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EFFECT OF SOME ENVIRONMENTAL CONTROL PARAMETERS AND RETENTION TIME ON BIOGAS PRODUCED FROM WASTES OF BUFFALO FEEDING

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Abstract

The biogas could be produced from farm animals and poultry wastes, as well as plant residues. This research work was carried out at Abu-Ghaleb Village, Northern of El-Giza governorate, Egypt to evaluate the biogas production and its components for dry and wet fermentation of buffalo wastes and feeding buffalo wastes at temperatures of 35, 45 and 55 ºC and retention times 60, 45 and 30 days. The biogas production was evaluated according to standard conditions (STP).The typical fermentation unit was designed in this study on a continuous basis. The fermentation unit was set up at one stage using a 0.39 MPa pressure at a fixed rate. This pressure was chosen to allow the use of a magnetic pump to give the requirements for this rate of disposal. Fixed during operation during observation phase. The best temperature was 55ºC, which gave the maximum biogas production rate (7.95 liter/day), cumulative (477.0liters) and methane percentage (65.78%) from minimum retention time (30 days). The best fermentation type was wet fermentation (20% ST), which gave the highest biogas production rate and cumulative and minimum retention time as compared with dry fermentation (40% ST). The buffalo waste gave the highest biogas production rates and cumulative and minimum retention time compared with feeding buffalo wastes. It is possible to conclude that the high temperature and high moisture content catalyzes production of biogas with better qualities.

Keywords : Biogas, Buffalo waste, Wet, Dry, Fermentation unit, Methane, Feeding waste.

Introduction

Energy maintains our entire economic system and supplies us with comfortable lives, for example, transports us, machines fuel and cooks our food. The amount of energy that fossil fuels could provide is ultimately limited. This means that the energy supply of the future needs solutions at the present. For sufficient energy in future centuries, it is essential to further develop the utilization of renewable energy sources. Renewable energy resources can be defined as energy resources that are replaced rapidly by natural processes. It can be divided into geothermal, hydroelectric, solar, wave tidal, wind and biomass.

Biogas technology depends on the anaerobic fermentation of solid and liquid wastes and is based on the treatment of sewage and plant and animal wastes and garbage in an economical and safe.

The biogas can be used directly in cooking. A cubic meter can operate a 10-foot refrigerator for 1-2 hours. Biogas is composed of two layers, one liquid and the other solid. Biogas is an important source of renewable energy, which refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. It was produced by anaerobic fermentation with anaerobic organisms, which digest material inside a closed system, or fermentation of biodegradable materials Jagadabhi (2011).The fermentation process takes place at mesophilic (35- 42 °C) or thermophilic (45-60 °C). It is important to keep a constant temperature during the fermentation process, as temperature changes or fluctuations will affect the biogas production negatively (Karakashev *et al*., 2005).

The livestock produce large quantities of waste materials, which is an excellent raw material for production of biogas. The quantity of biogas, which can be manufactured from various types of animal excrements and other agricultural wastes, depends on the organic matter content and the degree of decomposition of organic matter in the process of anaerobic fermentation (Ošlaj and Bogomir 2010). Dry fermentation of kitchen waste and chicken manure. Results vary a lot due to heterogeneity of food. In general, kitchen bio wastes are considered as good substrates for anaerobic fermentation (AD), especially for co-fermentation (Kuglarz *et al*., 2011). Methane (CH_4), a pungent and colorless gas, has caused significant environmental and health concerns at local, regional, and global scales. Methane's potential detriments to the environment include acidification of the ecosystem through nitrification and leaching, eutrophication of surface water and formation of particulate matter ($PM_{2.5}$) (Anderson *et al*., 2003). Deposition of methane emissions from intensive agricultural activities contributed to eutrophication of nearby bodies of water, such as Lake Erie and Chesapeake Bay (Gay and Knowlton, 2005; Hribar, 2010). Packed-bed Processing unit were widely used in Europe for reduction of CH_4 emissions. However, this type of fermentation units naturally has high air resistance or pressure drop problems. The packed-bed material easily clogs with dust accumulation, which consequently reduces the fermentation unit efficiency. Shah *et al*. (2008) developed a regenerating fermentation unit for CH_4 reduction using alum solution as the scrubbing liquid that achieved 58% efficiency with a pressure drop of approximately 110 Pa. Spray Processing unit cause very low pressure drop and therefore are promising for application at AFOs in the U.S., where large numbers of axial fans are used for ventilation of large animal fattening (Manuzon *et al*., 2007). The effluent of acid Processing unit also has potential to be used as N fertilizer for crops. Manuzon *et al*. (2007) developed a prototype spray acid fermentation unit that could achieve 30% to 60% removal efficiency for inlet CH_4 concentrations ranging from 100 to 5 ppm, respectively, with a backpressure of 27.5 Pa on the fans. Significant droplet interaction (droplet coagulation and breakage) and droplet entrainment, which affected CH_4 removal efficiency and accumulated staging effects of the acid spray fermentation unit, were observed in the lab by Manuzon *et al*. (2007). Had-locon *et al*. (2014) resolved the above-mentioned droplet interaction problem with a modular design and a laboratory optimization study of the spray fermentation unit module (SSM), which resulted in much higher CH_4 removal efficiencies of 87% to 99% for air streams with CH_4 concentrations ranging from 100 to 5 ppm. Acid spray fermentation unit prototypes for buffalo operations need to be developed based on the SSM.

