Biogas Production from Ruzi grass in the Continuous Stirred Tank Reactor (CSTR)

N. Bussabong[1], A. Watcharenwong[2], and S. Dararat[3]

Abstract**—** The aim of this study was to investigated the biogas production from Ruzi grass (*Brachiaria ruziziensis*). In the laboratory-scale experimental work, process performance and biogas production was investigated in batch reactor and semi-continuously stirred tank reactor (CSTR). The both reactors ware operated with a total hydraulic retention time (HRT) of 15 days, and an organic loading rate (OLR) of 1.4 g VSd^{-1}, constantly throughout the experiment. The performance of the biogas production of Ruzi grass as the mono-substrate had value of 244 ml d^{-1}. The characteristic of the anaerobic digestion reaction was investigated by following parameters; pH, Alkalinity, volatile fatty acids (VFA), and soluble chemical oxygen demand (SCOD).

Keywords**—** Biogas production, CSTR**,** Ruzi grass, Energy crop

I. Introduction

GLOBAL energy demand has been increased over the year due to an increasing of the world population. The majority energy in the world comes from non-renewable resources. This energy has been taken from fossil fuels. Thai government and ministry of energy have been planning to use renewable energy in order to reduce the import of energy. Many developing has to be conceptual to find the alternative energy, and many of research has to find the suitable resourced to produce an alternative energy such as solar energy, geo thermal, hydropower, wind energy, ocean energy, bio-energy [1].

Biomass, a renewable energy source, biological conversion of biomass (energy crops, agricultural wastes) and various organic wastes (organic fraction of the municipal solid wastes-OFMSW) have great potential for continuous production of biogas in order to reduce carbon dioxide (CO_2) emissions and protect the environment [2]. Previously, Biogas production has been by-product of sewage sludge treatment. However, biogas has become a well-established energy resource, especially through the use of crop residues or crops. Biogas produced through anaerobic digestion of organic materials provides a clean and versatile carrier of renewable energy, as methane can be used in replacement for fossil fuels in both heat and power generation and as a vehicle fuel [3]. Therefore anaerobic digestion to produce a combustible, clean, healthy and economic gas is one of the alternative options, for changing the pattern of crop residues utilization [4], [5]. Thailand has high potential of sources of biomass. Thailand is an agricultural area suitable for growing of many plants, especially annual crops that can be used as an energy crop or raw material of agricultural biogas plant.

Fresh crops can be used as substrate in reactor designs, but precautions have to be taken when fibrous crop material is used, can be block pumps or pipes of the reactor. Therefore, this study was set to prevent blocking of feed tubes by reducing particle size in pre-treatment batch reactor before feed into semi- CSTR reactor.

II. Materials and Methods

A. Substrate

Ruzi grass (*Brachiaria ruziziensis*) was used as the mono-substrate. Ruzi grass was obtained from a farm of Suranaree University of Technology in Nakhon Ratchasima, Thailand. Fresh Ruzi grass was prepared by chopped into pieces, then crushed into small pieces using blender. The substrate was stored at 4°C until further use.

B. Inoculum and Nutrient supplementation

The inoculum used in the experiment, was also obtained from wastewater treatment plant in SermSuk Public Co., Ltd., Thailand. Nutrient addition is a prerequisite in the biogas production of Ruzi grass. The composition of the nutrient-supplemented was as follows: $(NH_4)_2SO_4$: 132 mgL^{-1}, $NaH_2PO_4.H_2O$: 75.5 mgL^{-1}, Yeast extract: 10 mgL^{-1}, $CaCl_2.3H_2O$: 50 mgL^{-1}, $MgSO_4.7H_2O$: 90 mgL^{-1}, Nutrient solution: 0.3 mgL^{-1}, $FeCl_3.H_2O$: 1.5 mgL^{-1}, H_3BO_3: 0.15 mgL^{-1}, $CuSO_4.5H_2O$: 0.03 mgL^{-1}, KI: 0.18 mgL^{-1}, $MnCl_2.4H_2O$: 0.12 mgL^{-1}, $ZnSO_4.7H_2O$: 0.12 mgL^{-1}, EDTA: 0.15 mgL^{-1}, $CoCl_2.6H_2O$: 10.9 mgL^{-1}, $Na_2MoO_4.2H_2O$: 0.06 mgL^{-1}[6]. This content all the necessary macro and micro nutrient was required for optimum anaerobic microbial growth. The nutrient was stored at 4°C until further use.

