Pilot scale acidogenic fermentation of microsieved cellulosic sludge for Short Chain Fatty Acids production

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Abstract: In this work, cellulosic sludge was recovered from municipal wastewater by means of microsieving through pilot rotating belt filter and fed in a fermentation unit for Short Chain Fatty Acids production. According with loadings, the removal efficiencies varied between 17-76% for suspended solids and 10-61% for the COD, while less than 27% for nitrogen and phosphorus. The acidogenic fermentation of the CS was conducted initially in batch mode to evaluate the short chain fatty acids production yields at different pH. The higher value was obtained at pH 9 (521 mgCOD per g of volatile solids) while without any pre-treatment the yield was of 232 mgCOD per g of volatile solids. Then, a 2.6 m^3 Sequencing Batch Fermentation Reactor was operated at 4 days of hydraulic retention time and mesophilic temperature (37°C). The VFAs production achieved were as high as 2.1 $kgCOD_{VFA}/m^3$ day reactor, where up to 50% was propionate.

Keywords: wastewater micro-sieving; cellulosic sludge; acidogenic fermentation; short chain fatty acids.

Water resource recovery facilities (WRRF) move further toward the goal of net-zero energy with technologies that maximize carbon recovery from wastewater. The rotating belt filter has been recently applied to replace primary clarifier as primary treatment. Rusten and Lundar (2006) reported the economic benefits of this technology because reduced of 50 % the costs compared with primary clarifiers. Moreover this technology reduces the energy need for aeration without negative effect on the denitrification, while the high biodegradability of produced sludge determines a potential methane production of 323-366 $NmlCH_4/gVSS$ (Paulsrud et al., 2014). Ruiken et al, 2013, reported that the net energy need for the wastewater treatment would amount to at least 40% less compared with the reference without fine-mesh sieving (Stowa 2010-19). Moreover, the resulting filtered material could represent up to 30% of the total COD and use efficiently biomass power plants for energy generation whereas the resulting sieved wastewater gives advantages in optimizing the wastewater treatment process. On the other hand, Crutchik et al. (2018) evaluated the on-site conversion of the cellulosic sludge to SCFAs through acidogenic fermentation whether the SCFAs are considered as high value-added precursors for the production of energy, polyhydroxyalkanoates, chemical industry, etc.

Currently, the development of new technologies aiming the valorisation of the cellulosic primary sludge is a target of the EU through innovation action in the framework of Horizon2020. Among the others, the scale-up of the short-chain fatty acids (SCFAs) production by the acidogenic fermentation of CS was the task of the Horizon 2020 Smart-Plant project.

During the project, municipal wastewater was sieved by Salsnes Filter (Salsnes Filter, PO BOX 279, N-7801 Namsos, Norway), obtaining average removal efficiencies of 44% for suspended solids (range 17-76%), 35% for COD (range 10-61%), 27% for nitrogen while regarding the phosphorus removal is not significant.

The total solids (TS) content in CS was the most variable parameter that ranged between 21 and 73 gTS/kg. The sludge composition was quite constant on dry basis with a volatile fraction of 92% dw. The COD/N and COD/P ratios were 55 mgCOD/mgN and 266 mgCOD/mgP respectively, indicating the lower presence of nutrients compared with a secondary sludge. Potential SCFA production was investigated with batch tests varying the initial pH. The maximal yield was reached with pH 9 and was 521 $mgCOD_{SCFA}/g$ VS, corresponding to increase of 125% compared with untreated sludge (Figure 1a).

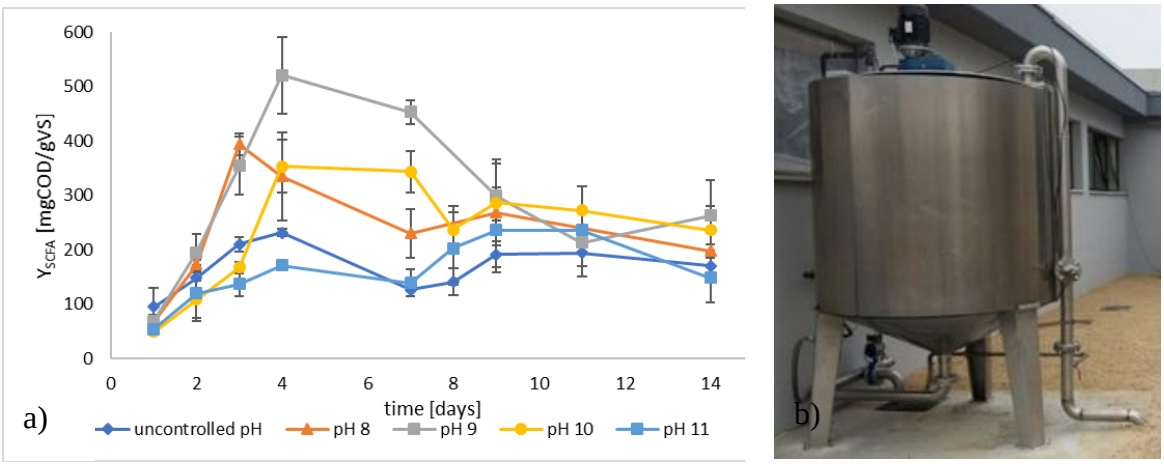

Figure 1 a) Variation of SCFA yield on volatile solids basis adjusting the initial pH and b) pilot scale SBFR

Semi-continuous trials were operated in a 2.6 m^3 sequencing batch fermentation reactor (SBFR) fed daily with untreated CPS to reach solid retention time (SRT) of 10 and 4 days. Performances and effluents characteristics were reported in Table 1. Although the SCFA concentrations were comparable in the different operational conditions, the flow rate determined productivity of 0.8 and 2.1 kg/m^3d using 10 and 4 days of SRT, respectively.

Table 1 Yields and fermentation liquid characteristics obtained with SRT of 10 and 4 days

SRT (days)	Y_{SCFA} (mg*COD/g VS*)	**SCFA** (mg/L)	**Acetic acid** *(%)*	**Propionic acid** *(%)*	**Butyric acid** *(%)*	NH_4^+ (mgN/L)	PO_4^- (mgP/L)
10	150	8347	24%	49%	10%	290	70
4	165	8360	30%	46%	13%	370	101

The study will be completed with currently underway semi-continuous test adjusting sludge pH at value 9 and operating with SRT of 4 days. Preliminary results under this condition confirmes the higher yield observed in the batch test (almost 290 mgCOD/gVS) and propionic acid contributes for 50% of total SCFA.
According with the findings obtained in the semi-continuous trails, the potential SCFA production accounts for 12-23 $gCOD_{VFA}$ per m^3 of treated wastewater on basis of applied operational conditions.

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