This research was carried out to increase the production of biogas and its components resulting with the fermentation unit was set up at one stage from buffalo wastes and feeding buffalo wastes using the dry and wet fermentation process and decrease the retention time for decomposition of wastes.

Materials and Methods

The experiments were conducted in the private farm at Abu-Ghaleb village, Giza, Egypt.

MATERIALS

Wastes type

The buffalo wastes consists of cattle dung, that were collected from cattle farm, while the feeding wastes of buffalo samples were obtained from the remaining foods in the kitchen, such as plant residues. The wastes were analyzed for chemical characteristic such as total Solids, organic carbon, nitrogen, potassium and phosphorus percentage as shown in Table (1). To achieve the dry fermentation, cattle dung was used without adding water, while at wet fermentation; water was added to the different prepared raw materials to configure a composite of desired total solids concentration of 10% as recorded by Zennaki, *et al*. (1996).

The Digesters

A six laboratory glass digesters were used to carry out twelve treatments. Each digester volume was 5 liters and connected with tow plastic Jars, one filled with water to receive the produced gas, and the other was empty to receive the displaced water as a result of biogas production. The volume of displaced water was equal to biogas produced volume as shown in Fig. (1). Four digesters were installed inside water path which provided with electric heater 1200 W to keep the temperature at the desired level. The other two digesters were remained in the 35^o C temperature.

Instruments

The pH meter type of (daigger 5500) ranged from -6.00 to 20 and an accuracy of +/-0.01was used to measure the pH values for the organic waste.

A Biogas analyzer (GA 5000) was used to measure the percentage of CH_4 (0-100%), CO_2 (0-100%), O_2 (0-25%), H_2 (0-1000ppm) and H_2S (0- 10,000ppm) in the biogas.

The temperature of biogas digester was measured using thermometer in a range of (0-100 ˚C) with an accuracy of 1˚C.

A flow meter was used to measure volumetric flow rate of a biogas (liter per minute) with an accuracy of +/-0.01. An electric oven was used to dry samples with temperature range of 40 - 250ºC and accuracy of 1 ºC. An incineration oven (wise therm) was used to incinerate samples with ranged from 300 to 1000 ºC with an accuracy of 1ºC.

A flame photometer was used for determination of potassium (K). Spectrophotometer was used to the routine determination of nitrogen (N) and phosphorus (P) in input and output material Methods:

Laboratory experiments were carried out to evaluate the performance of the anaerobic digesters for producing biogas from organic wastes. All experiments were operated at pH ranged of 6-8 and retention times ranged from 40-75 days. The total solid of dry fermentation was about 30% TS, while the total solid of wet fermentation was about 10%. The amount of water required to adjust the total solids of slurry was calculated as follows according to Lo *et al*. (1981).

$$DW=Rm\ (TSm-TSdig\ /\ TSdig)$$

Where:

DW = dilution water required, kg;
Rm = amount of raw materials added, kg;
TSm = total solid fraction of raw materials; % and,
TSdig = total solids of fermentation materials, %.

