Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 52 (2014) 216 – 222

Energy Procedia

2013 International Conference on Alternative Energy in Developing Countries and Emerging Economies

Biogas Production from Co-digestion of *Pennisetum pururem* cv. Pakchong 1 Grass and Layer Chicken Manure Using Completely Stirred Tank

W. Wilawan[a], P. Pholchan[b], and P. Aggarangsi[a]*

[a]*Department of Mechanical Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai, 50200, Thailand*

[b]*Department of Environmental Engineering, Faculty of Engineering, Chiang Mai University , Chiang Mai, 50200, Thailand*

Abstract

In this research, the production of biogas from co-digestion of *Pennisetum purpureum* cv. Pakchong1 grass and layer chicken manure using completely stirred tank was investigated. The experiment was defined to examine effect of the change in carbon to nitrogen (C/N) ratios and the organic loading rates (OLRs) on biogas production and system steady-state performance. Primary analyses suggested that an approximate content of grass and manure was 50 : 50 % by weight to achieve C/N ratio of 20 and 70 : 30 % by weight for C/N ratio of 30 respectively. The experimental reactor was set to operate at a fixed total solid content of 4% with two cases of C/N ratio at four different OLRs of 1.1, 1.4, 1.7 and 2.2 kg VS/ (m^3.d). Each condition was operated for 1.5 time of reactor retention time. The result suggested that maximum steady-state methane yield of 0.27 ± 0.01 L CH_4/kg VS_{added} can be achieved at C/N ratio of 20 with OLR of 1.1 kg VS/ (m^3.d). Moreover, the results also suggested that methane yield decreased for an increase in OLR. Nonetheless, the work presented herein can provide an insight information for design and operation optimization according to economical investment analysis.

Selection and peer-review under responsibility of the Organizing Committee of 2013 AEDCEE

Keywords: *Pennisetum purpureum* cv. Pakchong1 Grass; Chicken Manure; Co-digestion, Methane Yield; Biogas

* Corresponding author. Tel.: +6-685-150-4321; fax: +6-653-942-007.
E-mail address: pruk.a@cmu.ac.th., warawut.wilawan@gmail.com

Selection and peer-review under responsibility of the Organizing Committee of 2013 AEDCEE
doi:10.1016/j.egypro.2014.07.072

1. Introduction

Recently, the supplementary energy have been widely studied and developed due to increasing of energy requirements [1, 2].Biogas as an energy source is one of the most important renewable energy developments due to its renewable character and a net carbon neutral energy conversion.

Pennisetum purpureum or elephant grass is one of the most popular used materials for biogas production. Elephant grass requires very little additional nutrients for growth, is easily grown and can be harvested up to four times a year, making this plant one of the most prospective crops for energy use [3, 4]. However, it has been suggested that the nitrogen and VFA:alkalinity ratio of *Pennisetum purpureum* can be low and this is one reason why it has generally been used in co-digestions with other wastes [5]. Chicken manure is one of the most promising feedstocks for biogas production [6, 7]. Moreover, it has been suggested that chicken manure is best treated with other wastes because of its high content of nitrogen, phosphorus and potassium [8, 9]. Therefore, co-digesting *Pennisetum purpureum* with chicken manure should increase the methane yield performance. However, information on the effects carbon to nitrogen (C/N) ratio and the organic loading rate (OLR) of co-digestion of *Pennisetum pururem* and chicken manure on the methane production potential and the operation stability is still lacking.

In this research, biogas production from anaerobic co-digestion of *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure was investigated using completely stirred tank reactors (CSTRs). The purpose of this research was to evaluate the effect of C/N ratios and OLRs on anaerobic co-digestion of *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure for biogas production.

2. Methods

2.1. Feed stock preparation and analysis

The *Pennisetum purpureum* cv. Pakchong1 grass having the age of 30-45 days was utilised with layer chicken manure obtained from R.P.M. Farm & Feed Company Limite, Thailand. The silage *Pennisetum purpureum* cv. Pakchong1 grass was prepared by being crushed by Disc and hammer mill before compacted in an airtight container for 15 days. The silage grass and layer chicken manure were then stored at temperature of 4°C to prevent biological decomposition. The inoculum was obtained from an anaerobic digester treating dairy manure of Chiangmai Freshmilk Company Limited, Lumphun,Thailand. The characteristics of the substrates tested in this study, including *Pennisetum purpureum* cv. Pakchong1 grass and layer chicken manure, are shown in Table 1.

