THE EFFECT OF BUFFALO DUNG TREATMENT WITH PAUNCH FLUID ON BIOGAS PRODUCTION

E. Abdelsalam[1], M. Samer[2], M. A. Abdel-Hadi[3], H. E. Hassan[4] and Y. Badr[4]

ABSTRACT

Anaerobic digestion is a biological process used to convert organic wastes into biogas and a stable bio-fertilizer for agricultural applications as environmentally friendly product. The produced biogas is used as an alternative renewable energy source. The aim of this study was to analyze the influence of paunch fluid (PF) content on biogas and methane yield from buffalo dung as biowastes. A series of laboratory experiments using 2 L biodigesters (i.e., BD1 till BD6) were carried out in batch operation mode. Each biodigester was fed with fixed 750 g of fresh buffalo dung (D) and mixed with 750 ml of PF and distill water (W) with different ratios (i.e., BD1= 50%, BD2= 50%, BD3= 37.5%, BD4= 37.5%, BD5=0% and BD6= 100% of PF). The results showed that the best performance for biogas and methane production was the biodigester BD3 and BD4 with 37.5% of PF, i.e. biogas yield was 205.8 and 224.2 ml g VS^{-1}, respectively, after 40 days of hydraulic retention time (HRT). While the other biodigesters BD1, BD2, BD5 and BD6 with 50, 50, 0 and 100% of PF delivered a biogas yield of 177.3, 133.1, 172.7 and 0 ml g VS^{-1}, respectively. Additionally, methane production showed the similar performance, i.e. digesters BD4, BD3, BD1, BD5, BD2 and BD6 delivered a methane yield of 144.7, 130.3, 120.4, 104.8, 84.2 and 0.0 ml g VS^{-1}, respectively. These results showed that, the highest biogas and methane yield was delivered when buffalo dung was treated with 37.5% of PF. Although, many references showed that, 50% of PF delivered the highest biogas and methane yields. Therefore, the effect of PF concentration on biogas and methane production must be investigated intensively.

Keywords: ***Anaerobic digestion, biogas, methane production, paunch/rumen fluid, inoculum, buffalo (Bubalus bubalis) dung, manure treatment.***

1. Assist. Lecturer, Nat. Inst. of Laser Enhanced Sc. (NILES), Cairo University.
2. Assoc. Prof., Ag. Eng. Dept., Fac. of Agric., Cairo University.
3. Assoc. Prof., Ag. Eng. Dept., Fac. of Agric., Suez-Canal University.
4. Prof. Dr., Nat. Inst. of Laser Enhanced Sc. (NILES), Cairo University.

1. INTRODUCTION

Biomass energy, as a renewable and sustainable form of energy, is becoming more important due to its environmentally-sound and energy-saving production methods (***Berndes et al., 2003***). When organic matter – such as food, plant debris, animal manure, sewage sludge, and biodegradable portions of municipal solid waste – undergoes decomposition in absence of free oxygen, it normally generates a gas which consists of 40-70% methane, the rest being mostly carbon dioxide with traces of other gases (***Ferrer et al., 2011; Weiland, 2010***). Anaerobic digestion (AD) can be considered as one of the most important techniques to convert organic waste into renewable energy in the form of methane (***Holm-Nielsen et al., 2009***). The reason that anaerobic digestion is a widely used technique can be contributed to the fact that, apart from the biogas production and organic waste stabilization, it has several other advantages, e.g. a low cell yield, a high organic loading rate, limited nutrient demands and low costs for operation and maintenance of the reactor system (***Wijekoon et al., 2011***). It must be mentioned that a mixture of CH_4 and CO_2 is not the only gas possible by anaerobic degradation of organic matter. Of the two, methane is produced only if methanogenic bacteria are involved in the anaerobic decomposition (***Chen et al., 2008***).

The AD process is normally classified into three different temperature ranges, namely psychrophilic (<20 ºC), mesophilic (20-40 ºC) and thermophilic (>40 ºC) (***El-Mashad et al., 2004***). ***köttner*** (***2003***) reported that the process of anaerobic digestion is running at its optimum temperature range of 25 to 38 ºC (mesophilic conditions), the latter prefer temperatures in the range of 38 ºC are greater stability of digestion process, easier to control and utilized in about 95 percent of all digesters. Furthermore, a mesophilic treatment at 38 ºC reportedly destroys 99.9% of pathogens (***Erickson et al., 2004***). Under different conditions, and with other species of anaerobic microorganisms, gases such as hydrogen and hydrogen sulfide may be generated instead of methane (***Diaz et al., 2010; Singh and Mandal, 2011***). But methanogenic bacteria occur very commonly in nature and in most instances anaerobic digestion does result in the generation of the predominantly CH_4-CO_2 mixture which is widely

referred as 'biogas' (***Abbasi et al., 2012a***). Nowadays, the use of biogas has spread from small farms to big animal farms. It is expected that biogas will be a significant source of energy in the future to preserve the environment, solve the pollution problem and to promote better health to agriculture and community. After animal excrement had been fermented in the biogas plant, it becomes a good quality and odorless substrate, which is better than fresh manure in improving the soil for the agriculture (***Ndegwa and Thompson, 2001***). A 'biogas digester' is also an essentially anaerobic digester/fermenter/reactor. This term is used for systems which are employed primarily for biogas production as distinct from other terms which are applied to systems which are primarily used for waste treatment and in which biogas is a major by-product (***Abbasi et al., 2012b***).