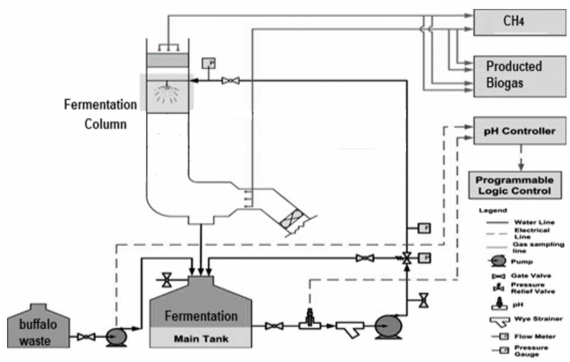


Fig. 1 : Schematic of the fermentation unit design, monitoring and measurement instrumentation, and farm experiment setup.

The experiment was carried out with liquid recirculation until a desired concentration of $(NH_4)_2SO_4$ was achieved in the solution. The scrubbing capacity of the re-circulating liquid was maintained by controlling its pH at an optimum level of 1.80. Above this value, a relay was switched on to pump 50% acid to the main tank. Due to evaporation loss at the fermentation unit vent, water was added periodically to maintain the volume solution of 568 L.

Field Experiment Plan

The typical fermentation unit was designed in this study on a continuous basis. The fermentation unit was set up at one stage using a 0.39 MPa pressure at a fixed rate. This pressure was chosen to allow the use of a magnetic pump to give the requirements for this rate of disposal. Fixed during operation during observation phase.

FIELD INSTRUMENTATION AND SAMPLING

Biogas and Methane Measurements

Methane concentrations were measured at the inlet and outlet ports of the fermentation unit. These were determined using a photo-acoustic CH_4 analyzer that was calibrated for CH_4 within the range of 0 to 100 ppm_v with an accuracy of ± 2 ppm_v (Chilgard RT CH_4 analyzer, MSA, Inc., Pittsburgh, Pa.). The sensor could operate in a temperature range of 0°C to 50°C and relative humidity range of 0% to 95% and produce 90% of the response within 70 sec after detecting a step change in input concentration. Sample air was drawn into the photo-acoustic sensor at a minimum flow rate of 0.75 L min^{-1} through a particulate filter and a solenoid valve. The three-way solenoid valve was controlled with a relay to switch sampling between the inlet and outlet ports every 30 min. Data were acquired by obtaining the 4 to 20 mA and 0 to 2.5 mV analog output of the instrument at 5 min logging intervals. The last three data obtained per switching cycle were averaged and considered the hourly average CH_4 concentration for each sampling part.

The photo-acoustic sensor may not function properly in very humid conditions. In order to verify the CH_4 concentration obtained with this instrument, another wet chemistry method to obtain average CH_4 concentrations was used (Fig. 2). In this method, 200 mL of 4% boric acid solution was placed in an Erlenmeyer flask with two drops of mixed indicator (0.5 g methyl red and 0.5 g Bromo cresol green in 520 mL ethanol and 480 mL water). The solution turns pink in an acidic solution. CH_4-laden air was bubbled into the solution at a flow rate of 1 L min^{-1}, and the setup was run for 72 h. As CH_4 came into contact with the boric acid solution, the color of the solution turned from pink to green. The samples were collected and titrated with standardized 0.5 N HCl. Air samples from both the inlet and outlet fermentation unit ports were tested with replicates. The CH_4 concentration was calculated using equations 1 and 2 measured using weatherproof HOBO data loggers (U23 Pro, Onset Computer Corp., Bourne, M ass.) with built-in sensors. The accuracies of the temperature and RH sensors are ± 0.2°C from 0°C to 50°C and ± 2.5% from 10% to 90% RH, respectively. Both sensors have 90% response within 5 min in air moving at 1 m s^{-1}. The sensors were set to log data every 2 min during the field experiment. Automatic readout was done using the product software (HOBO ware Pro) with an optic USB base station.

