic fermentation process. The HTC process was carried out at 230 ºC during 45 min. As inoculum a sludge from an anaerobic digester was used, with a previous thermally pretreatment for the inhibition of methanogenic microorganisms. The AF process was carried out in batch mode and in mesophilic range (35 (1) ºC) using as substrate the PW obtained from a first filtration of HTC product with a 0.5 mm filtration pore size and with an extra filtration by 0.45 µm. The effect of the pH on VFA production was also analyzed, working with the original pH of the mixtures (7.2-7.3) and adjusting it at 5.5 (with HCl 2N) and 9.0 (with KOH 2N), respectively. Process evolution was studied by making sacrificies of samples during 30 d of experiment, analyzing TS, VS, pH, VFA, total and soluble DQO, glucose, lactic acid and ethanol concentrations, as well as gas volume production and its composition.

The highest production of VFA was obtained for PW filtered by 0.45 µm and working with the original pH, achieving concentrations of 9.0 g DQO/L, followed by both experiments that worked with pH = 9.0 with a VFA production of 8.5 g DQO/L. In the case of the experiment that used PW without an extra filtration and without pH modification there was a VFA production of 7.7 g DQO/L. The experiments carried out with pH = 5.5 did not produce any VFA. Biogas production was almost insignificant and no methane was detected.

Regarding the results obtained, another experiment was carried out to study VFA chain elongation into medium chain carboxylic acids (MCCAs) with the addition of different doses of ethanol and lactic acid (from 5 to 15 g/L), respectively. The best condition (PW filtered by 0.45 µm and original pH) was used and also working in batch mode and mesophilic range, studying process evolution during 30 days. A higher production of VFA was obtained when the dose of ethanol was increased until 15 g/L in the reaction medium, achieving a production of 21.2 g DQO/L of which acetic acid (C2) and caproic acid (C6) represented the 16.3% and 45.6%, respectively, comparing to control where C2 and C6 represented the 41.5% and 0.1%. In the case of the experiments with 15 g/L of lactic acid, the total VFA production was 23.1 g DQO/L, but chain elongation only achieved an increase in butyric acid (C4) concentration, representing the 37.2% of the total VFA production, respect to the 1.0% of C4 achieved in the control reactors.

In the chemical industry, C4 is used in the production of many additives in foods, perfumes, flavorings or also in the pharmaceutic industry [1]. In the case of C6, it is used as an antimicrobial agent in the pharmaceutical industry, as an additive in human and animal feed or a possible precursor of biofuels [2]. In conclusion, with the addition of higher doses of ethanol a higher VFA total production is achieved and also a higher caproic acid concentration, while in the case of the lactic acid addition the chain elongation is favored until butyric acid.

References

[1] Goldberg, I. & Rokem, J.S., (2009). Organic Fatty Acid Production. Encyclopedia of Microbiology (third edition).
[2] Cavalcante, W.; Leitão, R. et al (2017). Anaerobic fermentation for n-caproic acid production: A review. Process Biochemistry 54 (106-119).

Acknowledgements

The authors would like to thank Spanish MCIN/AEI/UE (10.13039/501100011033) through the TED2021-130287B-I00 project.