Among domesticated livestock, ruminant animals (cattle, buffalo, sheep, goat, and camel) produce significant amounts of methane as part of their normal digestive processes (***Chhabra et al., 2009; Nusbaum, 2010***). In the rumen (large fore-stomach) of these animals, microbial fermentation converts feed into products that can be digested and utilized by the animal (***Janssen, 2010; Weimer et al., 2009***). This microbial fermentation process (enteric fermentation) produces methane as a by-product, which is exhaled by the animal. Methane is also produced in smaller quantities by the digestive processes of other animals, including humans, but emissions from these sources are insignificant (***USEPA, 2012***).

Rumen in the mammalian animals is a natural cellulose-degrading system and the microorganisms inside have been found to be able to effectively digest lignocellulosic biomass. Furthermore, methane or volatile fatty acids, which could be further converted to other biofuels, are the two major products in such a system (***Yue et al., 2013***).

Rumen fermentation is always associated with the formation of biogas rich in methane, which is a valuable energy gas. Researchers have found that a high VFA concentration could be obtained in the rumen fluid inoculated reactor at the initial phase and methane was the major product in the subsequent period (***Yue and Yu, 2009***). Rumen microorganisms exhibited higher ability and activity to degrade the lignocellulosic biomass, such as organic fraction of municipal waste and grass, compared to other usual anaerobic microorganisms (***Sonakya et al., 2003; Lopes et***

al., 2004; ***Liu et al., 2009***). Methanogenic microorganisms also exist in rumen that converts acetate part in methane and carbon dioxide. In case of the use of rumen fluid inoculums for biogas production, ***Lopes et al.*** (***2004***) reported that a strong influence of the bovine rumen fluid inoculums on anaerobic bio-stabilization of fermentable organic fraction of municipal solid waste. However, the optimum inoculums content could not be determined due to the fact that the experiments were not extensively investigated study using inoculums content more than 15% (***Lopes et al., 2004***). The rumen is an exclusive organ of ruminant animals in which digestion of cellulose and other polysaccharide molecules occur through the activity of specific microbial populations. The capacity of cellulose digestion that these animals possess is related to the presence of anaerobic microorganisms in its rumen, which decompose glucose polymer chains up to acetate. According to ***Aurora*** (***1983***) rumen contains the highly anaerobic bacteria dominated by cellulolytic bacteria able to biodegrade cellulosic material. In addition, ***Budiyono et al***. (***2009***) and ***Sunarso et al.*** (***2010***) have also reported that rumen fluid inoculated to biodigester gave significant effect to biogas production. Rumen fluid inoculums caused biogas production rate and efficiency increase two to three times in compare to manure substrate without rumen fluid. In addition, to our best knowledge, in case of using rumen fluid as inoculums; data concerning the study of the effect of inoculums content to biogas production rate from cattle manure are very limited.

In Egypt, 18% of the agricultural wastes are used directly as fertilizer. Another 30% is used as animal fodder. The remainder is burnt directly on the fields or is used for heating in the small villages, using low efficiency burners (***El-Mashad et al., 2003***). Dung (feces), manure (feces + urine) and slurry (manure + water) are not only treated anaerobically to produce biogas, but also aerobically to reduce harmful gaseous emissions (***Samer et al., 2014***).

Buffalo discharge was ranged between 8 to 12 kg/animal/day (***Rofiqul et al., 2008***), 15 kg/animal/day (***FAO, 2005***) and 16.4 kg/animal/day (***DGS, 2006***). The average compositions of fresh dung are 20.5% total solids (TS) and its contents of OTS 17.45%. While C:N ratios of fresh cattle and buffalo dung are 38.1 and 29.0, respectively (***Shilpkar and Chaudhary,***

2007). ***Nanda and Nakao*** (***2003***) pointed that one kg fresh buffalo dung produces 0.037 m^3 of biogas. On the other hand, one kg OTS from buffalo dung produces 0.105 0.468 m^3 of biogas while methane yield ranged between 0.069 to 0.284 m^3 (***Abdel-Hadi and Abd El-Azeem, 2008***).

The objective of this study is to study the influence of paunch fluid content for biogas and methane production from buffalo dung using lab scale bench system. The results of this research will be used as a guide line for studying the effect of using metallic nanoparticles to enhance biogas production and methane yield.

2. MATERIALS AND METHODS

2.1 Fresh dung and paunch fluid

The fresh raw dung was collected randomly from buffalo holding pen unit located in the Western Farm of the faculty of agriculture, Cairo University, Giza city, Egypt. While, the paunch contents were obtained from a slaughtered buffalo (female, 2 years, 450 Kg); taken from the slaughterhouse of the same farm.

2.2 Sample preparation

The collected raw dung was homogenized by mixer for 30 minutes. On the other side, the paunch fluid was prepared according to (***Budiyono et al., 2009***), where the paunch content was poured in a tank with capacity of 50 L then, 25 L of distilled water were added and mixed with the paunch content. The obtained slurry was filtered by cloth filter to separate solid content.