Table 1. The characteristic of *Pennisetum purpureum* cv. Pakchong1 grass and layer chicken manure

Parameter	Nepier Grass	Chicken manure
TS (mg/kg)	199,943	416,680
VS (mg/kg)	182,005	305,330
C/N	43.6	7.6
Moisture (%)	73.03	64.49

2.2. Experimental set up and analysis

The co-digestion of *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure using two completely stirred tanks (named R1 and R2) operated as Anaerobic Sequencing Batch Reactor (ASBR) was examined at C/N ratios of 20 and 30 using R1 and R2, respectively. Each reactor was operated at four different OLRs, i.e. 1.1, 1.4, 1.7 and 2.2 kg VS/ (m^3.d). The studied reactors had a height of 50 cm, diameter of 30 cm and effective volume of 25 L. A feeding port was installed on the top of the reactor, while the effluent was drawn off through a port installed at the bottom. Each reactor was started up at the OLR of 0.5 kg VS/m^3-day. The OLR was then gradually increased (not higher than 25% for each change) to OLR of 1, 1.2, 1.7 and 2.2 kg VS/ (m^3.d**)**, respectively. The solid concentration of the feedstock was fixed at 4% for all experiments. The biogas production was measured by pump meter.

Statistical analys is for performance comparison was done using either the Student t-test or ANOVA.

3. Results and discussion

The influence of C/N ratios and OLRs on pH values, alkalinity (Alk) production, volatile fatty acids (VFAs) production, VFA/Alk, and methane yield were evaluated and present as following;

3.1. pH of co-digestion of Pennisetum pururem cv. Pakchong 1 grass and layer chicken manure.

pH is an important parameter influencing the performance of anaerobic digestion processes. In this work, both reactors were operated without any adjustment for pH inside the reactor. The pH profiles of co-digestion of *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure are shown in Fig. 1. The average pH of effluent from R1 and R2 were 7.08 ± 0.05 and 6.93 ± 0.03, respectively. This value showed that the reactors worked within the optimum interval (pH ≈ 6.80 – 7.20) for methane formation [10, 11].

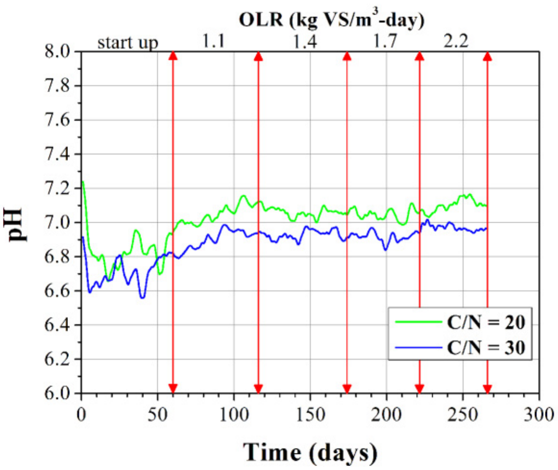

Fig. 1. The pH of co-digestion of *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure

3.2. Alkalinity (Alk) and volatile fatty acids (VFAs)

For process stability, alkalinity of anaerobic reactor should not be lower than 1500 mg/L [12]. Throughout the study (Fig. 2), the average alkalinity of effluent was higher than 3000 mg/L.

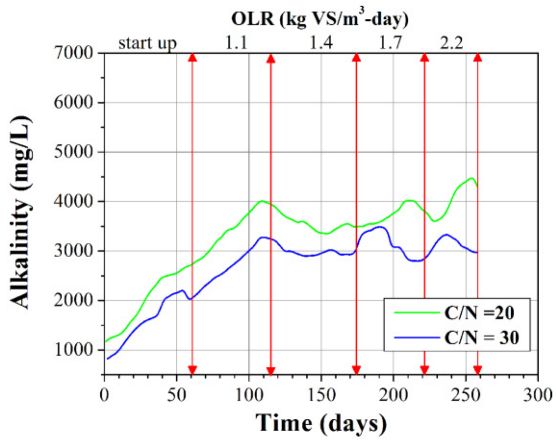

Fig. 2. Alk of co-digestion of *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure

The concentrations of total VFAs produced are shown in Fig. 3. The average VFAs concentrations of effluent from R1 and R2 were 623 ± 202 and 686 ± 190 mg/L, respectively. For anaerobic digestion to proceed normally, concentration of VFAs should be kept below 2000 mg/l. [13]. the relatively lower level of VFAs during the start up period (Fig 3) could be attributed to lower organic loading rate. Low levels of VFAs at all studied OLRs observed in this work indicated that the ASBR process was a system capable of maintaining active methanogens at low levels of VFAs for the applied feedstock.

