ANAEROBIC DIGESTION OF SEWAGE SLUDGE AND CATTLE MANURE FOR BIOGAS PRODUCTION: INFLUENCE OF CO-DIGESTION

R. HASSAN

Department of Civil Engineering, Faculty of Engineering, AswanUniversity, 81542 Aswan, Egypt.
E-mail: eng_r_m@yahoo.com

ABSTRACT

The objective of this paper was to carry out the co-digestion of sewages sludge (SS) and cattle manure (CM) in a single stage fed-batch anaerobic digester for biogas production. The influence of the cattle manure as a co-substrate on the stability and efficiency of the process was determined. Batch digestion tests were carried out in one liter glass digester with an effective volume of 0.8 liter. Mesophilic fermentation under temperature equal to 35°C was conducted for sewage sludge as well as mixtures of sewage sludge and cattle manure based on total solids (TS) and (VS) proportions. Characteristics of initial wastes and digestion feed were performed using standard methods, where the measurements of methane were conducted by using gas chromatograph. The cattle manure waste turned out to be highly desirable as co-substrate for methane fermentation. It exhibited a positive influence on the total biogas production, process stability, organic matter reduction as well as biogas yield. The highest methane content in the biogas was 62% with the biogas flow of 130 ml/day.

Keywords: Co-digestion, Sewage sludge, Cattle manure, Mesophilic, Biogas

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1. INTRODUCTION

In recent years, an increased attention has been carried out to minimize the amount of excess sludge, because it represents a rising challenge for wastewater treatment plants (WWTPs) due to economic, environmental and regulatory factors (Mahvi [1]). For instance, the cost of sludge treatment and disposal has accounted up to 60% of the total operating cost in municipal wastewater treatment plants (Baghapour et al. [2]). Currently, the most widely used treatment process for the recovery of the sludge is anaerobic digestion at different temperature conditions (Rubia et al. [3]). Anaerobic digestion is a process in which microorganisms break down biodegradable materials in the absence of oxygen. It provides volume and mass reduction up to 50% of the input material (Shokri [4]). It is considered a renewable energy source because the methane-rich biogas produced is suitable for energy production and can replace fossil fuels (Clemens et al. [5]). The methane in biogas can be burned to produce both heat and electricity (Brooks et al. [6]; and Hutnan et al. [7]) Moreover, the possibility to recycle the exit residue from the digester as fertilizes (Zhang et al. [8]).

Significant effort has been dedicated in recent years to find ways of improving the performance of anaerobic digesters treating different biomass. One of the options for improving yields of anaerobic digestion of organic matter is co-digestion of multiple substrates. Anaerobic co-digestion is presented as a successful methodology that combines several types of biodegradable wastes able to improve the digestion efficiency and increase the production potential of biogas (Alvarez and Liden [9]). It offers more ecological, technological, and economic advantages than fermenting a single substrate (Lehtomäki et al. [10]). Anaerobic co-digestion may enhance the stability of the anaerobic process and exhibit a more stable biogas production (El Mashad and Zhang [11]). Kangle et al. [12] reported that the main advantages of the co-digestion process are: increased biogas production, additional amount of fertilizer, additional income, and higher organic matter bioconversion.

The literature contains a number of interesting reports dealing with the application of co-digesting sewage sludge with other substrates: municipal solid wastes (Davidsson et al. [13]; Agdag and Sponza [14] and Neves et al. [15]); animals manure as well as agriculture wastes (Rughoonundun et al. [16] ; Komatsu et al. [17]; and Gomez et al. [18]).Although several publications dealing with the increasing of biogas production through anaerobic co-digestion of sewage sludge, but less studies has been carried out to address the co-digestion of sewage sludge and cattle manure.

The aim of this study is therefore to assess the performance of anaerobic co-digestion of sewage sludge and cattle manure, as well as evaluate the effects of caw manure addition as a co-substrate on the overall stability and efficiency of the process.Such a solution will allow to develop a sewage sludge utilization technology enabling the production of bio-energy and wastes utilization.

