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Anaerobic co-digestion between canned sardine wastewater and glycerol waste for biogas production: Effect of different operating processes

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Abstract

The effect of glycerol waste (GW) concentration was studied in anaerobic co-digestion with canned sardine wastewater (CSW), has been examined using the 1-stage mesophilic (P1), 1-stage thermophilic (P2) and 2-stage mesophilic (P3) process. P3 process was the best process, could improve the biogas production (bio-hythane) in the case of canned sardine industry. Anaerobic batch co-digestion between 4%GW (v/v) and CSW in P3 had the maximum yield of hydrogen and methane. The hydrogen and methane yield were 43.00 ml H_2/g COD_r and 303.69 ml CH_4/g COD_r, respectively. Total hydrogen and methane production increased 648.57 and 7.75 fold compared with the single-digestion of CSW at 5 and 45 days of fermentation. The total energy yield in bio-hythane formation was 8.07 MJ/kg COD with consisting 43.11% CH_4, 21.45%H_2 and 35.43% CO_2. Using GW as co-substrate was the synergism for increasing the potential to produce hydrogen and methane (bio-hythane) in CSW.

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1. Introduction

Canned sardine industry is the main industry to create the benefit of Thailand. The process of canned sardine must use plenty of water, resulting the high wastewater about 14-20 m^3/ton of material [1]. The chemical composition of canned sardine wastewater (CSW) contain 100-3,000 mg/l of BOD, 1,000-18,000 mg/l of COD and 80-1,000 mg/l of nitrogen [2]. The type of CSW is wastewater protein, which is decomposed into ammonia nitrogen fast and many in the AD. Such compounds have a direct effect on inhibiting the activity of methanogen if it is too concentration, resulting the efficiency in the production of biogas and effluent treatment reduced [3]. Generally, total ammonia nitrogen (TAN), i.e. ammonium ion (NH_4^+); AI + free ammonia nitrogen (NH_3); FAN, is agreed as an inhibitor in the AD from the breakdown of proteins available in the substrate [4]. So, adjust the C/N ratio of the substrate using co-digestion strategy can reduce the concentration of TAN. Yenigum and Demirel [4] reported that the optimal C: N ratio between 25 – 35 due to low and stable TAN and FAN but if the C: N ratio lower 15 resulted in the higher TAN and FAN in the AD process, which the optimization of C:N ratio resulted in a stable co-digestion process. From such limitations, the biogas is produced a small amount is not worth the investment for construction of anaerobic treatment systems. So, this system has been less popular in the canned sardine industry.

Glycerol waste (GW) or crude glycerol is the waste from biodiesel production. Generally, for every 100 kg of biodiesel production generated the GW about 10 kg. The composition of GW contains 50-60% of glycerol, 12-16% of alkalis, 15-18% of methyl esters, 8-12% of methanol and 2-3% of water [5]. Glycerol is used in the pure form in many industries such as cosmetic, food and pharmaceutical etc. GW is used less as comparing with pure glycerol because the purification process of GW is too expensive. So, the AD is an alternative way for using GW in the present because GW is inexpensive, easy to implement and good carbon source for fermentation in biogas production [6]. Rivero et al. [5] reported that the high C of GW increases the C: N ratio in the mixture, reduces the inhibitors of the process though an excess of N and enhances the methane production about 50-200% in the AD process. From the advantage of such, GW interesting can use as co-substrate in the co-digestion process for solving in the case of the substrate is high nitrogen for increasing biogas production. Anaerobic co-digestion between animal manure and 3-6% glycerin could produce 570-680 lCH_4/gVS, which was equal to a threefold enhancement over manure alone [7].

Presently, AD can operate the many methods such as 1-stage mesophilic AD, 1-stage thermophilic AD, 2-stage mesophilic AD and 2-stage thermophilic AD etc., which each process has its advantages and disadvantages of different. Mesophillic and thermophilic AD is operated the process temperature ranging 30-40 ^oC and 45-65 ^oC [4]. Yenigum and Demirel, [4] reported that the advantages of thermophilic process comparing to mesophilic process for including higher rates of digestion, higher rates of methane production, faster solid-liquid separation and minimization of bacteria and viral pathogen accumulation. Disadvantage of the thermophilic process is to work at high temperatures cause higher cost for heating [8]. For 2-stage AD, the first stage is called acidogenic stage, which produces volatile fatty acids (VFAs) after that solubilized effluent from acidogenic stage is fed into the second stage (methanogenic stage) for methane and carbon dioxide production [9]. The advantage of 2-stage AD comparing with 1-stage AD is increasing the net energy balance, higher organic loading rates, enhancing the specific activity of methanogens, increasing methane production rate and increasing overall COD and VS reduction efficiencies [10]. Akyol et al. [9] reported that researchers generally accept that AD systems operating in 2-stage configuration are preferable to conventional 1-stage systems in terms of methane production and digestion stability.

The aim of this study is to evaluate the potential of biogas production from batch anaerobic co-digestion mixed CSW and GW by comparison to the effect of different process in operation, which is 1-stage mesophilic, 1-stage thermophilic and 2-stage mesophilic process by using mixed anaerobic microflora, comparing the differences of GW concentration in the mixed substrate to biogas production and using co-digestion strategy to develop the biogas system of canned sardine industry.