Mesophilic and Thermophilic dark fermentation of process water from food waste hydrothermal carbonization

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Food waste (FW) generation (approximately 1050 million t in 2022 according to the United Nations Environmental Program) is rising due to population growth and human activity, demanding novel sustainable valorization routes to overcome this problem [1]. The FW properties (high moisture, carbon-rich organic compounds and biodegradability) suits for dark fermentation (DF) substrate application, which is a biological process that produces biohydrogen and volatile fatty acids (VFA) with low carbon emissions and being cost effective. However, hydrolysis stage reduces overall efficiency of the process when complex substrates are applied. Hydrothermal carbonization (HTC) addresses this issue by converting wet biomass at mild temperatures into hydrochar (usable as biofuel or soil amendment) and process water (PW), rich in carbohydrates and aminoacids, suitable as DF substrate.

In this work, the HTC (Parr instrument model 4524, 180 ºC, 1h) of FW from a local business (91.2% moisture, 89.1 g_{COD}/kg) was carried out to produce PW (60.7 g_{COD}/L, 3.4$\%_{w/w}$ carbohydrates) for DF feedstock application. Continuous DF was conducted in a 3 L CSTR, inoculated with thermally pretreated (105º, 1h) anaerobic sludge for mesophilic (MF; 37 ºC, pH 4.8) experiments, and adapted (55 ºC, 14 d) mixed sludge for thermophilic (TF; 55 ºC, pH 5.5) tests at a hydraulic retention time of 5 d, evaluating the effect of the organic loading rate (OLR; 2.5, 5, and 7.5 g_{COD}/L d) on H_2 and VFA production.

Optimal OLR for H_2 production was 5 g_{COD}/L d, reaching 54.0 ± 1.4 and 39.5 ± 1.6 mLH_2/g_{COD}, at TF and MF being the H_2 percentages in the biogas of 37% and 48%, respectively. At 7.5 g_{COD}/L d, specific H_2 yields fell to 34.1 ± 2.5 and 14.5 ± 1.6 mLH_2/g_{COD}, associated with substrate inhibition [2]. While at lower OLR (2.5 g_{COD}/L d), the H_2 yield was 32.9 ± 1.6 at TF and 3.6 ± 0.9 mL H_2/g_{COD} on MF, associated with lack of substrate [2]. VFA production peaked at 7.5 g_{COD}/L d (10.2 ± 0.5 and 10.1 ± 0.2 g_{CODeq}/L for TF and MF, respectively), whereas at the optimal H_2 production conditions (TF and OLR 5 g_{COD}/L d), VFA production reached 7.8 ± 0.4 g_{CODeq}/L, with acetate (2.4 g/L) and butyrate (2.2 g/L) as main metabolites. Microbial taxonomy analysis shows that, under these TF optimal conditions, the microbiome was dominated by *Thermoanaerobacterium* (23%), *Acetobacter* (20%), *Clostridium sensu stricto 1* (7%), and *Lactobacillus* (18%), which builds a hydrogen-producing bacteria and lactic acid bacteria synergic consortium that improves complex substate conversion and optimizes H_2 production [3]. Besides, MF optimal H_2 production test promoted *Caproiciproducens* (32%), *Clostridium sensu stricto 12* (27%), and *Clostridium sensu stricto 11* (18%), all well-known hydrogen-producing bacteria [4]. It can be concluded that temperature range and OLR are key parameters on continuous DF, with TF and OLR 5 g_{COD}/L d as optimal conditions using HTC-PW from FW as substrate. Moreover, Lactate-Driven metabolic pathways promote synergetic activity on the microbial consortium to enhance H_2 production on DF.

Acknowledgements: Authors greatly appreciate funding from MCIN/AEI/10.13039/501100011033 and European Union "NextGenerationEU/PRTR" (PID2022-138632OB-I00), and Comunidad de Madrid (TEC-2024/BIO-177). M.P. Díez also thanks the MICINN and the ESF for a research grant (PRE2020-094041).

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