2. MATERIALS AND METHOD

2.1 Collection of Substrates and Inoculums

Sewage sludge taken from a full scale municipal wastewater treatment plant operated on the activated sludge method, and cattle manure was collected at a farm in the rural area. Pervious fermentation anaerobically treated sewage sludge was used as inoculums. The characteristics of substrates were analyzed as shown in Table 1.

Table 1. Characteristics of sewage sludge and caw manure

Parameter	Sewage sludge	Cattle manure
pH	6.32	8.11
TS (%)	4.80	16.85
VS (%)	3.60	13.92
VS/TS	0.75	0.83
Carbon, C (% TS)	37.62	27.30
Nitrogen, N (% TS)	4.85	4.90
C/N ratio	7.76	5.57

2.2 Batch Experiments

Batch experiments were performed in a glass bottle with total and working volumes equal to 1.0 and 0.8 liter respectively. Digesters were maintained at a constant temperature of (35 ± 1 °C) by placed in the heating bath. Their content was mixed periodically by using magnetic mixer (300 rpm). The system of experiments set-up is shown in Fig. 1.

The digestion was carried out for sewage sludge exclusively (R1 – blank sample) as well as co-digestion with the cattle manure. In co-digestion, the amount of sewage sludge in each digester was kept constant (8.25 g-VS/L), while varying the amount of cattle manure added of digestion R2, R3, R4 as 6, 4, and 2 g-VS/L respectively. In digestion R5, cattle manure was designed alone at the load of 6 g-VS/L. The characteristics of the different experiments are shown in Table 2. After set-up the reactors were flushed for two minutes with pure N_2 gas to ensure anaerobic environment in the head space of the batches.

Both quantitative and qualitative analyses of the biogas produced were carried out during the experiment. Biogas was collected by water displacement method and the volume was calculated daily and stopped after biogas was insignificantly produced. The produced biogas was passed through a glass bottle contain 5% NaOH solution before collecting and measuring the volume in order to remove CO_2 (Wellinger and Lindberg [19]). The biogas samples were taken by using 0.1 ml glass syringe at two positions as shown in Fig. 1. Biogas samples periodically were examined by gas chromatography to determine the CH_4 and CO_2 content. The pH, Total solids (TS) and volatile solids (VS) of sewage sludge and cattle manure samples were determined according to standard methods (APHA [20]).

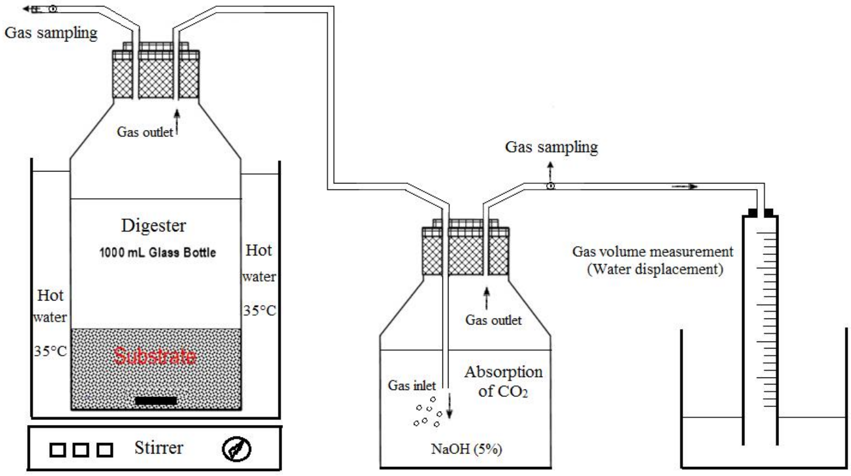

Fig.1: Set-up of laboratory batch assessment of anaerobic digestion

Table 2. Characteristics of digestion conditions

Parameter	R1	R2	R3	R4	R5
SS (g-VS/L)	8.25	8.25	8.25	8.25	-
CM (g-VS/L)	-	6	4	2	6
SS/CM	-	1.375	2.063	4.125	-
pH	6.32	7.62	7.43	7.19	8.11
C/N ratio	7.76	7.08	6.65	6.37	5.57

3. RESULTS AND DISCUSSION

This study step was directed to study either the effect of co-digestion of sewage sludge with cattle manure to biogas production is significant or not.The total volume of biogas production was observed during 30 days as depicted in Fig. 2a. In other term, the CH_4 and CO_2 contents arepresented in Fig. 2b and 2c respectively.

