Valorisation of cellulosic sludge by fermentation process: VFAs production and phosphorus recovery

D. Crutchik, N. Frison, A. Mattioli and F. Fatone

Department of Biotechnology, University of Verona, Verona, Italy.
(E-mail: *dafne.crutchikpedemonte@univr.it; nicola.frison@univr.it; andrea.mattioli@univr.it; francesco.fatone@univr.it)*

Abstract
Primary sludge from municipal wastewater is a potential source for valorisation of cellulosic matter. A possible way to obtain cellulosic sludge is enhanced primary separation using fine-mesh sieves. This work investigates volatile fatty acids (VFAs) production and phosphorus (PO_4^{3-}-P) release from the fermentation of cellulosic sludge at two pH conditions (8 and uncontrolled pH) and at constant temperature of 37 ºC. Also, the recovery of the released phosphorus by struvite crystallisation was studied. Preliminary results indicated that the cellulosic sludge fermentation liquid (SFL) could be a suitable source of VFAs and PO_4^{3-}-P, in which it is possible to recover PO_4^{3-}-P by struvite crystallisation and then it could be used as carbon source for other biological processes.

Keywords
cellulosic sludge; sludge controlled fermentation; volatile fatty acids; struvite

INTRODUCTION

Primary sludge (PS) from municipal wastewater is a potential source for valorisation of cellulosic matter. Cellulose represents approximately 30-50% of the influent suspended solids in WWTP of Western European countries (STOWA, 2012), where around 10 kg/PE of toilet paper are discharge every year with the wastewater (Rusten, 2006). Enhanced primary separation using fine-mesh sieves is an emerging technology (EPA, 2013) able to retain up to 50-80% of the raw cellulose in the primary sludge (Rusten, 2006), which is suitable to be valorised as other valuable materials, such as recycled toilet paper, biomass fuel, asphalt and VFAs (STOWA, 2012). Among them, VFAs have been demonstrated that can be used as carbon source to enhance the biological phosphorus removal (EBPR) or for the production of more advanced final products, such as polyhydroxyalkanoates (PHAs). Currently, only a few studies have investigated the cellulose recovery from sewage sludge (Ruiken et al., 2013) but the evaluation of the bioconversion of cellulosic sludge to VFAs through controlled fermentation was seldom reported. The aim of this work was to study the best fermentation condition of the cellulosic sludge to maximise the production of VFAs and phosphorus (PO_4^{3-}-P) recovery by struvite crystallisation.

MATERIAL AND METHODS

Fresh thickened PS was used to accomplish fermentation process. The PS was collected from the municipal WWTP of Verona (Italy). Here the PS is thickened up to 45% total solids (TS) by a gravity belt thickening. The cellulosic sludge used in this work was prepared by mixing the PS with toilet paper in order to obtain a cellulosic sludge with a cellulose content of around 35% (Ruiken et al., 2013). Before the preparation of cellulosic sludge, the toilet paper was kept in wastewater for 4 h to achieve a cellulosic sludge with similar characteristics to those found in WWTPs. A sequencing batch fermentation reactor (SBFR) with a working volume of 4 L and equipped with a blade stirrer installed in the bottom was used. Our previous results (data not shown) indicated that cellulosic sludge fermentation at 37 ºC and pH of 8 allows to enhance the VFAs production and PO_4^{3-}-P release. For this reason, the SBFR was operated under two different periods: period I, in which the SBFR was operated with uncontrolled pH as reference scenario; and period II, where the pH of the cellulosic sludge fed was changed at pH 8. While the fermentation temperature was maintained at

37±1°C by a thermostatic bath. The HRT was kept at 4 days. Samples were periodically taken from the SBFR to determine the concentrations of PO_4^{3-}-P, NH_4^+-N, VFAs and pH. All samples were centrifuged and filtered through cellulose membrane filters. Once the operation of SFBR was stable, PO_4^{3-}-P recovery from cellulosic SFL by struvite crystallisation was studied. $Mg(OH)_2$ was used as Mg^{2+} and alkali sources to promote struvite crystallisation. The crystallisation pH was fixed at 8.5.

