Acidogenic co-fermentation of Waste Activated Sludge and Glycerol at different pH control conditions to tune the volatile fatty acids (VFAs) profile

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Bio-based Volatile Fatty Acids (VFAs) could be produced by means of mixed microbial culture (MMC) acidogenic fermentation using a wide variety of biodegradable organic wastes (Lee et al., 2022). The acidogenic co-fermentation of Waste Activated Sludge (WAS) from municipal wastewater treatment plants with other readily biodegradable substrates has been found highly synergistic since WAS is usually rich in nutrients and could provide buffer capacity to maintain pH conditions leading to higher VFA yields (Perez-Esteban et al., 2022). Although the fermentation yield and product profile is affected by the working pH of MMC acidogenic fermentation, pH itself is not enough to predict the product profile, since other factors such as the composition of the co-substrate and the variability of WAS properties impact the fermentation performance. This study is focused on the impact of pH control on MMC acidogenic co-fermentation of WAS with glycerol, a by-product derived from biodiesel production that is characterized by its high biodegradability and solubility in water (Astals et al., 2012).

Anaerobic batch fermentation experiments were conducted in pyrex serum bottles (250 mL) to assess the impact of WAS and glycerol co-fermentation (15% glycerol on VS basis) under various pH control strategies using KOH, with and without a methanogens inhibitor (2-bromoethanesulfonate or BES). All tests were performed by triplicate as well as their controls to assess VFA production of WAS mono-fermentation. To assure anaerobic conditions, the headspace of the bottles was flushed with N_2 for 2 min (ca. 5 L/min) and sealed with PTFE-butyl septum with a screwcap. The bottles were placed in an incubator at a controlled temperature of 35ºC (UF750, Memmert GmbH) and were mixed manually once per day. Samples of each bottle were taken periodically through the septum by using a needle connected to a 5 mL plastic syringe. The total sampling withdrawal always represented less than the 20% of the initial volume. The duration of each test was set at 14 days.

During WAS mono-fermentation (24 g VS/Kg), a maximum VFA concentration of 1.76 g COD/L was observed around day 7 of operation and from this point onwards, VFA concentration decreased, mainly linked to a decline in acetic acid concentration. This reduction could be attributed to the proliferation of methanogenic microorganisms that consume acetic acid. However, when WAS mono-fermentation was carried out using BES supplementation, VFA production progressively increased until reaching 4.6 g COD/L, with the fermentation liquid being enriched in acetic acid and propionic acid (37.0% and 16.9%, respectively).

When glycerol was used as a WAS co-substrate without controlling the pH, VFA production increased up to 7.4 g COD/L after 15 days. The addition of BES to this mixture slightly improved production to 7.7 g COD/L and no acetic acid consumption was observed during the fermentation. Under these operating conditions, the resulting VFA profile was particularly rich in propionic (46.3% of total VFAs) and valeric acids (18.0%).

To assess the impact of pH control on VFA production, the initial pH was adjusted to 9 (using 0.45 g of KOH) which significantly enhanced VFA production, reaching a peak of 11.4 g COD/L on day 8. However, VFA production subsequently declined towards the end of the batch due to acetic acid consumption over time. The dosification of BES under these pH-adjusted conditions led to a continuous increase in production up to 12.3 g COD/L, yielding a profile with a substantial amount of propionic acid (40.1% of the total VFA production).

Another pH control strategy was tested involving the periodic addition of alkali (0.34 g of KOH every 3 days) to maintain the pH at alkaline values. Under this pH control strategy, VFA production reached nearly 13 g COD/L by the tenth day, after which production fell as acetic acid was consumed. By preventing methanogenic activity with BES addition using this pH control strategy, the highest VFA production was achieved, reaching 14.3 g COD/L enriched in acetic and propionic acids (40.4% and 32.0% of total VFA production, respectively).

Building upon these batch results, the operation of semi-continuous fermenters was carried out to compare the long-term acidogenic co-fermentation performance of WAS and glycerol with and without pH control. Preliminary results clearly shows that propionic acid production was promoted (24.4% of total production) using WAS and glycerol co-fermentation, although the addition of KOH lead to an enhancement of the solubilization yield,

resulting in a higher VFA production also enriched in propionic and valeric acids (representing 74.0% of the VFA production).

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References:

Astals, S., Nolla-Ardèvol, V., Mata-Álvarez, J. (2012) Anaerobic co-digestion of pig manure and crude glycerol at mesophilic conditions: Biogas and digestate. Bioresource Technology, 110, 63-70

Lee, J., Chen, W.H., Park, Y.K. (2022). Recent achievements in platform chemical production from food waste. Bioresource Technology, 366, 128204

Perez-Esteban, N., Vinardell, S., Vidal-Antich, C., Peña-Picola, S. Chimenos, J.M., Peces, M., Dosta, J., Astals, S. (2022) Potential of anaerobic co-fermentation in wastewater treatments plants: A review. Science of the Total Environment, 813, 152498