Production of hydrogen and volatile fatty acids on thermophilic dark fermentation process from hydrothermal carbonization process water of food waste

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Abstract

Food waste (FW) management is a major issue worldwide due to the rapid population growth and human lifestyle, being necessary to find efficient, affordable and within a circular economy approach for its valorization. Hydrothermal carbonization (HTC) is a thermochemical process that allows the treatment of wet biomass to obtain a slurry fraction composed by a carbonaceous solid fraction named hydrochar, suitable for biofuel or soil amendment application, and a liquid fraction, known as process water, enriched in easy biodegradable compounds. Dark fermentation (DF) is a biological process where specific anaerobic bacteria transform organic substrates into value-added products, mainly H_2 and volatile fatty acids (VFA), being reported high yields on thermophilic conditions using mixed sludge as inoculum [1].

The aim of this study is to find an optimal valorization approach of FW by coupling HTC and DF processes. Food waste, characterized by 90% moisture and 89.1 g_{COD} L^{-1}, is treated by HTC at 180 ºC and 45 min. Hydrochar and process water are obtained by centrifugation and filtration of the HTC slurry. The obtained hydrochar have a high heating value of 23.0 MJ kg^{-1} and its charaterized by a C content of 57$\%_{w/w}$. Process water with a chemical oxygen demand value of 60.7 g L^{-1} and a carbohydrates concentration of 3.4$\%_{w/w}$ is used a substrate in DF experiments. A mixed sludge obtained from a wastewater treatment plant was evaluated as inoculum on mesophilic (36 ºC) and thermophilic (55 ºC) range with and without thermal pretreatment (105 ºC, 1 h) on batch tests (inoculum: 5 gVS L^{-1}; substrate-inoculum ratio of 1.6). Once selected the most active inoculum, DF of process water is carried out in a CSTR (3 L; organic load rate (OLR): 5 g_{COD} L^{-1} d^{-1}), evaluating the effect of pH (4.8, 5.5) and hydraulic retention time (HRT; 3.5 d, 5 d) on H_2 and VFA production.

The analysis of batch experiments in terms of H_2 production indicated that the maximum yield (44.4 mL H_2 g_{COD}^{-1}) was achieved at thermophilic conditions with the no-pretreated inoculum. A H_2 production of 39.0 mL H_2 g_{COD}^{-1} was found using thermophilic conditions and heat pretreated inoculum, whereas H_2 production of 34.5 mL H_2 g_{COD}^{-1} were found at mesophilic conditions and heat pretreated inoculum. In continuous experiments using thermophilic conditions and no-pretreated inoculum is observed a maximum H_2 production (54.8 mL H_2 g_{COD}^{-1}) at pH 5.5 and HRT 5 d. A decrease of HRT at 3.5 d caused a drop of 10 % in the H_2 production, while working at pH 4.8 the H_2 production was 34.9 mL H_2 g_{COD}^{-1} and 11.0 mL H_2 g_{COD}^{-1} at HRT 3.5 d and 5 d, respectively. Regarding to VFA production, the highest production (8.30 g_{CODeq} L^{-1}) was found at pH 5.5 and HRT 5 d, achieving an acetic and butyric acid concentration on reactor effluent of 2.50 g L^{-1} and 2.39 g L^{-1}, respectively. A decrease of HRT caused a decrease on VFA production of 30%, while a change of pH to 4.8 lead to a concentration of 7.55 g_{CODeq} L^{-1} and 5.57 g_{CODeq} L^{-1}, at HRT of 5 d and 3.5 d, respectively. Metagenomic DNA analysis by Next Generation Sequencing of key reactor effluents revealed that all reaction media were dominated by thermoanaerobacteriales and acetobacterales order, related to anaerobic H_2 production pathways [2]. However, in the reaction media obtained at pH 5.5 and HRT 5 a high relative abundance of Lactobacillales, was also observed, which could create positive synergies with hydrogen-producing bacteria to enhance H_2 yields [2]. It can be conclude that the integration of HTC process and DF at thermophilic conditions is a promising strategy for food waste valorization, being mainly pH the key process parameter to enhance H_2 and VFA production.

References

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