2.3 Samples and substrate analysis

The pH and the temperature were measured using a pH meter (Jenway 3520, Staffordshire, UK). Total solids (TS), volatile solid (VS) and ash were determined using the standard methods (***EPA, METHOD 1684, 2001***) using muffle furnace (Ney Tech, Vulcan D-550, York, USA) as shown in Table (1).

$$\text{Total Solids (\%)} = \frac{W_{total} - W_{dish}}{W_{sample} - W_{dish}} * 100 \qquad (1)$$

$$\text{Volatile Solids (\%)} = \frac{W_{total} - W_{ash}}{W_{total} - W_{dish}} * 100 \quad (2)$$

Where:

W_{dish} *: Weight of dish, mg.*

W_{sample} *: Weight of wet sample and dish, mg.*

W_{total} *: Weight of dried residue and dish, mg.*

W_{ash} *: Weight of ash and dish after ignition, mg.*

Organic carbon was calculated according to (***Black et al., 1965***) using the following equation:

$$\text{Organic carbon (\%)} = VS(\%)/1.724 \quad (3)$$

Table (1): Chemical composition of fresh dung and paunch fluid.

parameter	Fresh Dung (D)	Paunch Fluid (PF)
TS (%)	17.01	1.49
VS (%)	13.05	1.17
VS (%) from TS	76.72	78.52
Ash (%)	3.96	0.69
Organic carbon (% from VS)	44.52	46.14
Total Nitrogen (%)	1.7	3.2
C:N ratio	26:1	14:1
pH	6.87	6.37

2.4 Experimental set up

A batch anaerobic system was designed, according to the design guidelines and parameters developed by ***Samer*** (***2010 and 2012***), and constructed on the workshop Nat. Inst. of Laser Enhanced Sc. (NILES), Cairo University. The main experiment tools consist of: biodigester, temperature control and biogas measurement. A 2-liter wide neck reaction Pyrex flask (Scilabware, FR2LF, Staffordshire, UK) was used as biodigester, plugged with tightly Teflon cap, equipped with step motor (5 rpm) for mixing the substrate for 1min every hour (***Keshtkar et al., 2003***) and gas outlet connected to biogas holder and measurement (in ml), through water trap to reduced water vapor (Fig.1).

In order to withdraw samples or to enable pH measurements without interrupting the anaerobic conditions of the system, a plastic tube with long of 12 cm and a diameter of 2 cm was fixed in a hole in the cap and immersed in the substrate. The temperature was controlled using a thermostatic water bath (Raypa, BAD-12, Barcelona, Spain) and maintained at 38.5±0.3 ºC.

Biogas Digesters Biogas Holders

Fig. (1): The experimental lab scale biogas unit's set-up.

The volume of biogas formed was measured by ’liquid displacement method’ using ultra clear polypropylene graduated cylinder (1000 ml, ± 10 ml, Azlon) connected to gas outlet by 6 mm plastic hose at its base and placed upside down in another polypropylene cylinder (2000 ml, Azlon) filled with water (Fig. 2). Methane (CH_4) and carbon dioxide (CO_2) percentages were measured using portable gas analyzer (Geotech, GA2000, Warwickshire, UK). CH_4 and CO_2 were measured by dual wavelength infrared cell with reference channel. The recorded data were downloaded from the gas analyzer to PC using Gas Analyzer Manager Software (GAM, version 1.4.0.12) in the form of Excel Worksheet.

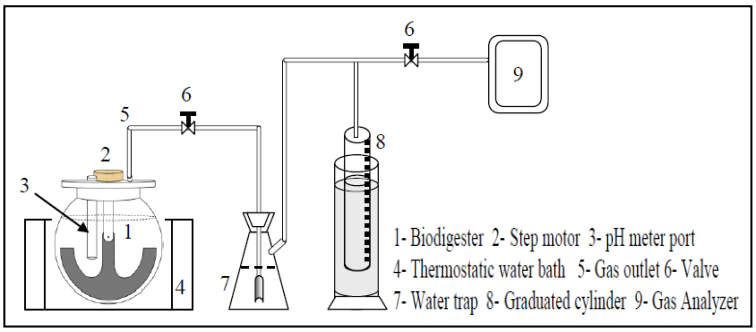

Fig. (2): The schematic diagram of experimental laboratory set up.

2.5 Experimental design

A series of laboratory experiments using 2000 ml biodigester; with 10% headspace of biodigester (***Samer, 2010***), were performed in batch operation mode to investigate the influence of rumen fluid content on biogas and methane production. Each biodigester was fed with 750 g of fresh buffalo dung (D) and mixed with 750 ml paunch fluid (PF) and distilled water (W) with different ratios. According to (***Budiyono et al., 2009***), the best performance for biogas generation was obtained if paunch fluid is in the range of 25-50%. Considering this range; two biodigesters were fed with 50% paunch fluid, two with 37.5%, one with 0.0% and one 100% as shown in Table 2. While, Table 3, presents the initial composition of six biodigesters' substrate used in the study.

Table (2): Experimental design of six biodigesters.

