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Anaerobic Digestion of Starch Wastewater: the Effect of pH and Oxidation Reduction Potential on the Reactor Performance

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A B S T R A C T

Anaerobic digestion (AD) of starch wastewater for biogas production has been widely installed in Thailand for a decade. Unfortunately, this specific waste stream contains low alkalinity (Alk) and high volatile fatty acids (VFAs) which could easily lead to system instability. The appropriate monitoring indicators could help to decrease chance of reactor failure. The aim of this study is to investigate the performance of the AD system and the effect of operating parameters i.e. oxidation-reduction potential (ORP) and pH on the system in a continuous stirred tank reactor operated in semi-continuous mode at organic loading rate (OLR) of 1.0 kg COD/m3.day. The temperature was controlled at a mesophilic condition (35±2°C) for the whole experiment. The results showed that the average ORP and pH were -400 ±50 mV and 7.0 ± 0.2, respectively. The average biogas and methane yields were 0.901±0.128 NL/g VS added and 0.528±0.076 NL/g VS added, respectively. The methane composition was 58.43±4.76 %. The total COD and filtrated COD removal efficiencies were 94.75±1.42% and 97.88±0.53%, respectively. It could be concluded that at the low OLR (i.e. 1.0 kg COD/m3.day), pH and ORP was stable and fell within the recommended range for AD and indicated the stability of the system.

1. INTRODUCTION

Biogas generated by the AD processing digestion of animal waste, agricultural residuals waste, and household's kitchen waste, can be replaced natural gas efficiently. Organic compounds converted into gas, usually methane, and carbon dioxide can valorize energetically. The number biogas from anaerobic digestion (AD) systems has increased rapidly because of various factors including financial incentives for renewable energy facilities, governmental policies on climate change, landfill, and increasing of energy consumption [1]. Biogas is a modern form of bioenergy that can be produced through anaerobic digestion or fermentation of a variety of biomass sources. Anaerobic Digestion (AD) defined as the biological process, where the organic components metabolized in a non-oxygen-requiring environment [2]. AD plays an important role not only in the management of pollution, but it also has many advantages in producing energy efficiently. The process of biogas formation is a result of linked process steps, in which the initial material is continuously broken down into smaller units [3]. Specific groups of micro-organisms are involved in each individual step [4]. The AD process has four main process steps: hydrolysis, acidogenesis, acetogenesis, and methanogenesis [5] AD often affected by changes in its environmental conditions. These factors include pH, oxidation reduction potential (ORP), nutrients and trace metals, toxicity and inhibition. Therefore, the success of the AD reactors must be carefully monitoring on those factors, which are essential for the goodness of microorganism involved in the process [6]. The effects of these environmental factors can generally make us able to evaluate the effective amounts of biogas product.

Thailand is the leading country with agriculture produce to the world. Cassava is the second significant produce after rice which is leading Thai economic become stronger. Thailand also was ranked as the world's largest cassava products exporter with annual production of 33 million tons in 2016 or around 67% of the global market [7]. Starch wastewater from the starch products have many nutrients such as nitrogen, carbon, potassium, phosphorus, zinc, manganese, calcium, magnesium, sulphur, copper, iron and sodium [8]. The use of agroindustry residues in biotechnological processes has been indicated as an approach to reduce the volume of waste released directly into the environment or involving high costs for effluent treatment [9]. AD of starch wastewater is very sensitive for renewable energy in Thailand. Nowadays, many researchers will focus on the production of biogas which using different condition and substrate. This study will be using starch wastewater from flour manufacturer factory for digestible feedstock to producing biogas in using semi-completely stirred tank reactor. The objective of this research is

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to observe the effect of pH and ORP on the anaerobic digestion of starch wastewater.

2. MATERIALS AND METHODS

2.1 Starch Wastewater Characteristic

The study was conducted at the Energy Research and Development Institute – Nakornping laboratory, which used starch wastewater from a flour manufacturer located in Khampengpet Province, Thailand. Starch wastewater sample were stored at 4°C before each use. Characteristic of starch wastewater are shown in Table 1.

Table 1. Characteristics of starch wastewater sample

Parameter	value
pH	3.87±0.09
COD total (mg/L)	50293±5766
COD filtrate (mg/L)	20308±2159

2.2 Inoculum

Inoculum was collected from the commercial anaerobic digester treating cow manure in Lamphun, Thailand.

2.3 Continuous stirred tank reactor (CSTR)

The lab-scale CSTR was made of from stainless steel class 304. The total volume of reactor was 9 L with the effective volume of volume 7 L. The temperature was controlled at 35±2°C. The pH and ORP of the system were monitored continuously using a pH and ORP meter. The gas pipe was connected at the top of reactor. The gas bag was use for biogas collection. The diagram of lab-scale CSTR was presented in figure 1.

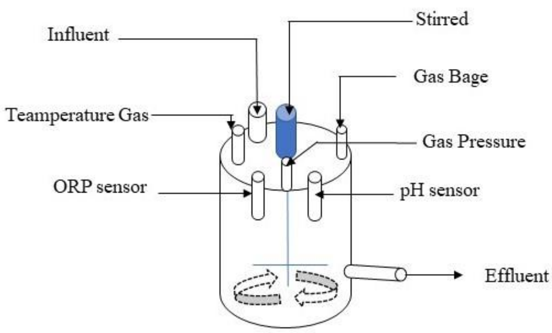

Figure 1. Diagram of lab-scale CSTR

2.4 Reactor operation

The lab-scale CSTR reactor was seeded using 2L of inoculum and 5L of water. The start-up period was 21 days. The organic loading rates (OLR) at start- up period was started at 0.5 kg COD/m3.day for one week. After that, gradually increasing of OLR was about 25% until OLR was 1.0 kg COD/m3.day. Before sampling the samples from the reactor, the agitator was stopped about 30 minutes, for stabilization and preventing sludges wash out.