Fig. 2a shows that, in general, biogas production rate tend to obey sigmoid function (S curve) as generally occurred in batch growth curve. Biogas production is slow at the beginning and the end period of observation. This is predicted due to the biogas production rate in batch condition is directly corresponds to specific growth rate of methanogenic bacteria in the bio-digester (Nopharatana et al. [21]). In the around of the first 10 days observation, biogas production is low or indeed do not formed yet due to the lag phase of microbial growth. In the range of 10 to 30 days observation, biogas production is significantly increased due to exponential growth of microorganisms and then tends to decrease due to stationary phase of microbial growth.

Fig. 2a also shows that, generally, substrates consist of sewage sludge and cattle manure (R2, R3, and R4) exhibit higher biogas production than substrates contain sludge or cattle manure only (R1 and R5).The highest biogas production was obtained in digestion R2 where the SS/CM ratio is 1.375 (Table 2). This result shows that the co-digestion cause cumulative biogas production more than twice fold in compare to mono-digestion experiments. This is suggesting that the anaerobic bacteria in sewage sludge works effectively to degrade organic substrate from manure. In other term, the increasing of content percentage of cattle manure is statistically gave the significant effect to biogas production (R2>R3>R4). This is agree with other results of researcher before (Forster-Carneiro et al. [22] and Castilloet et al. [23]) who reported that the higher percentage of caw manure content gave the higher production of biogas.