Air speed was measured periodically using a velocity meter (Velocicalc 8345, TSI, Inc., Shoreview, Minn.), traversing the duct to obtain the average measurement (ASHRAE, 2009). The airflow rate was calculated based on the calculated average speed.

Static pressure drop on the fan caused by the restriction of the entire fermentation unit and its components was measured using a manometer (Durablock, Dwyer Instruments, Inc., Michigan City, Ind.). Figure 3 shows the locations where static pressure was measured. The 45° transition after the fan was not considered part of the restriction, as most representative farms do not necessarily have fans installed in this orientation.

Liquid Phase Measurements

The pH of the fermentation unit liquid is the primary measurement for the acidity of the solution. It was controlled and monitored using a pH controller and transmitter (PHCN-961, Omega Engineering, Inc., Stamford, Conn.) that can display pH values from -2 to 16 with an accuracy of ±0.01 pH. The instrument can be operated from -10°C to 50°C (14°F to 122°F). The data were obtained from the 4 to 20 mA analog output of the controller using an Onset data logger. The sensing electrode for pH is an in-line flat-surface electrode (PHE-5460, Omega Engineering, Inc., Stamford, Conn.) that can be used at temperatures from 0°C to 88°C (32°F to 190°F) and up to 100 psi_g pressure.

Figure (3) showing A Biogas analyzer (GA 5000) was used to measure the percentage of CH_4 (0-100%), CO_2 (0-100%), O_2 (0-25%), H_2 (0-1000ppm) and H_2S (0- 10,000ppm) in the biogas.

The temperature of biogas digester was measured using thermometer in a range of (0-100 ºC) with an accuracy of 1ºC. flow meter was used to measure volumetric flow rate of a biogas (liter per minute) with an accuracy of +/-0.01. An electric oven was used to dry samples with temperature range of 40 - 250ºC and accuracy of 1 ºC. An incineration oven (wise them) was used to incinerate samples with ranged from 300 to 1000 ºC with an accuracy of 1ºC. A flame photometer was used for determination of potassium (K). A Spectrophotometer was used to the routine determination of nitrogen (N) and phosphorus (P) in input and output material.

Experimental Conditions:

The different studying factors were experimented as shown in Fig. (4).

The collected data were analyzed by general descriptive statistical analysis. The data were analyzed with JMP 10.0 (SAS Institute, Inc., Cary, N.C.) using analysis of variance (ANOVA), t-tests for paired comparisons, and Tukey-Kramer honest significant difference (HSD) for pair wise mean comparisons at a 95% confidence interval. Scatter plot and regression analysis were used to compare results of two methane measurement methods.

Results and Discussion

The current study investigated to evaluate the biogas production rate and its components for dry and wet fermentation of buffalo wastes and feeding buffalo wastes at temperatures of 35, 45 and 55 °C and retention times 60, 45 and 30 days. The biogas production was determined at the standard conditions (STP).

The effect of temperature on biogas production rate at wet 20%-total solids (ST) and dry 40%-ST fermentation for different wastes was investigated. The obtained results were illustrated in Table (1) and Figs. (5 and 6).

The results indicated that the highest biogas production rate was at temperature of 55°C at different wastes and fermentation types followed by 45°C and 35°C temperature respectively.

The highest biogas production rate at temperature of 55°C for wet fermentation was 7.95 liter/day at the 30^{th}day for buffalo wastes, while was 3.32 liter/day in the 30^{th}day for feeding buffalo wastes. While these values at 45ºC were; 5.73 liter/day in the 30^{th}day for the buffalo wastes and 2.57 liter/day in the 55^{th}day for feeding buffalo wastes. The lowest value was 2.67 liter/day in the 60^{th}day for buffalo wastes and 1.27 liter/day in the 60^{th}day for feeding buffalo wastes at 35°C temperature. The lowest retention time was 35 and 45 days at farm and feeding buffalo wastes respectively at the highest temperature of 55°C, followed by 45 and 60 days at 45°C with the same wastes respectively. The highest retention time was 30 and 45 days for buffalo and feeding buffalo wastes respectively at 55°C temperature.