2.5 Analytical Method

The efficiency of lab scale CSTR was investigated at OLR 1 kg COD/m^3.day. The influent and effluent were analysed for pH, Total COD (TCOD), Filtered COD (FCOD), Alk, TS, VS, SS, VSS, TKN and TP, following the Standard Methods (APHA, 2012), while VFA of the effluent were determined using direct titration method. The biogas composition was analysed using a portable gas analyser.

3. RESULT AND DISCUSSION

3.1 Efficiency of lab scale CSTR

Chemical oxygen demand (COD) is defined as the amount of a specific oxidation which reacts with the sample under controlled condition and can represent organic matters in a substrate. COD total removal is an important indicator of biomass transformation into methane by microorganisms. Organic materials (COD) of substrates will be converted into biogas by activities of bacteria [4]. The TCOD, FCOD, VS removal were 94.75±1.42%, 97.88±0.53% and 90.94±3.29%, respectively (Figure 2). These results were similarly with [4] which the efficiency of the reactor in terms of COD removal ranged from 89.12 to 93.20% at OLR 1.1 kg COD/m^3.day.

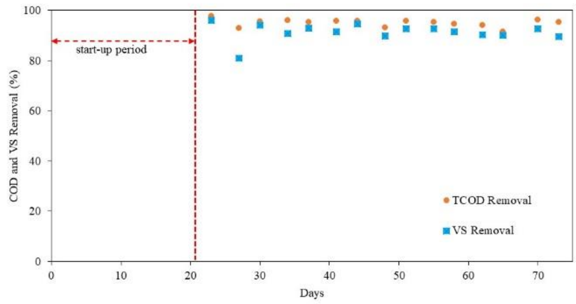

Figure 2. The percentage of COD and VS removal

3.2 Methane yield

At the OLR was 1 kg COD/m3.day, the volume of biogas and methane production volume were 4.72±0.85, 2.78±0.59 L/d, respectively, when the methane content was 58.4±4.8%. As the result of the experiment, the biogas production and yield from first started up were low during the first 21 days (start-up period) until the OLR was increased (Figure 3). The average biogas and methane yield of starch wastewater were 0.901±0.128 and 0.528±0.076 NL/g VS added, respectively. Ref. [4] reported the average methane production from wastewater of factory producing potato chips, maize chips and other snack using mesophilic anaerobic treatments at OLR 1.1 kg COD/m^3.day of 0.394 m^3 CH_4/kg COD removed. The result from this study was slightly higher (0.463 m^3 CH_4/kg COD removed) than that from the mentioned research.

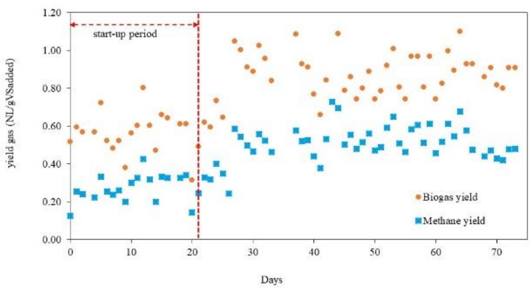

Figure 3. Yield gas production of starch wastewater.

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3.3 Correlation between VFA and ORP

The average VFA and Alk of the effluent were 200±69 and 3908±342 mg/L, respectively. The VFA and Alk and ratio were in the recommended range (VFA/Alk < 0.3) for biogas production [10]. In this study, the maximum VFA/Alk ratios were 0.05 which represented the good performance of the anaerobic process. The ORP value was slightly low (-380 mV) at the start up period, then it was stable throughout of this study (-400 ± 50 mV, figure 4). The study of [11] showed that the suitable ORP was ranged -340 mV to -355 mV for biogas production form food waste and leachate. In addition, Ref. [12] shown that suitable ORP for biogas production from the thermal pretreatment of the municipal sludge by using CSTR was in the range of −600 mV to −580 mV. So, it could be concluded that the appropriate ORP for AD process was strongly depended on type of substrate.

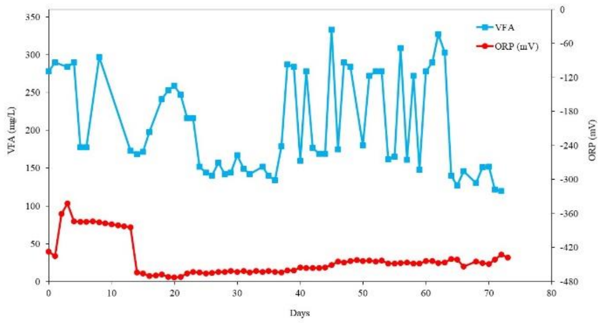

Figure 4. Relationship between ORP and VFA.

4. CONCLUSION

It can be concluded that this process should be flowing by the performance of CSTR for biogas production form starch wastewater is highly effective, which allows us to obtain the total COD and filtrated COD removal efficiencies were 94.75±1.42% and 97.88±0.53%, respectively. The performance of CSTR was higher, yield methane production was 0.528±0.076 NL/g VS added. So, at the OLR (1 kg COD/m^3.day), pH and ORP was stable and fell within the recommended range for AD and indicated the stability of the system. Thus, these parameters could be applied to indirectly indicate the reactor performance.

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