N. Bussabong is student at the School of Environmental Engineering, Institute of Engineering, Suranaree University of Technology, Nakhon Ratchasima, 30000, Thailand. (e-mail : narimon.b@gmail.com).

A. Watcharenwong is lecturer at the School of Environmental Engineering, Institute of Engineering, Suranaree University of Technology, Nakhon Ratchasima, 30000, Thailand. (corresponding author's phone: +6644224537 ; fax: +6644224606; e-mail: w.apichon@sut.ac.th).

S. Dararat is researcher at the Department of Environmental Technology and Resources, Thailand Institute of Scientific and Technological Research (TISTR), Pathumthani,12120, Thailand. (e-mail: somchi2002@yahoo.com).

C. Reactors Setup and Operation

Experiment setup had two CSTR reactors. The first reactor was pre-treatment of substrate to improve degradability of recalcitrant materials by a process called batch reactor, reactor had volume of 1.6 L operated with a liquid working volume of 1.3 L. The second reactor was CSTR reactor had volume of 3.1 L operated with a liquid working volume of 2.9 L. The both reactors were built from acrylic plastic cylinders. The bottom plate supported the paddle mechanical mixer, mixer motor. The top plate supported feed tube and biogas tube. The side of the reactor had cylinder supported the sampling port. The both reactors were stirred using the paddle mechanical mixers operated with 60/30 minute on/off by timer. First, inoculum and nutrient were fed into batch-reactor operated with a HRT of 3 days combined with CSTR reactor operated with HRT of 12 days, had total HRT of 15 days. The both reactors were filled with inoculum and nutrient up to 30% of the total volume of each reactor and were run for approximately 2 months, until steady state was achieved. Then, slurry substrate (Ruzi grass) was fed into batch reactor which operated with an organic loading rate (OLR) of 1.4 g VSd^{-1} with nutrient fed. Effluent of batch reactor was semi-continuously fed at a rate of 510 mL every 3 days into the CSTR reactor by pumping. Sodium bicarbonate ($NaHCO_3$) was added as buffering agents to provide alkalinity and to keep mixture pH stable. The biogas production was recorded daily and measured by water displacement systems connected to the headspace of the effluent vessels. The biogas production was monitored throughout the 90 day.

D. Analytical Methods

The initially characteristics of Ruzi grass was determined; Total Solids (TS) and Volatile Solids (VS). The following operation parameters were monitored; alkalinity, volatile fatty acids (VFA), soluble COD (SCOD) and pH which was carried out according to the standard methods [7]. Daily gas production was measured by water displacement method [8].

III. Results and Discussion

The characteristics of Ruzi grass was summarized in Table I. Ruzi grass had ratio of VS/TS around 0.89 which mean lots of biogas production.

TABLE I
CHEMICAL CHARACTERISTICS OF RUZI GRASS USED AS MONO-SUBSTRATES

Parameter	Unit	Value
pH		7.2
Total Solids (TS)	% ww	24.06
Volatile Solids (VS)	% ww	21.47
VS/TS ratio		0.89

Operation parameters within 90 days operated of the anaerobic digestion in the CSTR reactor were investigated. The performance of the biogas digester in terms of alkalinity was shown in Fig. 1 (a) The Alkalinity in batch reactor operation ranged between 2,100 and 5,000 mgL^{-1}, with an average value of 3,406 mgL^{-1} and in CSTR reactor ranged between 2,175 and 4,362 mgL^{-1}, with an average value of 3,556 mgL^{-1}. Alkalinity during the batch reactor operated between days 21-39 had a very high variation. However, this amount of buffering capacity should enough for preventing pH drop due to increasing amount of VFA in the system. [9].