RESULTS AND DISCUSSION

The fermentation pH was around 4.9 for the whole experimental time. Even when the pH was similar during SBFR operation, the composition of both effluents (period I and II) was slightly different in terms of VFAs concentration. Figure 1 shows the VFAs concentration and its composition from cellulosic sludge fermentation. For period I, the production of VFAs was 165 mg COD/g VS_{fed}, with a VFAs concentration in SFL of 8.6 g COD/L. Acetic acid was the most prevalent VFAs in the SFL (52% of the total VFAs) and propionic acid the second one (36%). n-butyric (7%) and n-valeric (5%) acids were also detected. The aforementioned results indicated that the cellulosic SFL obtained from fermentation at uncontrolled pH could be a suitable carbon source for other biological processes, such as biological nutrients removal or PHAs production. Moreover, high levels of released nutrients were observed from cellulosic sludge fermentation at uncontrolled pH. The released concentrations of PO_4^{3-}-P and NH_4^+-N were 2.2 mg PO_4^{3-}-P/g VS_{fed} and 7.7 mg NH_4^+-N/g VS_{fed}, with nutrients concentrations in the SFL of 130 mg PO_4^{3-}-P/L and 408 mg NH_4^+-N/L. For struvite crystallisation test, the percentage of phosphorus recovery was 94.7%, with a final phosphorus concentration of 7.4 mg PO_4^{3-}-P/L. From the obtained results it can be determined that it is feasible to recover PO_4^{3-}-P from cellulosic SFL. Moreover, the period II of SBFR operation is in progress and will be completed during the coming weeks. The preliminary results showed that the strategy to adjust the pH of the influent SBFR at 8 could be a good option for obtaining high production of VFAs. At the moment VFAs production is still increasing and it is around 210.4 mg COD/gVS_{fed}, with a VFAs concentration of 12.3 g COD/L. The released nutrients concentrations were 2.0 mg PO_4^{3-}-P/g VS_{fed} and 6.5 mg NH_4^+-N/g VS_{fed} during this period. In this regard, struvite crystallisation test should be developed in order to determine the efficiency of phosphorus recovery from the SFL of period II. Thus, the preliminary results indicated that the valorisation of cellulosic sludge by fermentation process could become an attractive VFAs source, obtaining high VFAs concentrations. At the same time cellulosic SFL could be a potential resource for PO_4^{3-}-P recovery by precipitation processes.

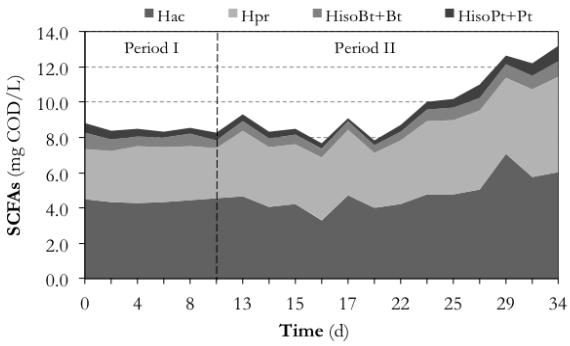

Figure 1. VFAs concentration and its composition in the cellulosic sludge fermentation liquid.

REFERENCES

Ruiken., C.J., Breuer., G., Klaversma, E., Santiago, T., van Loosdrecht, M.C.M. (2014). Sieving wastewater - Cellulose recovery, economic and energy evaluation. Water Research, 47, 43-48.

Rusten, B., 2006. Evaluation and testing of fine mesh sieve technologies for primary treatment of municipal wastewater. Water Science and Technology, 54(10), 31-38.

STOWA report. (2012). Verkenning naar mogelijkheden Voor Verwaarding Van zeefgoed.

Verachtert, H., Ramasamy, K., Meyers, M., Bever, J. (1982). Investigation on cellulose degradation in activated sludge plants. Journal of Applied Bacteriology, 52, 185-190.