Biodigester	D:W:P	Dung	Water	PF	PF
		g	ml	ml	%
BD1	1:0:1	750	0.0	750	50
BD2	1:0:1	750	0.0	750	50
BD3	1:0.25:0.75	750	187.5	562.5	37.5
BD4	1:0.25:0.75	750	187.5	562.5	37.5
BD5	1:1:0	750	750	0.0	0.0
BD6	0:0:1	0.0	0.0	1750	100

Table (3): Initial chemical composition of six biodigesters substrate

Biodigester	TS	VS	Ash	Organic carbon	C:N ratio	pH value
	%	%	%	% from VS		
BD1	8.74	6.54	2.20	43.40	25.5:1	6.78
BD2	8.64	6.29	2.35	42.23	24.8:1	6.77
BD3	8.71	6.42	2.28	42.78	25.2:1	6.78
BD4	8.41	6.18	2.23	42.63	25.1:1	6.85
BD5	7.91	5.91	1.99	43.37	25.5:1	7.1
BD6	1.49	1.17	0.69	46.14	14:1	6.37

The 38.5 ºC (mesophilic bacteria ranges) was selected as optimum temperature of bacteria due to the fact that the paunch condition on animal ruminants is 38.5 ºC (***Budiyono et al., 2009***) and the operation

was stabilized at 38.5±0.3 ºC. The performance of each biodigester was assessed with respect to cumulative volume of biogas produced and corrected according to standard pressure (760 mm Hg) and temperature (0 ºC) STP (***Hansen et al., 2004***).

3. RESULTS AND DISCUSSION

3.1 The influence of paunch fluid content on biogas and methane production

The influence of paunch fluid content on biogas and methane production were investigated by varying the paunch percent in mixed samples with fixed 750 g of fresh buffalo dung as shown in Table 2. ***Budiyono et al.*** (***2009***) concluded that the best total solid contents for biogas generation was 7-9%, therefore, the TS of each biodigester were stabilized in this range (i.e. 7.91-8.74%) as shown in Table 3. While, Table 4 shows the final composition of the effluent.

The cumulative volumes of biogas and methane production were observed and recorded through 130 days. The daily biogas and methane production was recorded and the curves were drawn using all data which were displayed in an interval of 5 days. The peak of biogas and methane production rate was observed during 35-40 days of operation of all biodigesters as shown in Fig. 3; therefore, the cumulative production curve was divided into two Stages: "Stage 1" is from 0 to 40 days and "Stage 2" is from 41 to 130 days.

Table (4): Final composition of six biodigesters effluent.

Biodigester	TS	VS	Ash	Organic carbon	Digestibility of TS	Digestibility of VS	pH value
	%	%	%	% from VS	%	%	
BD 1	5.82	4.22	1.60	42.08	33.38	35.40	7.4
BD 2	5.30	3.00	2.30	32.83	38.68	52.32	7.4
BD 3	5.16	3.47	1.69	39.04	40.74	45.92	7.3
BD 4	5.67	3.65	2.02	37.36	32.59	40.92	7.4
BD 5	5.77	4.01	1.76	40.31	26.99	32.14	7.3
BD 6	0.64	0.21	0.43	19.33	57.14	73.33	7.6

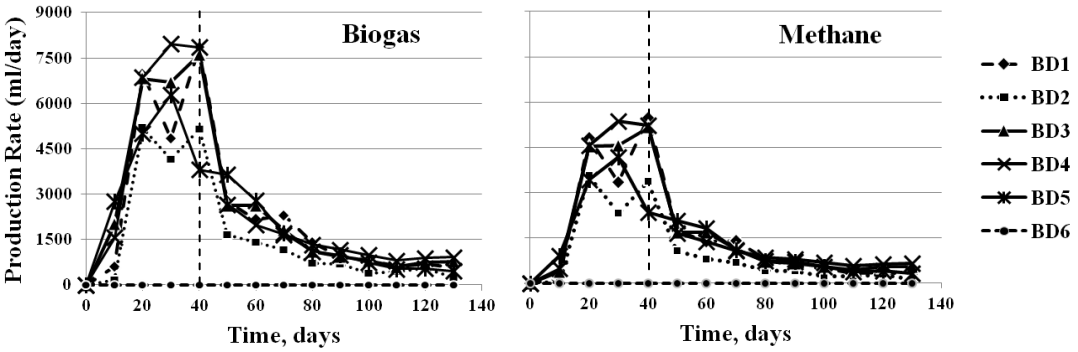

Fig. (3): Biogas and methane production rate during 130 days of anaerobic digestion.

Fig. (4), present the cumulative biogas and methane production curves during "Stage 1" (i.e. 0-40 days of the experiment) which have a tendency to obey sigmoid function (S curve) as generally occurs in batch growth curve and as stated by ***Budiyono et al.*** (***2009***).