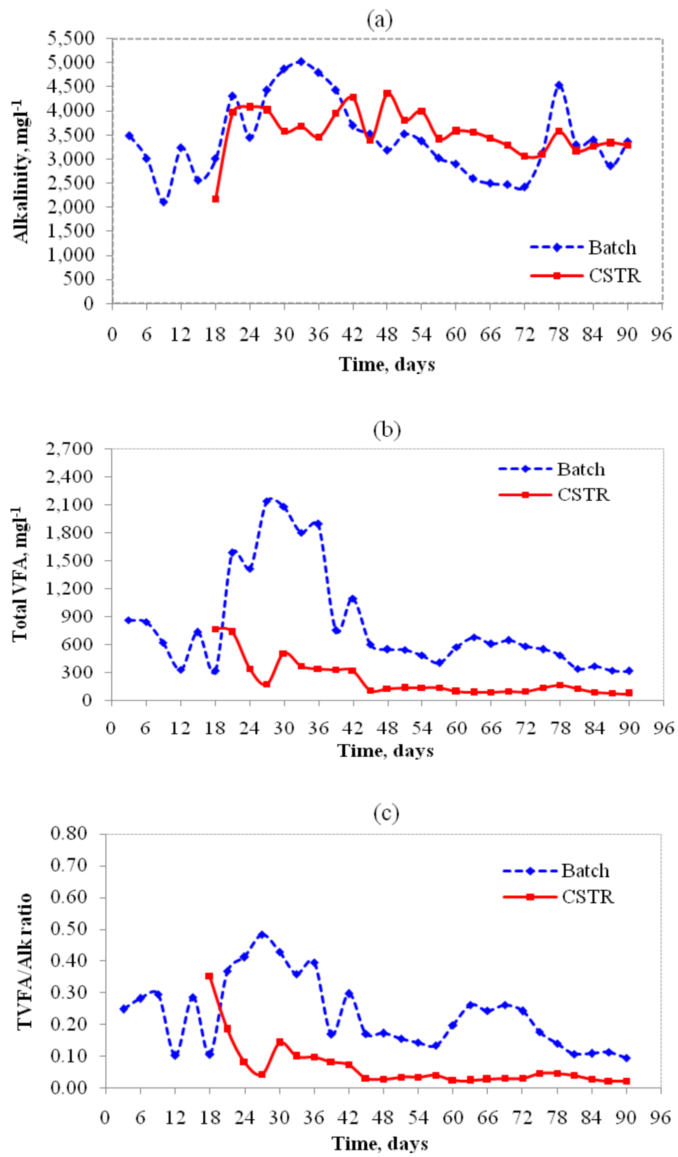

Fig. 1 Operating condition within 90 days; (a) Alkalinity, (b) TVFA and (c)TVFA/Alkalinity ratio

Form Fig. 1 (b), the concentration of volatile fatty acids in batch reactor ranged between 315 and 2,137 mgL^{-1}, with an average value of 816 mgL^{-1}. In CSTR reactor, concentration of volatile fatty acids ranged between 72 and 768 mgL^{-1}, with an average of 225 mgL^{-1}. The VFA in the batch reactor operation between days 21-42 had a very high variation. The concentration of VFA was high in batch reactor but lower in the CSTR reactor because VFA produced from fresh substrate in the batch reactor.

Form Fig. 1 (c) TVFA/Alkalinity ratio in batch reactor ranged between 0.09 and 0.48 mg/L, with an average value of 0.23. TVFA/ Alkalinity ratio in CSTR ranged between 0.02 and 0.35 mg/L, with an average value of 0.07. The ratio of volatile fatty acids to alkalinity followed the same trend as the VFAs, with values of less than 0.4 indicating a safe and a stable digestion process as well [9]. $NaHCO_3$ seemed to function better to provide the adequate buffering capacity and keep the reactor pH stable.

