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Biogas production from potato-juice, a by-product from potato-starch processing, in upflow anaerobic sludge blanket (UASB) and expanded granular sludge bed (EGSB) reactors

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ABSTRACT

In this study, the utilization of potato-juice, the organic by-product from potato-starch processing, for biogas production was investigated in batch assay and in high rate anaerobic reactors. The maximum methane potential of the potato-juice determined by batch assay was 470 mL-CH_4/gVS-added. Anaerobic digestion of potato-juice in an EGSB reactor could obtain a methane yield of 380 mL-CH_4/gVS-added at the organic loading rate of 3.2 gCOD/(L-reactor.d). In a UASB reactor, higher organic loading rate of 5.1 gCOD/(L-reactor.d) could be tolerated, however, it resulted in a lower methane yield of 240 mL-CH_4/gVS-added. The treatment of reactor effluent was also investigated. By acidification with sulfuric acid to pH lower than 5, almost 100% of the ammonia content in the effluent could be retained during the successive up-concentration process step. The reactor effluent could be up-concentrated by evaporation to minimize its volume, and later be utilized as fertilizer.

1. Introduction

'Potato-juice' is one of the main streams of organic by-products from potato-starch processing. Potato-juice is the thin liquid by-product obtained after the fruit water protein coagulation and separation. The potato-starch processing scheme is shown in Fig. 1. Per ton potato-starch produced, approx. 3.5 tons of potato-juice is produced as by-product (AKK, 2009). This organic by-product is rich of biodegradable components such as starch and proteins, which could be used for biogas production through anaerobic digestion. In recent years, the biogas production in Europe has increased constantly, the primary production of biogas reached 7.5 million tons of oil equivalents in 2008 (Stolpp, 2010). Anaerobic digestion is a sustainable way for producing energy in the form of biogas and, at the same time, treating industrial wastes. Several studies have previously reported anaerobic treatment of industrial wastewater from processing of potato chips and snacks, potato frozen food, and potato starch (Hadjivassilis et al., 1997; Zoutberg and Eker, 1999; Ma et al., 2008; Monou et al., 2008). Kryvoruchko et al. (2009) also reported anaerobic digestion of starch potato processing by-products such as potato pulp, potato peel pulp and potato fruit water in batch assays.

High-rate anaerobic treatment system, such as up-flow anaerobic sludge blanket (UASB) reactor is the most popular system used for the treatment of industrial wastewaters (Gomec, 2010; Sevilla-Espinosa et al., 2010). The expanded granular sludge bed (EGSB) reactor has been developed later, in order to improve sludge/wastewater contact and to reduce dead space in the reactor (de Man et al., 1988; van der Last and Lettinga, 1991). The EGSB is a modified version of UASB operated at high superficial up-flow velocities, which can be achieved by applying a higher height/diameter ratio for the reactor and by applying effluent recirculation (O'Reilly and Colleran, 2005). The EGSB reactors are now gaining more attention than UASB applications due to the EGSB's higher loading rates favored by the hydrodynamics (Puñal et al., 2003). UASB and EGSB systems have been applied to a wide range of wastewaters strength. The treatment of diluted wastewater with chemical oxygen demand (COD) below 2 g/L has also been reported (Jeison and Chamy, 1999; Rajesh et al., 1999). According to Boulenger et al. (1999), a full scale anaerobic treatment plant including a 400 m^3 combined pre-acidification tank and a 990 m^3, UASB reactor could be operated with good process performance, with raw wastewater with a COD concentration of 9–16 gCOD/L. Wastewaters with COD concentrations higher than 20 gCOD/L are considered to be high strength wastewaters (Jeganathan et al., 2007). Previous investigations have found that influent concentrations lower than approx. 17 gCOD/L were required for successful operation of UASB reactors (Cao et al., 1992; Gao 2010). At higher strength of wastewater, other reactor configuration such as a hybrid PBR-UASB might be necessary (Jeganathan et al., 2007). Several recent studies have focused on understanding the process

