The Study of Organic Loading Effect from Layer Chicken Manure for Biogas Production in a Large Farm by Modified Covered Lagoon Reactor in Thailand

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Abstract

This research was studied and experimented the effect of organic loading for biogas production from layer chicken manure using the Modified Covered Lagoon Reactor (MCLR) biogas system. The MCLR biogas system consisted of a 200 m^3 raw material mixing tank, a 4,000 m^3 reactor, a 4,000 m^3 biogas balloon storage, heating unit and electrical generating station. The experiment was performed by the average of waste-water volume daily to be added into the biogas system was 562 m^3 day^{-1}. The following parameters of the waste water were measured in order to monitor and control the biogas system:1) pH, 2) Alk, 3) VFA, 4) COD, 5) SS, and 6) VS. From the experiment, it was found that the average amount of biogas production was 10,234 $m^{-3}day^{-1}$ and the average biogas production rate was 0.54 m^3 kg^{-1}COD or 0.82 m^3 $kg^{-1}VS^{-1}$. The composition of the biogas was methane (54.66%), carbon dioxide (44.47%) and hydrogen sulfide (3,774.92 ppm). In addition, this result from experiment can be calculated to the Organic Loading Rates (OLRs) for the biogas production system. The results showed that all parameters and the amount of the biogas production were rather constant for all organic loading rates ranged (from 1.0 to 5.0 kg^{-1}COD m^3 day^{-1}). Since, the biogas production rate of biogas system was decreased when the OLRs increased. The COD reduction is constant but the VS reduction is non-constant that the biogas production system was stable. The organic loading rate was increased that the VS reduction was decreased. The organic loading rate for the VS reduction was highest at 1.0 kg^{-1}COD $m^{-3}day^{-1}$. In the conclusion, the biogas production system can be operated and the organic loading rate at 1.0 kg^{-1}COD $m^{-3}day^{-1}$ caused the maximum biogas production rate of the Modified Covered Lagoon Reactor (MCLR) biogas system from layer chicken manure.

KEYWORDS: Biogas; Layer Chicken Manure; Modified Covered Lagoon

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Introduction

Recently, there are produce the biogas energy for many farms on the world. In China, the development of the industry has the potential to improve the biogas energy for rural area and sustainable energy for China [1]. Animal manure can be input for biogas production. In the Northern part of Vietnam, a survey was conducted by in-depth interviews on 54 pig farms in two Northern Vietnamese provinces, Thai Binh and Bac Giang the survey showed that biogas was produced from 43% of the total manure produced on all surveyed farms [2]. The biogas plants in Portugal are analyzed, despite the fact that the organic effluents are a relevant energy source (873 Mm^3 biogas per year; 4,889 GW-h/year). In 2007, the power from biogas generation is about 10% of the potential electrical power (229 MW) [3]. The biogas was attained from anaerobic decomposition of organic residue. The organic residues were getting from the sugar industry, alcohol industry, urban solid wastes, urban liquid wastes and livestock residues [4]. Thailand, the expansion of economic and social was increased which cause of demand for energy was increased. Thai government announced that needs to increase the alternative energy from 6.4% to 20.3% of commercial primary energy by 2022. The abundant and varieties of biomass and agricultural wastes should have potential for supply to biogas production in country which is the potential of biogas production [5]. In the large industrial farms such as cattle farms, chicken broiler farms and chicken eggs farms have a growth continued to support market increasing of consumers in the country and abroad. The biogas technology has development for swine farm in Thailand [6]. The biogas production from anaerobic digestion of chicken manure with swine manure or slaughterhouse sludge was assessed in the laboratory [7]. The biogas production from broiler chicken manure using the CSTR system that was studied [8] and measured parameters of pH, Alkalinity (Alk), Volatile Fatty Acids (VFA), Chemical Oxygen Demand (COD), Suspended Solid (SS) and Volatile Solid (VS) [9]. At present in Thailand, the large chicken eggs farms have the biogas production that many biogas plants will use the covered lagoon technology production. This technology has lowest the investment and also maintenance is easy, but disadvantage is largest area for the installation plant. It can also create a panel fin inside the digester to increase the decomposition of organic matter as well that this technology called the Modified Covered Lagoon Reactor (MCLR). Therefore, in this paper the study of the parameters for the biogas production by modified production per day, the amount of biogas production per organic loading rate, the percentage of reduction of COD, VS, and SS and the rate of chicken manure biogas per volume. The measurement of parameter values prepared wastewater (Influent), in the reactor and after leaving the system (Effluent). Also measure the amount and rate of biogas production from layer chicken manure and biogas composition. Then calculation of the amount of biogas per organic loading rate suitable for operate the biogas production plant.