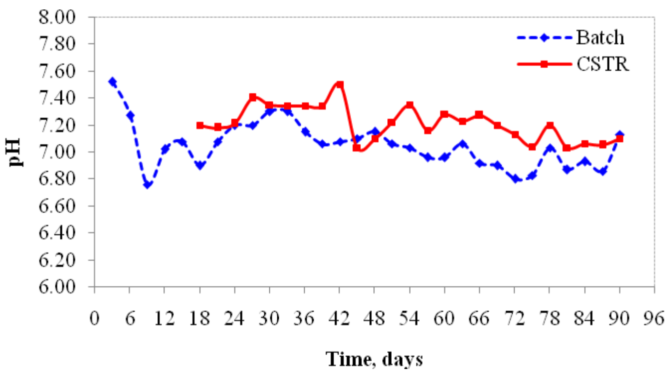

Fig. 2 pH in each reactor during anaerobic digestion process

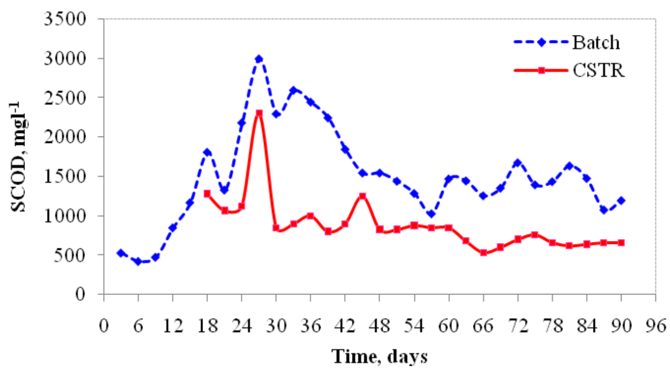

Fig. 3 SCOD in each reactor during anaerobic digestion process

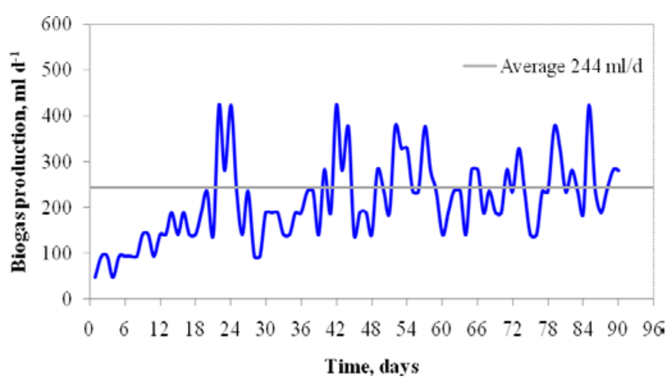

Fig. 4 Total biogas production from Ruzi grass during anaerobic digestion process

Fig. 2 pH in batch reactor ranged between 6.76 and 7.52 with an average value of 7.05. pH in CSTR reactor ranged between 7.03 and 7.50 with an average value of 7.21. CSTR reactor had slightly higher pH than batch reactor. In this experimental work, pH was manually measured and adjusted by $NaHCO_3$ in order to hold pH between 6.8 - 7.2 which suitable for methanogenic bacteria [10].

The alkalinity, VFA concentration, and pH were very important in digester operation. The pH was the key indicator of operational stability [11]. The growth rate of methanogens is greatly reduced below pH 6.6, whereas an excessively alkalinity or pH can lead to disintegration of microbial granules and subsequent failure of the process [10]. Increasing the concentration of VFA might lead to a decreasing in the buffering capacity in the system [12].

Fig.3 concentration of SCOD in batch reactor ranged between 489 and 3,000 mg/L, with an average value of 1,550 mg/L. SCOD in CSTR reactor ranged between 533 and 2,300 mg/L, with an average value of 888 mg/L. This indicated that post treatment of the effluent was required.

Daily total biogas production of Ruzi grass as mono-substrate in both reactors (batch and CSTR) was given in Fig.4. The performance of biogas production ranged between 47 and 423 mLd^{-1} with an average value of 244 mLd^{-1}. Energy crops and crop residues can be digested either alone or in co-digestion with other materials, employing either wet or dry processes [13].

IV. Conclusion

The present study demonstrated the biogas production from Ruzi grass in laboratory scale reactors. Average biogas production in this system is around 244 mLd^{-1} indicated that Ruzi grass can use as a feed stock for biogas plant. However, this study was operated with a constant OLR and HRT throughout the experiment. In order to improve performance of biogas production from Ruzi grass further studies are required; for example, vary in the OLR or HRT or scale up of the experimental reactors. It was concluded that Ruzi grass as energy crop can be an alternative energy resource.

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