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Abstract

Optimal recovery of targeted Volatile Fatty Acids by municipal cellulosic sludge fermentation

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Abstract

The main objective of wastewater treatment has always been the quality of the final effluent as well as on the efficiency of the treatment process. Nowadays, it was recognized that municipal wastewater has become an attractive source of renewable resources (i.e. cellulose, PHA, phosphorus, nitrogen…) to be efficiently recovered applying the appropriate technologies even in existing wastewater treatment plants. Among them, the sieving of wastewater by rotating belt filtering (RBF) allows the recovery cellulosic sludge, from which it can be derived several biomaterials of high added value, such as, clean cellulose, biomass for fuel, components for asphalt and Volatile Fatty Acid (VFAs), etc. The latter are intermediates for a further upgrading to valuable compounds such as the polyhydroxyalkanoates. VFAs can be produced by an efficient fermentation of the cellulosic sludge under mesophilic (30-40°C) or thermophilic (50–60 °C) conditions and enhance the production and composition of volatile fatty acids. Moreover, alkaline pH is an effective method to increase the biodegradability of the sewage sludge and orient the final recovered VFA mixture to the highest content of propionic acid, but maximal cellulose degradation increased with pH from pH 6.0 to 7.5 (Hu et al., 2005). The aim of this work was to optimize the temperature of fermentation and the influent pH of real cellulosic sludge from the sieving of municipal wastewater in a lab scale Sequencing Batch Fermentation Reactor (SBFR) in order to maximize the VFAs production efficiency. The process will be implemented at pilot scale in Carbonera (Treviso – Italy) where, according with the objectives of the Horizon2020 SMART-Plant project, the fermentation of cellulosic sludge will drive the VFAs production which are the precursors for further PHA production.

Fresh Primary Sludge was collected from the municipal WWTP of Carbonera and thickened up to 35-42% total solids (TS). Then, the cellulosic sludge was prepared by increasing the amount of toilet paper in order to obtain a content of cellulose of around 35% (TS based), as reported by Ruiken et al., (2013). Before the preparation of cellulosic sludge, the toilet paper was kept in wastewater simulating a retention time of 4 h, so to obtain similar conditions to those found in WWTPs. Table 1 summarized the characteristics of the cellulosic sewage sludge.

Table 1. Characteristics of the cellulosic sewage sludge

Parameter	Units	Average (min-max)	St. Dev.
Total Solid	gTS/kg	56 (42.9-78.6)	11.1
Total Volatile Solid	gTVS/kg	47.8 (38.3-60.9)	7.8

% Content of cellulose	kg/kgTS x 100	34.2 (31.2-37.9)	1.5
Specific Biogas Production (SGP)	m^3biogas/kgTVS	0.60 (0.58-0.62)	0.02

Every day, the SBFR with 4 liters of volume was discharged and then fed with the same volume of cellulosic sewage sludge according with a hydraulic retention time (HRT) of 3-4 days. Three main experimental periods were considered during 133 days of operations, based on the initial pH of the feeding and the fermenting temperature of the SBFR (Table 2).

Table 2: Operating fermenting conditions adopted during the experimental periods

Parameter	Days	Initial pH	Temperature
Period 1 (P.1)	0-13	No control (6.0-6.5)	37°C
Period 2 (P.2)	13-92	7.9-8.1	37°C
Period 3 (P.3)	93-133	7.9-8.1	55°C

Figure 1 shows the obtained results. Under mesophilic conditions (Period 1 and Period 2), the increase of the initial pH of the feeding by soda affected positively the production of VFAs.

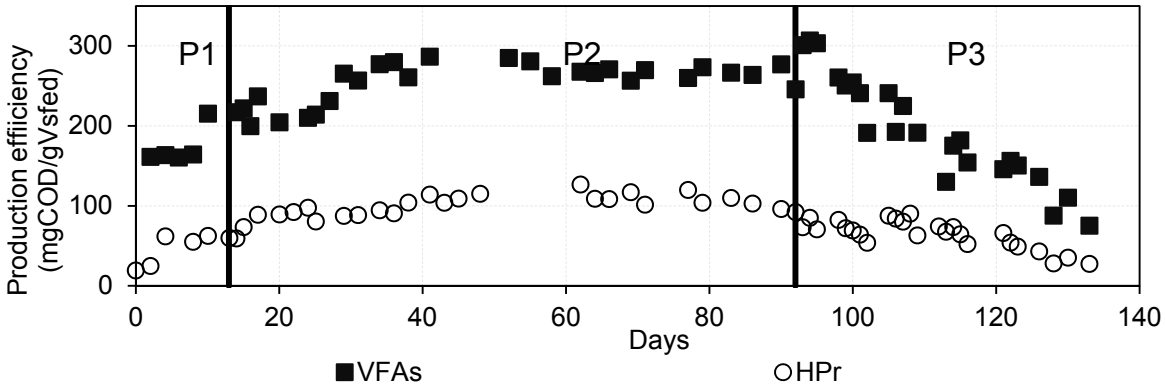

Figure 1. Profile of the production efficiency of VFAs and HPr. (P.1: 37°C, no pH control in the feeding; P.2: 37°C, pH control at 8.0 in the feeding; P.3: 55°C, pH control at 8.0 in the feeding)

The VFAs production efficiency increased gradually from around 160 mgCOD/gTVS fed (Period 1) up to a stable range of 250-300 mgCOD/gTVS (Period 2). At these conditions, the concentration of the propionic acid (HPr) was around 40%, which corresponded to a production efficiency up to 126 mgCOD/gTVS. In period 3, the higher temperature seems to have a sterilization effect for acidogenic bacteria contained in the cellulosic primary sludge. In fact, the thermophilic conditions were detrimental for the VFAs production efficiency which decreased drastically under 100 mgCOD/gTVS.

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