Modified Covered Lagoon Biogas Production Plant

Biogas is produced by anaerobic digestion with anaerobic bacteria or fermentation of decomposable materials such as manure, sewage, municipal waste, green waste, plant material, and crops [10]. Biogas is a product composed mainly of methane (CH_4), carbon dioxide (CO_2), hydrogen sulfide (H_2S), ammonia (NH_3), Oxygen (O_2) and vapors (H_2O) [11]. Biogas have the physical and chemical properties close to natural gas which can be used to boiling water and cooking instead of LPG, used as fuel for process heating, producing electricity via internal combustion engine and used as a replacement of diesel or gasoline to drive equipment [7]. A covered lagoon digester is a large anaerobic lagoon with a long retention time and a high reduction factor. Typically, the covered lagoons are used with flush manure management systems that discharge manure at 0.5 to 2 percent solids. This type of digester is also used in the places where large quantity of liquid waste is produced [12]. The modified covered lagoon technology was create a panel fin inside the digester by building baffles channels in the digester, as shown in Fig. 1. The baffles channel will make the wastewater in a digester that is longer for retention time. The wastewater flow has movement slowly will make the degrading microorganisms are improved. covered lagoon technology from the layer chicken manure of the large farm in Thailand is evaluated. The parameters are the rate of biogas

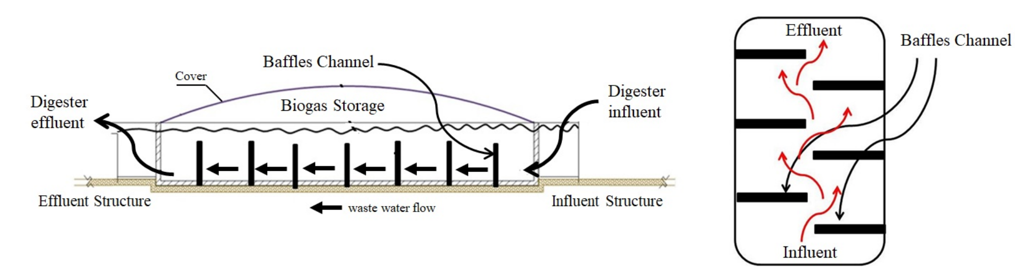

Fig. 1 Modified Covered Lagoon Reactor

Materials and Methods

Experimental Set-up

The layer chicken manure for experimental in this work was brought from a chicken farm in Khonkaen province, as shown in Fig. 2. This biogas production from layer chicken manure was studied by means of the Modified Covered Lagoon Reactor (MCLR), as shown in Fig. 2. The MCLR biogas system consists of 1) the raw material from farms, 2) the raw water, 3) mixing tank, 4) fermentation reactor or MCLR, 5) biogas storage balloon, 6) blower or biogas fan pump, 7) biogas part for heating production in fertilizers and 8) biogas part for fuel in electrical generating system. In the experiment, 12 ton-layer chicken manure/day, 200 m^3 for mixing tank, 4,000 m^3 for reactor, 500 $m^3\ hr^{-1}$ for blower and 4,000 m^3 for biogas storage balloon was used to collect the biogas from layer chicken manure and the composition of biogas were measured by Biogas analyzer.

Experimental Method

The experiment started from prepared waste-water into the MCLR biogas system. Parameters of waste-water (pH, Alk, VFA, COD, SS and VS measuring in laboratory) were measured before the waste-water was fed into the system (Influent value). Then the average amount of waste-water volume daily to be added into the biogas system was 562 $m^3\ day^{-1}$ and the raw material (layer chicken manure) was mixed with raw water at the ratio of 1:4 by volume. When, the biogas will be produced that the rate of biogas production was recorded per day from the MCLR biogas system. Then, it was measured parameters as same as waste-water influent in reactor and overflow (effluent).