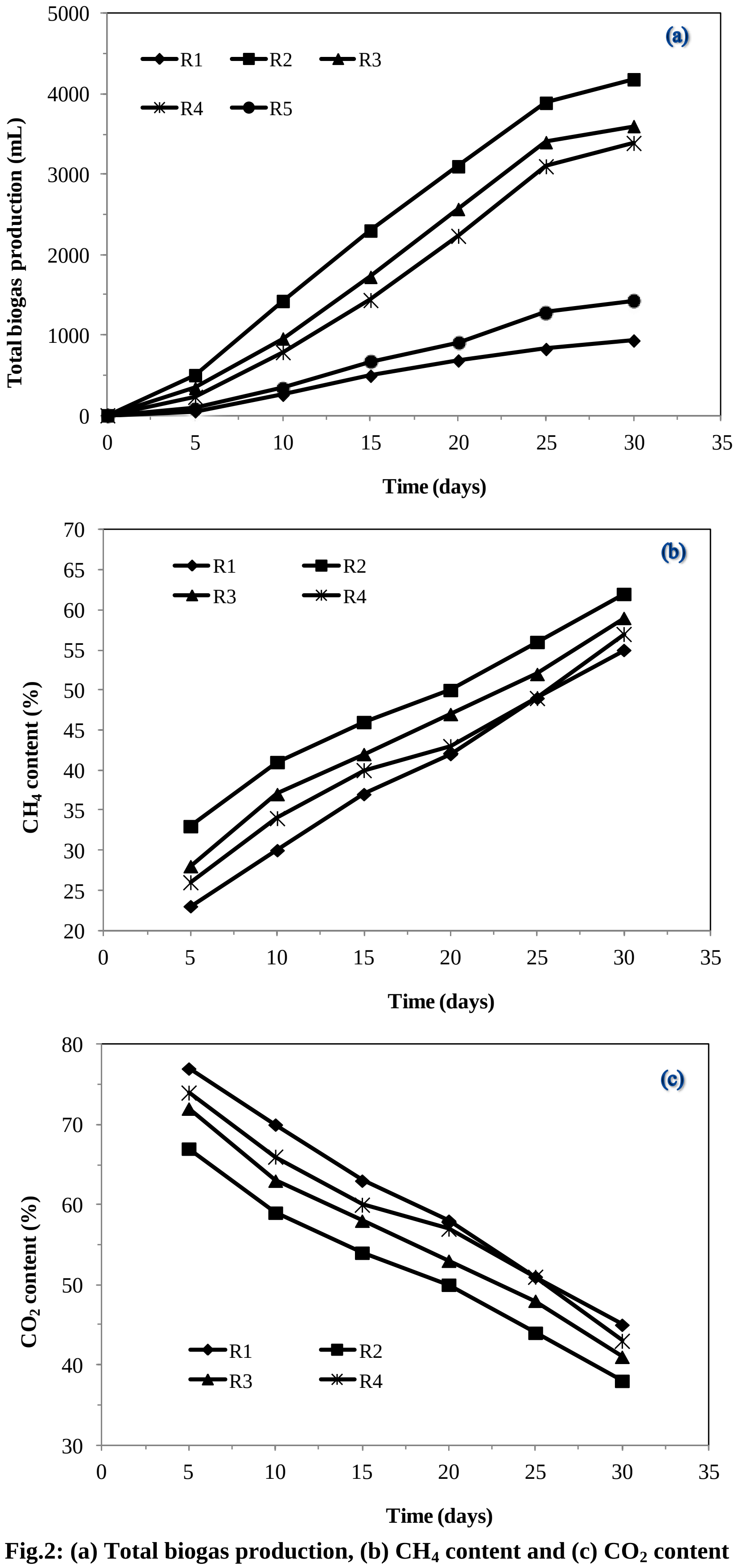

Fig.2: (a) Total biogas production, (b) CH_4 content and (c) CO_2 content (R1: 8.25 g-VS_{SS}/L; R2: 8.25 g-VS_{SS}/L + 6 g-VS_{CM}/L; R3: 8.25 g-VS_{SS}/L + 4 g-VS_{CM}/L; R4: 8.25 g-VS_{SS}/L + 2 g-VS_{CM}/L; R5: 6 g-VS_{CM}/L).

Figs. 2b and 2c show the productions of CH_4 and CO_2 in batch tests. The CH_4 content increased fast during the initial 10 days. The CH_4 content of biogas increased to 41% in co-digestion of R2–R5 until day 10. Thereafter, it increased gradually in the following days. The highest CH_4 content was 62% in co-digestion of R2, where it is 54% in the sample containing exclusively sewage sludge (R1).

The increase in CH_4 concentration might have been caused by the addition of ingredients containing large amounts of easily-biodegradable substances (Hartmann and Ahring [24]). By contrast, a higher CO_2 content was obtained at the initial of digestion. The CO_2 content decreased gradually along with the increase of CH_4 content. The lowest CO_2 content could reach a level of 40%.

Igoni et al. [25] reported that a typical biogas composition obtained during anaerobic digestion; comprises of methane (55-75%), carbon dioxide (30-45%), some inert gases (N_2, H_2, CO, and O_2) and sulfur compounds. The CH_4 composition (62%) recovered in this research was within the range of CH_4 composition in typical biogas

4. CONCLUSION

Anaerobic digestion processes are widely recognized as particularly suitable for treatment and stabilization of wastewater sludge, while in the presence of bacterial activity, producing bio-gas (mainly methane). Biogas production was studied by performing alaboratory experiment using co-digestion of sewage sludge and cattle manure. The important finding from thisresearch is that the cattle manure seeded to biodigester hassignificant effect to cumulative biogas production andbiogas production rate. Co-digestion of sewage sludge and cattle manureenhanced biogasproduction rate and efficiency increase two to three times incompare to mono-digester for both wastes.

Also, co-digestion had a positive impact on the quality (CH_4 content) of biogas produced. Although further study is required in a large volume in order to optimize process operating parameters in a real case. Also, co-digestion with carbon-rich wastes like sugarcane bagasse will increase the overall efficiency of the digestion process.

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