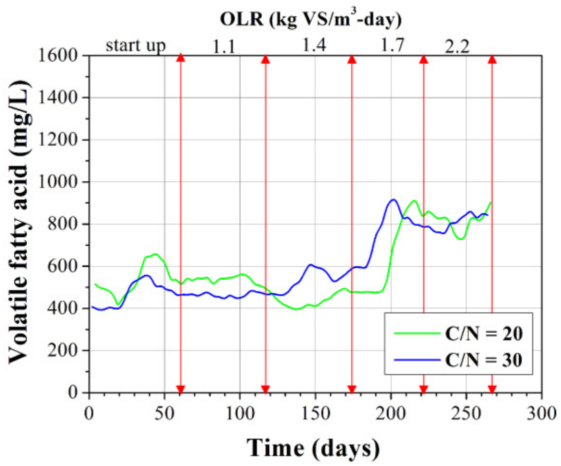

Fig. 3. VFA of co-digestion of *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure

One of the criteria for judging digester stability is the VFA:Alk ratio. When the VFA:Alk ratio is less than 0.4 anaerobic process was stable without an acidification risk. VFA:Alk ratio between 0.4-0.8 signals some instability of the microorganisms functioning inside the reactor, while VFA:Alk of more than 0.8 indicates significant instability [14, 15]. For the co-digestion of *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure, the VFA: Alk ratio did not rise beyond the critical value of 0.4 (Fig. 4) suggesting reactor stability for biogas production from the used feedstock.

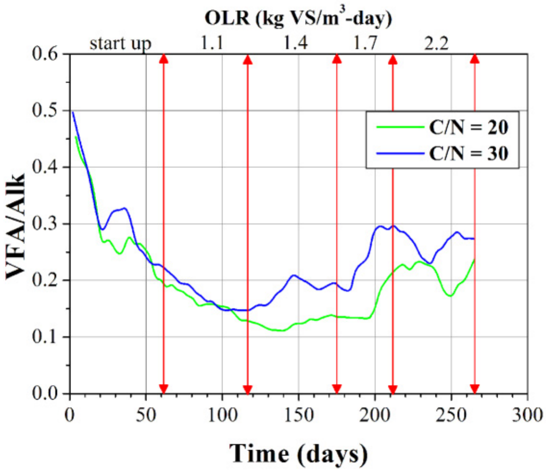

Fig. 4. VFA/Alk of co-digestion of *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure

3.3. Methane yield of co-digestion of Pennisetum pururem cv. Pakchong 1 grass and layer chicken manure

After start-up was achieved with *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure. The component ratio of *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure was 50 : 50 % by weight to achieve C/N ratio of 20 and 70 : 30% by weight for C/N ratio of 30. Both of reactors were used so that a comparison could be made between the duplicated system. The performance of the two digesters, in terms of methane yield, was very comparable (Fig. 5) As shown in Table 2, the OLRs were altered as difference proportions of co-digestate were used in the feed. The steady-state methane yield obtained in this study were 0 .27 ± 0.01, 0.22 ± 0.01, 0.21 ± 0.01 and 0.19 ± 0.02 L CH_4/kg VS_{added} and 0.23 ± 0.02, 0.19 ± 0.01, 0.15 ± 0.01 and 0.14 ± 0.01 CH_4/kg VS_{added} at C/N ratio of 30 under the OLR of 1.1, 1.4, 1.7 and 2.2 kg VS/ (m^3.d), respectively. Both of C/N ratio of 20 and 30 in methane yield at OLR of 1.1 kg VS/ (m^3.d) which were significantly higher (ANOVA, $p < 0.05$).

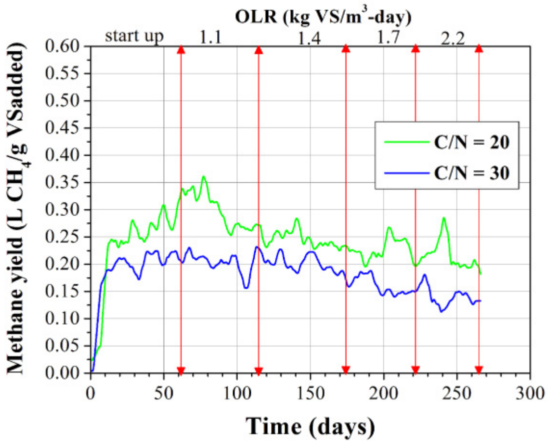

Fig. 5. Methane yield of co-digestion of *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure