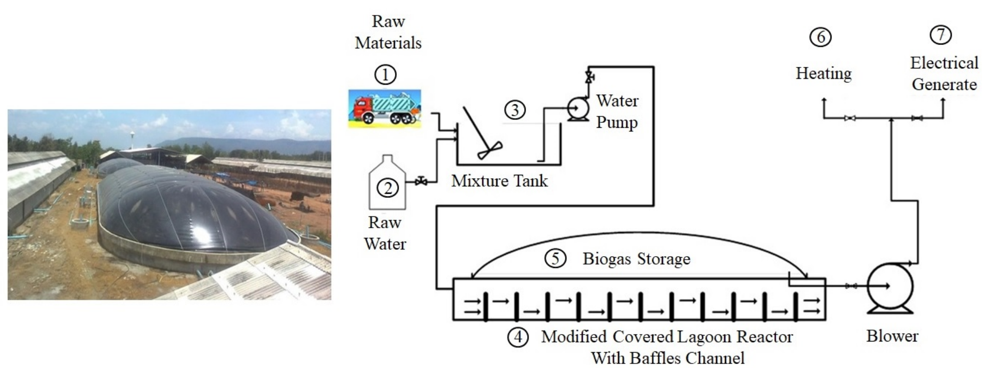

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Fig. 2 (a) The MCLR biogas production system by the layer chicken manure and (b) The MCLR biogas production system diagram with baffles channel.

Results and Discussion

Biogas Production Rate (BPR)

The main objective of this research was found the biogas production rate from layer chicken manure. The experimental was constantly added the average volume of waste-water into the biogas system. The average amount of biogas production was 10,234 $m^3\ day^{-1}$ and when calculation for the biogas production rate from organic loading rates changes were shown in Fig. 3. From the experimental showed that the amount of the biogas production daily to be constantly. It was found that organic loading rates system of 1.0 – 5.0 kg COD $m^{-3}day^{-1}$ and the biogas production rates (BPR) were decreased from 1.1 to 0.2 $m^3\ kg^{-1}$ COD day. The biogas production rate was highest at organic loading rates of 1.0 kg COD m^{-3}day as well as the average biogas production rate was 0.54 m^3kg^{-1}COD or 0.82 $m^3kg^{-1}VS^{-1}$. Comparison with the biogas production rate of the other raw materials was showed in Table 2. The biogas production rate was closed to that of the food waste and maximum value in this information. From the experiments, biogas composition can be shown that the average methane was 54.66%, the average carbon dioxide was 44.47%, and the average hydrogen sulfide was 3,774.92 ppm.

Table 1 The average of pH, Alkalinity, VFA, VFA/Alk in reactor and COD value in the system for various organic loading rates

OLRs ($kg\ m^{-3}d^{-1}$)	pH	Alk ($mg\ l^{-1}$)	VFA ($mg\ l^{-1}$)	VFA/Alk ratio	COD ($mg\ l^{-1}$)		
					Influent	Reactor	Effluent
1.08	7.92	8,666.67	1,999.83	0.23	25,866.67	6,306.67	6,426.67
1.53	7.96	7,815.91	1,509.09	0.19	27,927.27	7,957.27	8,276.36
2.04	7.91	7,786.17	1,481.65	0.19	32,821.28	8,355.11	8,741.70
2.51	7.91	7,829.89	1,655.16	0.21	37,432.61	8,161.74	9,757.83
3.00	7.93	7,672.73	1,565.15	0.20	42,784.85	9,363.94	9,822.12
3.42	7.91	7,493.75	1,531.23	0.20	43,803.57	7,817.50	8,590.00
4.02	7.85	7,361.11	1,498.56	0.20	45,422.22	9,178.89	9,344.44
4.44	7.87	6,675.00	1,406.25	0.21	52,050.00	10,950.00	9,145.00
4.99	7.89	6,458.33	1,637.50	0.25	67,266.67	10,790.00	10,673.33
Average	7.91	7,528.84	1,587.16	0.21	41,708.35	8,764.57	8,975.27

Performance Characteristics

The average pH value in the reactor was 7.91. These were found to be alkaline as a result of organic decomposition. All parameters were constant for all organic loading rates ranged. The average ratio of Alk/VFA of waste water in the reactor was 0.21 which the standard parameters of Alk/VFA for operation of biogas production in the reactor would not exceed 0.25 [7] for stability of biogas production. Also, COD value in the biogas system was very significant that was used for analyzing and causing to biogas production. In the experiment, it was found that average COD value of waste water before entering the system was 41,708.35 $mg\ l^{-1}$ and average COD value of waste water in the reactor was 8,764.57 $mg\ l^{-1}$. The average COD value of waste water over flow reactor was 8,975.27 $mg\ l^{-1}$, as shown in Table 1.