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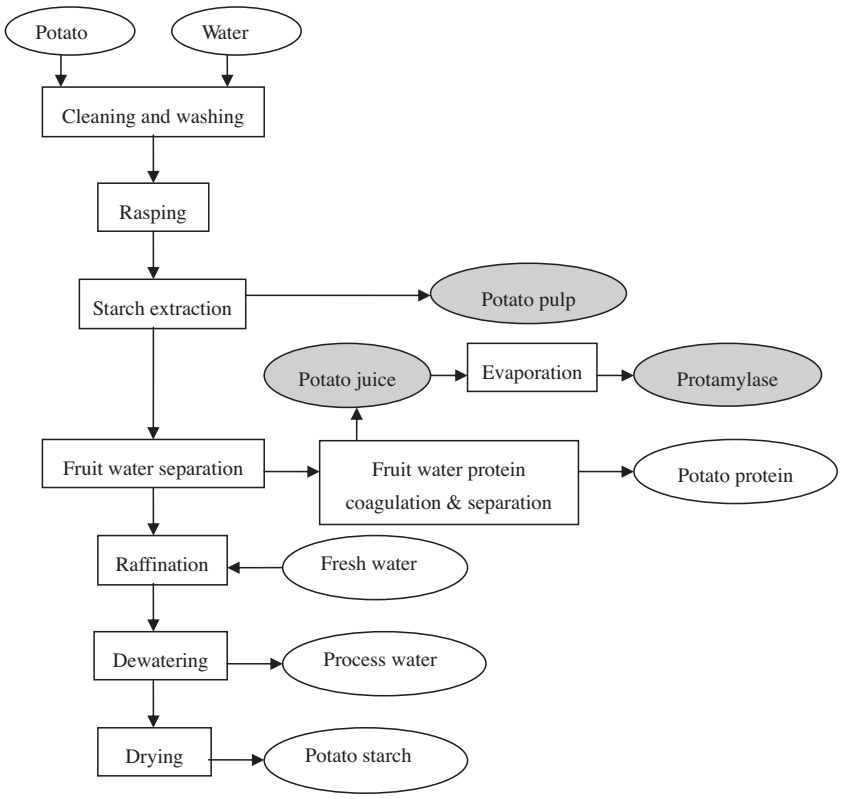

Fig. 1. Schematic presentation of the process steps of the potato startch processing industry. ⬭: compounds; ▭: processes; ⬬: by-products relevant for bioenergy production.

dynamics and granules behaviours inside the high rate reactor. Barampouti et al. (2005a,b) proposed a dynamic model for simulation of different process parameters such as VFA/bicarbonate alkalinity and biogas production of an UASB reactor treating potato processing wastewater. Liu et al. (2006) investigated the settling velocity model for anaerobic sludge granules and suggested that the granules settling process is in the intermediate flow regime rather than laminar flow. Although several studies on either UASB or EGSB reactors have been reported, there is still need for comparative studies of the two reactor types.

In the present study, anaerobic digestion of the potato-starch processing by-product, potato-juice from Karup Kartoffelmelfabrik, Denmark was tested for biogas production. Biogas potential of potato-juice was determined in batch experiment. Moreover, treatment of the potato-juice was tested in lab-scale UASB and EGSB reactors for biogas production. After anaerobic digestion, the effluent from the reactors will be up-concentrated by vacuum evaporation and then used as fertilizer. Therefore, this study also investigated the optimal method to prevent ammonia loss during evaporation, in order to provide high quality fertilizers.

Table 1
Characteristics of potato-juice.

Component	Units	Potato-juice
Total solids	% w/w	3.3
Volatile solids	% w/w	2.2
Total COD	g/L	25.2
Soluble COD	g/L	21.8
Total sugar	g/L	8.9
Lipid	g/L	0.15
Ammonium-N	g-N/L	0.3
Total-N	g-N/L	1.45
Protein	g/L	7.2
Total VFA	mM	3.34
Ethanol	mM	1.63
Lactate	g/L	0.21
Nitrate	g/L	0.22
Sulfate	g/L	0.61
Chloride	g/L	0.68
Calcium	g/L	0.017
Potassium	g/L	3.37
Sodium	g/L	0.14

2. Methods

2.1. Waste characteristics

Potato-juice was obtained from a potato-starch processing factory (Karup Kartoffelmelfabrik, Denmark). The substrate was stored at −18 °C right after arrival. The frozen substrate was thawed at 4 °C for 2–3 days before use.

Chemical composition of potato-juice is presented in Table 1. The potato-juice contains mainly carbohydrates and proteins, which are suitable for biogas production. The ion concentrations were all low, indicating low potential for ion inhibition. In order to counteract the negative effect of the high influent concentration in the potato-juice, the organic loading rate needs to be kept low.

2.2. Methane potential of potato-juice

A batch assay was set up to determine methane potential from potato-juice at different concentrations. The methane potential is defined as the ultimate specific methane production from a waste at "indefinite" time of digestion at optimal conditions, i.e. with supplement of active inoculum, supplement of necessary nutrients (Angelidaki et al., 2011). As the methane production rates are not important for this assay, it can be performed by either mesophilic