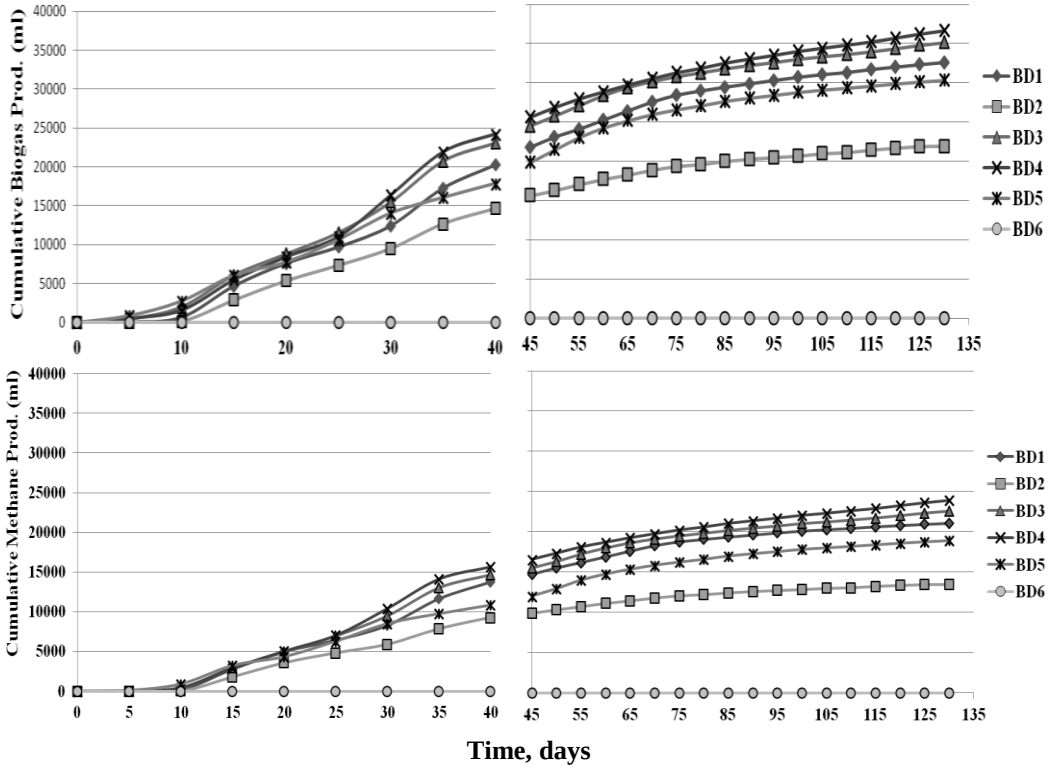

Fig. (4): Cumulative production of biogas and methane during two Stages of experiment.

In most cases, biogas and methane production is very slow at the beginning and the end period of observation. This was anticipated according to the specific growth rate of methanogenic bacteria in the biodigester (***Nopharatana et al., 2007***). On the other hand, in the first 15 days the biogas and methane production was inversely proportional to the paunch fluid content, this observation disagree with ***Budiyono et al.*** (***2009***) who reported that the substrates consisting of dung and paunch (12.5 to 50%) exhibit higher cumulative biogas production than substrates containing dung and water only (0% PF). This disagreement may be subjected to the competition between the bacterial cells or to longer time required to adaptation with the experimental conditions.
In the range of 15-40 days, the biogas and methane production significantly increased owing to the exponential growth of microorganisms. After 40 days from the beginning of the experiments (i.e., Stage 2), the biogas and methane production tends to decrease due to the stationary phase of the microbial growth (***Castillo et al., 1995***).

The correlation analysis, which was carried out to evaluate the relationships between the cumulative biogas and methane production in one hand and the digestion time for all rumen fluid contents on the other hand, proved that these correlations were linear and highly significant where R^2-value ranged between 0.9582 and 0.9897 for cumulative production of biogas and between 0.9482 and 0.9775 for cumulative production of methane during "Stage 1" of the anaerobic digestion as shown in Table (5). Additionally, "Stage 2" (i.e., 41-130 days of anaerobic digestion) shows the same high linearity but less than "Stage 1", where R^2-value ranged between 0.8971 and 0.9696 for cumulative production of biogas, and between 0.91 and 0.9751 for cumulative production of methane as shown in Table (5), "Stage 2". The aforementioned results indicate that biogas and methane production significantly decrease through "Stage 2". All biodigesters produced more than 58.8 and 57.3% of total biogas and methane yield, respectively, during "Stage 1", as shown in Fig. 5. Therefore, there is no economically reason to proceed further in "Stage 2" of the anaerobic digestion.
BD3 and BD4 with 37.5% rumen fluid produced the highest total biogas yields, 23125 and 24250 ml, respectively, during "Stage 1". While the

total biogas yields for BD1 and BD2 (with 50% PF) were lower and amounted to 20290 and 14655 ml, respectively. Although, BD5 had 0.0% of paunch fluid the biogas yield was 17865 ml which is higher than BD2. Additionally, the total methane yield shows the same behavior as biogas production, where BD4>BD3>BD1>BD5>BD2 by 15652.64, 14646.32, 13779.25, 10839.8 and 9275.26 ml, respectively. On the other hand, the resulted ratio of methane in biogas agrees with ***Lopes et al.*** (***2004***) who showed that the inoculum's amount contributed significantly in increasing the amount of methane in the biogas, where BD1 (with 50% PF) produced the highest content of methane by 67.9% of total biogas during "Stage 1", and then BD4 and BD5 (with 37.5 and 0.0% PF) which produced 64.5% and 60.7% methane, respectively as shown in Table 6.

Table (5): R^2-values for cumulative biogas and methane production curves.