Table 2. OLRs were altered as difference proportions of *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure

OLR (kgVS/m^3-day)	The steady-state methane yield ($L\ CH_4/g\ VS_{added}$)	
	C/N = 20	C/N = 30
1.1	0.27 ± 0.02	0.23 ± 0.02
1.4	0.22 ± 0.01	0.19 ± 0.01
1.7	0.21 ± 0.01	0.15 ± 0.01
2.2	0.19 ± 0.02	0.14 ± 0.01

4. Conclusion

Co-digestion of *Pennisetum pururem* cv. Pakchong 1 grass and layer chicken manure with 4% TS digestion was successful at all OLRs examined. Co-digestion was successful at all C/N ratios that were examined (20 and 30). The maximum steady-state methane yield of 0.27 ± 0.01 $L\ CH_4/kg\ VS_{added}$ can be achieved at C/N ratio of 20 with OLR of 1.1 kg VS/ (m^3.d).

Acknowledgements

The authors wish to thank the staff members at the Energy Research and Development Institute-Nakornping, for use of the research facilities which made this work possible. The Graduate School of Chiang Mai University is also acknowledged for additional financial support.

References

[1] Stijn C, Michele K, Yvonne Y. The role of bioenergy in a fully sustainable global energy system. *Biomass and Bioenergy* 2012; **41**: 21–33.

[2] Banos R, Manzano-Agugliaro F, Montoya FG, Gil C, Alcayde A, Gomez J. Optimization methods applied to renewable and sustainable energy: A review. *Renewable and Sustainable Energy Reviews* 2011; **15**:1753–1766.

[3] Strezov V, Tim J Evans, Hayman C. Thermal conversion of elephant grass (Pennisetum Purpureum Schum) to bio-gas, bio-oil and charcoal. *Bioresource technology* 2008; **99**: 8394-8399.

[4] Xin-MX, Xiang-QZ,Zhao-XD, He-RG. Dynamic changes of lignin contents of MT-1 elephant grass and its closely related cultivars. *Biomass and Bioenergy* 2011; **35**: 1732-1738.

[5] Callaghana FJ, Wasea DAJ, Thayanithya K, Forsterb CF. Continuous co-digestion of cattle slurry with fruit and vegetable wastes and chicken manure. *Biomass and Bioenergy* 2002; **27**: 71-77.

[6] Bujoczek G, Oleszkiewicz J, Sparling R, Cenkowski S. High solids anaerobic digestion of chicken manure. *J Agric Eng Res* 2000; **76**: 51–60.

[7] Abouelenien F, Nakashimada Y, Nishio N. Dry mesophilic fermentation of chicken manure for production of methane by repeated batch culture. *Journal of Bioscience and Bioengineering* 2009; **107**: 293–295.

[8] Lane AG. Anaerobic digestion of solid fruit waste supplemented with poultry manure in a horizontal plug-flow reactor. *Environ Tech Lett.*1984; **5**: 465–71.

[9] Hashimoto AG. Ammonia inhibition of methanogenesis from cattle wastes. *Agricultural Wastes* 1986; **17**: 241–61.

[10] Udeme J Ndon, Richard R. Daguewat. Effects of Temperature and Hydraulic Retention Time on Anaerobic Sequencing Batchreactor Treatment of Low Strength Waste Water. *Water Res* 1997; **31**: 2455–2466 .

[11] Wang QH, Kuninobu M, Ogawa H, Kato Y. Degradation of volatile fatty in highly efficient anaerobic digestion. *Biomass and Bioenergy* 1999; **16**: 407– 416.

[12] Webb AR, Hawkes FR. The anaerobic digestion of poultry manure: variation of gas yield with influent concentration and ammonium–nitrogen levels. *Agricultural Wastes* 1985; **14**: 135–156.

[13] Sneath. Continuous aerobic treatment of piggery slurry for odor control scaled up to a Farm-size Unit J Agr Eng Res 1992; **53**: 81–92.

[14] Switzenbaum MS, Giraldo-Gomez E, Hickey RF. Monitoringof the anaerobic methane fermentation process. *Enzyme Microb Tech* 1990; **12**: 722–730.

[15] Zickerfoose C, Hayes RBJ. Anaerobic sludge digestion:operations manual. EPA 430/9-76-001, US National Technical Information Service: SpringFeld, VA; 1976.