Process Efficiency

The percentage of COD and VS reduction was impact to efficiency of biogas production process. These parameters were determined the organic loading rates for indicate the efficiency of biogas system. The average percentage of COD and VS reduction were showed in Fig. 4. It was found that the percentage of COD reduction have similar values between 70–80% for all the organic loading rates. It showed that this biogas system can be removed COD constantly but the percentage of VS reduction was changed. The organic loading rate was increased that the percentage of VS reduction decreased. The organic loading rate for the percentage of VS reduction was highest (>80%) at 1.0 kg-COD $m^{-3}day^{-1}$ and then the percentage of VS reduction was dropped below 70% from 1.5 to 5.0 kg COD m^{-3} day^{-1}. It showed that the VS reduction of this experiment can eliminated the organic loading rate of 1.0 kg COD m^{-3} day. The results showed that at all organic loading rates, the change of COD reduction between waste water before entering the system and in the reactor was relatively constant. This means that the biogas production system was stable. However, at all organic loading rates from 1.0 to 5.0 kg COD $m^{-3}day^{-1}$, the biogas production system can be operated. From the Fig. 3, the result was shown that the maximum biogas production rate for the experimental at the organic loading rate of 1.0 kg COD m^{-3} day^{-1}.

Table 2 The comparison of biogas production rate from the others substrate and percentage of methane [8]

Substrate	Biogas Production Rate ($m^3kg^{-1}VS^{-1}$)	CH_4 Content (%)
Vegetable waste	0.26	64
Organic fraction of municipal solid waste	0.26	60
Municipal solid waste	0.38	64
Fruit and vegetable waste	0.47	65
Pig slurry	0.50	70
Cow slurry	0.30	55
Garden waste	0.50	N.A
Food waste	0.60	70
Fruit waste	0.50	N.A
Chicken Broiler Manure	0.35	62
Layer chicken manure (This study)	0.82	55

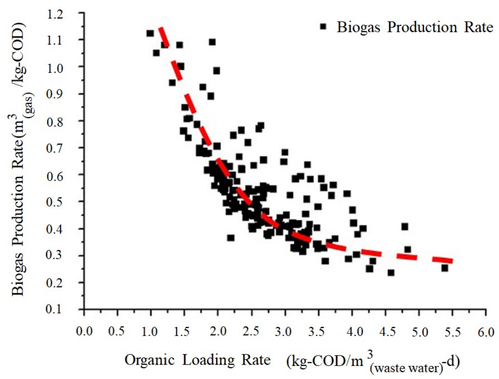

Fig. 3 The biogas production rate for various organic loading rates.

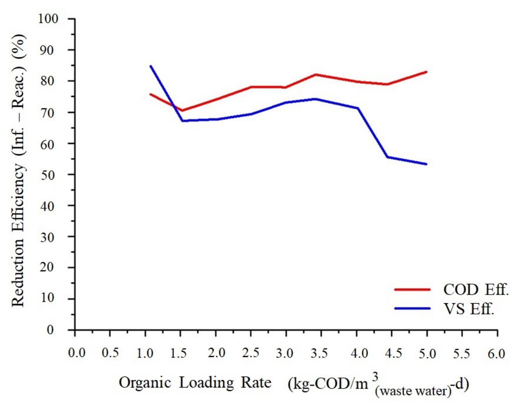

Fig. 4 COD and VS reduction for various organic loading.

Conclusion

This research was experimented of the biogas production from layer chicken manure using the Modified Covered Lagoon Reactor (MCLR) system. The experiment studied the amount of biogas production of a large farm in Thailand. The average amount of waste-water volume daily to be added into the biogas system was 562 m^3 day^{-1} and the raw material (layer chicken manure) was mixed with raw water at the ratio of 1:4 by volume. Then, the average amount of biogas production was 10,234 m^3 day^{-1} and the average biogas production rate was 0.54 m^3 $kg^{-1}COD$ or 0.82 m^3 $kg^{-1}VS^{-1}$. This biogas production rate was quite closed to the biogas production rate of the food waste. The average pH value in the reactor was 7.91. The average alkalinity and VFA value were 7,528 and 1,587 mg l^{-1} in the reactor, respectively. The average ratio of Alk/VFA in the reactor was 0.21. All parameters were rather constant for all organic loading rates ranged from 1.0 to 5.0 kg COD $m^{-3}day^{-1}$. The biogas composition was 54.66% of methane (CH_4), 44.47% of carbon dioxide (CO_2) and 3,774.92 ppm of hydrogen sulfide (H_2S). The COD reduction was constant but the VS reduction was changed. The organic loading rate was increased that the percentage of VS reduction decreased. The organic loading rate for the percentage of VS reduction was highest at 1.0 kg COD m^{-3} day^{-1}. However, the biogas production system can be operated and the organic loading rate at 1.0 kg COD m^{-3} day^{-1} which caused the maximum biogas production rate for the experiment.

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