Biodigesters	PF	R^2- value			
	%	Biogas		Methane	
		Stage 1	Stage 2	Stage 1	Stage 2
BD1	50.0	0.9603	0.9237	0.9529	0.91
BD2	50.0	0.9586	0.9401	0.9591	0.9328
BD3	37.5	0.9724	0.9277	0.9549	0.9437
BD4	37.5	0.9582	0.9696	0.9482	0.9751
BD5	0.0	0.9897	0.8971	0.9775	0.9141
BD6	100	N/A	N/A	N/A	N/A

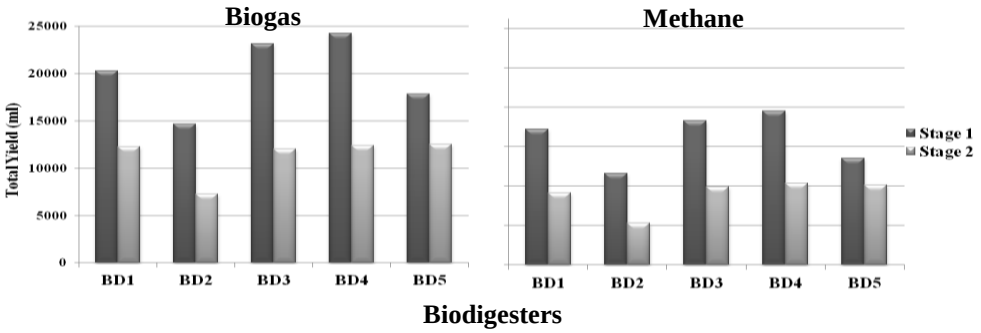

Fig. (5): Total biogas and methane yield during two stages of anaerobic digestion.

Table (6): Specific biogas and methane yield during "Stage 1"

Biodigester	PF	Biogas	Methane	Average CH_4
	%	ml gVS^{-1}	ml gVS^{-1}	%
BD 1	50.0	177.3	120.4	67.91
BD 2	50.0	133.1	84.22	63.29
BD 3	37.5	205.77	130.3	63.34
BD 4	37.5	224.2	144.7	64.55
BD 5	0.0	172.66	104.76	60.68
BD 6	100	0.0	0.0	0.0

4. CONCLUSIONS

According to the results of this study, it can be concluded that:

1. The first 15 days (i.e., Stage 1), the biogas and methane production was inversely proportional to the paunch fluid content.
2. In the range of 15-40 days (i.e., Stage 1), the biogas and methane production significantly increased owing to the exponential growth of microorganisms.
3. After 40 days from the beginning of the experiments (i.e., Stage 2), the biogas and methane production tends to decrease due to the stationary phase of the microbial growth.
4. BD3 and BD4 with 37.5% paunch fluid produced the highest total biogas yields, 23125 and 24250 ml, respectively, during "Stage 1". While the total biogas yields for BD1 and BD2 (with 50% PF) were lower and amounted to 20290 and 14655 ml, respectively.
5. The correlation analysis between the cumulative biogas and methane production for all paunch fluid contents were linear and highly

significant where R^2-value ranged between 0.9582 and 0.9897 for cumulative production of biogas and between 0.9482 and 0.9775 for cumulative production of methane during "Stage 1" of the anaerobic digestion.

6. During "Stage 2" the correlation analysis shows the same high linearity but less than "Stage 1", where R^2-value ranged between 0.8971 and 0.9696 for cumulative production of biogas, and between 0.91 and 0.9751 for cumulative production of methane.

7. The biogas and methane production significantly decrease through "Stage 2". All biodigesters produced more than 58.8 and 57.3% of total biogas and methane yield, respectively, during "Stage 1". Therefore, there is no economically reason to proceed further in "Stage 2" of the anaerobic digestion.

5. REFERENCES

Abbasi, T.; Tauseef, S. M. and Abbasi S. A. (2012a): Anaerobic digestion for global warming control and energy generation-An overview Renewable and Sustainable Energy Reviews 16 (2012) 3228– 3242

Abbasi, T.; Tauseef, S. M. and Abbasi, S. A. (2012b): Biogas energy. New York: Springer Verlag; 169 pp.

Abdel-Hadi, M. A. and Abd El-Azeem, S. A. M. (2008): Effect of Heating, Mixing and Digester Type on Biogas Production from Buffalo Dung. *Misr J. Ag. Eng.* 25(4): 1454-1477.

Aurora, S. P. (1983): Microbial Digestion in Ruminants. *Indian Council of Agricultural Research*, New Delhi.

Berndes, G.; Hoogwijk, M. and van den Broek, R. (2003): The contribution of biomass in the future global energy supply: a review of 17 studies. Biomass Bioenergy, 25: 1-28.

Black, C. A.; Evans, D. D.; Evsminger, I. E.; Clerk, F. E. and White, J. L. (1965): Methods of Soil Analysis: Part 1. *American Society of Agronomy*, Inc., Madison, USA.

Budiyono, B.; Widiasa, I. N.; Johari, S. and Sunarso S. (2009): Influence of inoculum content on performance of anaerobic reactors for treating cattle manure using rumen fluid inoculum. *International Journal of Engineering and Technology*, 1(3): 109-116.

Castillo, R. T.; Luengo, P. L. and Alvarez, J. M. (1995): Temperature effect on anaerobic of bedding manure in a one phase system at different inoculums concentration. *Agriculture, Ecosystems and Environment*, 54: 55-66.

Chen, Y.; Cheng, J. J. and Creamer, K. S. (2008): Inhibition of anaerobic digestion process: a review. Bioresource Technology, 99(10): 4044–64.

Chhabra, A.; Manjunath, K.; Panigrahy, S. and Parihar, J. (2009): Spatial pattern of methane emissions from Indian livestock. Current Science; 96(5): 683–9.

Deutsche Gesellschaft für Solarenergie e.V., (DGS). (2006): Study on Solar and Biomass Energy Potential and Feasibility in Lao PDR Asia Pro Eco project TH/Asia Pro Eco/05 (101302). *International Solar Energy Society*, Germany.

Diaz, I.; Lopes, A.C.; Pérez, S.I. and Fdz-Polanco, M. (2010): Performance evaluation of oxygen, air and nitrate for the microaerobic removal of hydrogen sulphide in biogas from sludge digestion. Bioresource Technology, 101(20): 7724–30.

El-Mashad, H. M.; Zeeman, G.; Van Loon, Wilko K. P.; Bot, G. P. A. and Lettinga, G. (2004): Effect of temperature and temperature fluctuation on thermophilic anaerobic digestion of cattle manure. *Bioresource Technology*, 95: 191-201.

El-Mashad, H. M.; Van Loon, Wilko K. P.; Zeeman, G.; Bot, G. P. A. and Lettinga, G. (2003): Reuse potential of agricultural wastes in semi-arid regions: Egypt as a case study. *Environmental Science & Bio/Technology*, 2: 53-66.

EPA. (2001): Total, Fixed, and Volatile Solids. Method 1684, January 2001. *U.S. Environmental protection Agency, Engineering and Analysis Division (4303),* 1200 Pennsylvania Ave. NW Washington, DC 20460.

Erickson, L. E.; Fayet, E.; Kakumanu, B. K. and Davis, L. C. (2004): Anaerobic Digestion. *National Agricultural Biosecurity Center*. Kansas State University.

FAO. (2005): Relevance of Biogas Technology to Nepal. *SESSION TWO, Consolidated Management Services Nepal*. FAO/TCP/NEP/4415-T

Ferrer, I.; Garfi, M.; Uggetti, E.; Ferrer-Marti, L.; Calderon, A. and Velo, E. (2011): Biogas production in low-cost household digesters at the Peruvian Andes. Biomass and Bioenergy; 35(5): 1668–74.

Hansen, T. L.; Schmidt, J. E.; Angelidaki, I.; Marca, E.; Jansen, J.; Mosbaek, H. and Christensen, T. H. (2004): Method for determination of methane potentials of solid organic waste. *Waste Management* 24: 393-400.

Holm-Nielsen, J.B.; Al Seadi, T. and Oleskowicz-Popiel, P. (2009): The future of anaerobic digestion and biogas utilization. Bioresource Technology 100(22): 5478-5484.

Janssen, P. H. (2010): Influence of hydrogen on rumen methane formation and fermentation balances through microbial growth kinetics and fermentation thermodynamics. Animal Feed Science and Technology; 160(1-2): 1-22.

Keshtkar, A.; Meyssami, B.; Abolhamd, G.; Ghaforian, H. and Khalagi Asadi, M. (2003): Mathematical modeling of non-ideal mixing continuous flow reactors for anaerobic digestion of cattle manure. Bioresource Technology 87: 113–124

Köttner, M. (2003): Integration of biogas technology, organic farming and energy crops. The future of biogas in Europe II, *European biogas workshop*, October 2nd to 4th 2003, University of Southern Denmark esbjerg / Denmark.

Liu, G.; Zhang, R.; El-Mashad, H. M. and Dong, R. (2009): Effect of feed to inoculum ratios on biogas yields of food and green wastes. *Bioresource Technology* 100: 5103-5108.

Lopes, W. S.; Leite, V. D. and Prasad, S. (2004): Influence of inoculum on performance of anaerobic reactors for treating municipal solid waste. *Bioresource Technology* 94(3): 261-266.

Nanda, A. S. and Nakao, T. (2003): Role of buffalo in the socioeconomic development of rural Asia: Current status and future prospectus. *Animal Science Journal* 74: 443-455.

Ndegwa, P. M. and Thompson, S. A. (2001): Integrating composting and vermin composting the treatment and bioconversion of biosolids. *Bioresource Technology* 76: 107-112.

Nopharatana, A.; Pullammanappallil, P. C. and Clarke, W. P. (2007): Kinetics and dynamic modeling of batch anaerobic digestion of municipal solid waste in a stirred reactor. *Waste Management* 27: 595-603. DOI: 0.1016/ j.wasman. 2006.04.010.

Nusbaum, N. J. (2010): Dairy livestock methane remediation and global warming. Journal of Community Health, 35(5): 500-2.

Rofiqul, I. M.; Rabiul, I. M. and Rafiqul, A. M. (2008): Renewable energy resources and technologies practice in Bangladesh. *Renewable and Sustainable Energy Reviews* 12: 299-343.

Samer, M. (2010): A software program for planning and designing biogas plants. *Transactions of the ASABE* 53(4): 1277-1285.

Samer, M. (2012): Biogas plant constructions. In: *Biogas*, S. Kumar (ed.), ISBN 978-953-51-0204-5. Rijeka, Croatia: InTech. DOI: 10.5772/31887. pp. 343-368.

Samer, M., Mostafa, E. and Hassan, A. M. (2014): Slurry treatment with food industry wastes for reducing methane, nitrous oxide and ammonia emissions. Misr J. Ag. Eng., 31 (4):1523-1548.

Shilpkar, P. M. S. and Chaudhary, D. R. (2007): An alternate use of Calotropis gigantea: Biomethanation. *Current Science* 92 (4): 435-437.

Singh, R. and Mandal, S. K. **(2011):** Microbial removal of hydrogen sulfide from biogas. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects; 34(4): 306–15.

Sonakya, V., Raizada, N., Dalhoff, R., Wilderer, P.A. (2003): Elucidation mechanism of organic acids production from organic matter (grass) using digested and partially digested cattle feed. Water Sci. Technol. 48, 255–259.

Sunarso, S.; Johari, S.; Widiasa, I. N. and Budiyono, B. (2010): The effect of feed to inoculums ratio on biogas production rate from cattle manure using rumen fluid as inoculums. *International Journal of Science and Engineering*, 1(2): 41-45.

USEPA. **(2012):** Sources and Emissions | Methane | Climate Change | gU.S. EPA. U. S. Environmental Protection Agency, Available: http://epa.gov/methane/sources.html

Weiland P. **(2010):** Biogas production: current state and perspectives. Applied Microbiology and Biotechnology, 85(4): 849–60.

Weimer, P. J.; Russell, J. B. and Muck, R. E. **(2009):** Lessons from the cow: what the ruminant animal can teach us about consolidated

bioprocessing of cellulosic biomass. Bioresource Technology, 100(21): 5323–31.

Wijekoon, K. C.; Visvanathan, C. and Abeynayaka, A. (2011): Effect of organic loading rate on VFA production, organic matter removal and microbial activity of a two stage thermophilic anaerobic membrane bioreactor. Bioresource Technology, 102 (9): 5353-5360.

Yue, Z. B. and Yu, H. Q. (2009): Anaerobic batch degradation of cattail by rumen cultures. Int. J. Environ. Pollut., 38, 299–308.

Yue, Z. B.; Li, W. W. and Yu, H. Q. (2013): Application of rumen microorganisms for anaerobic bioconversion of lignocellulosic biomass. Bioresource Technology, 128: 738–744

الملخص العربى

تأثير معالجة روث الجاموس بسائل الكرش علي إنتاج الغاز الحيوي

عصام عبد السلام[١] ، محمد سامر[٢] ، محمد علي عبد الهادي[٣]، حلمي السيد حسن[٤] ، يحيي بدر[٤]

الهضم اللاهوائي هو عملية بيولوجية تستخدم لتحويل المخلفات العضوية وروث الماشية إلى غاز حيوي وأسمدة حيوية متوازنة للإستخدامات الزراعية كمنتج صديق للبيئة. و يستخدم الغاز الحيوي كمصدر للطاقة المتجددة.

ويهدف هذا البحث إلى دراسة تأثير سائل الكرش (PF) على إنتاج الغاز الحيوي والميثان من روث الجاموس كمخلفات عضوية. حيث أجريت التجارب المعملية بالوحدة التجريبية للغاز الحيوي بالمعهد القومي لعلوم الليزر - جامعة القاهرة باستخدام ٦ مخمرات (هاضم حيوي BD) من BD1 حتى BD6 حجم كلي للمخمر الواحد ٢ لتر بنظام تشغيل الدفعة الواحدة. تم تغذية كل مخمر بكمية ثابتة من روث الجاموس ٧٥٠ جرام مخلوطة مع ٧٥٠ مل من سائل الكرش والمياه المقطرة بنسب خلط لسائل الكرش في الخليط الكلي ٥٠%، ٥٠%, ٣٧,٥, ٣٧,٥, صفر, ١٠٠% للمخمرات BD1, BD2، BD3، BD4, BD5، BD6 علي التوالي.

١. مدرس مساعد - المعهد القومي لعلوم الليزر - جامعة القاهرة.
٢. استاذ الهندسة الزراعية المساعد - كلية الزراعة - جامعة القاهرة.
٣. استاذ الهندسة الزراعية المساعد - كلية الزراعة - جامعة قناة السويس.
٤. استاذ - المعهد القومي لعلوم الليزر - جامعة القاهرة.

أظهرت النتائج أن أفضل أداء لإنتاج الغاز الحيوي والميثان كان في المخمر BD3 وBD4 بنسبة خلط ٣٧,٥% مع سائل الكرش، حيث كان الغاز الحيوي المنتج ٢٠٥,٨ و ٢٢٤,٢ والميثان ١٣٠,٣ و١٤٤,٧ مل لكل جم مادة عضوية جافه علي الترتيب بعد مرور ٤٠ يوم من زمن الأستبقاء (HRT). في حين أنتجت المخمرات الأخري BD1، BD2، BD5 و BD6 ذات نسب الخلط ٥٠%، ٥٠%، صفر% و ١٠٠% من سائل الكرش كمية من الغاز الحيوي بلغت ١٧٧,٣ ، ١٣٣,١ ، ١٧٢,٧ و صفر بينما كان الميثان ١٢٠,٤ و ٨٤,٢ و ١٠٤,٨ و صفر مل لكل جم مادة عضوية جافه علي الترتيب.

دلت النتائج أن أعلى كمية من الغاز الحيوي وغاز الميثان تم إنتاجها عند معاملة روث الجاموس بـ ٣٧,٥% من سائل الكرش في الخليط الكلي على الرغم أن العديد من المراجع أظهرت أن أعلى كمية من الغاز الحيوي وغاز الميثان أنتجت عند المعاملة بـ ٥٠% من سائل الكرش في الخليط الكلي. لذلك، يجب دراسة تأثير تركيز سائل الكرش على إنتاج الغاز الحيوي و غاز الميثان بشكل مكثف.