The highest biogas production rate at temperature of 55°C for dry fermentation was 4.85 liter/day at the 30^{th}day for buffalo wastes, while was 2.43 liter/day in the 30^{th}day at the same temperature for feeding buffalo wastes.

While these values at 45ºC were; 3.78 liter/day in the 45^{th}day for buffalo wastes and 1.89 liter/day in the 34^{th}day for feeding buffalo wastes. The lowest value was 1.89 liter/day in the 45^{th}day for buffalo wastes and 1.55 liter/day in the 45day for feeding buffalo wastes at 45°C temperature. The lowest retention time was 30 and 45 days for farm and feeding buffalo wastes respectively at temperature of 55ºC. Moreover, at temperature of 45ºC these values were 35 and 45 days for the same wastes, respectively. The highest retention time was 60 days for farm and feeding buffalo wastes respectively at 35° C temperature.

The cumulative biogas production for wet fermentation of buffalo wastes was 477.0, 257.85 and 238.5 liter at temperature of 35, 45 and 55°C, respectively, while was 123.6, 115.65 and 99.60 liter at the same temperatures for feeding buffalo wastes respectively as showed in Table (1) and Figs. (7 and 8). The cumulative biogas production for dry fermentation of buffalo wastes was 160.20, 170.10 and 145.50 liter at temperature of 35, 45 and 55°C, respectively, while was 76.20, 85.05 and 72.90 liter at same temperatures, respectively with feeding buffalo wastes as showed in Table (1) and Figs. (7 and 8).

The highest production rate of the biogas was obtained in the longest period at 55 °C. This may be due to the high growth rate of bacteria leading to fermentation and rapid decomposition, thus helping to produce biogas in the shortest possible time. The lowest temperature is 35 °C The lowest rate of biogas production compared to the upper temperature 45, 55 °C This may be due to the lack of activity of microorganisms in the low temperature and therefore we conclude that there is a relationship between the temperature and the rate of production of biogas and there is a relationship between the ratio Moisture and fermentation Production of biogas and its components, therefore it is possible to recommend the use of buffalo fattening waste at high temperatures and in the presence of a high moisture content to produce the biogas and its components better.

Fig. 2 : Portable gas analyzer (GA5000).

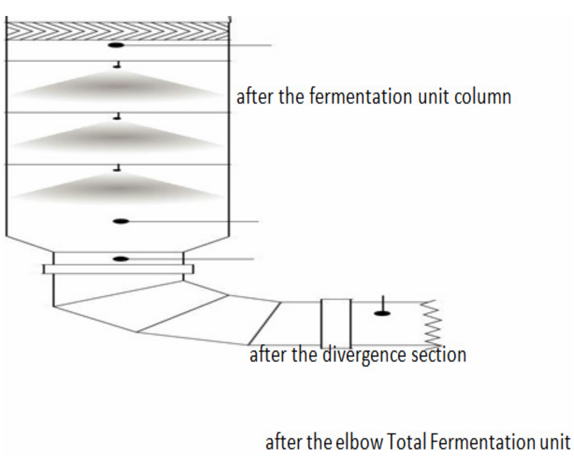
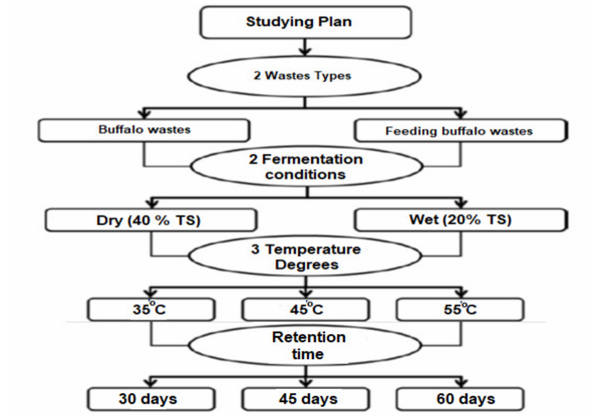


Fig. 3: Measurement locations of static pressure.



TS: Total Solids

Fig. 4 : Study plan and Factors.

Table 1 : The effect of different temperatures, buffalo waste, fermentation types on biogas production rates and cumulative.

Waste type	Fermentation Conditions	Temp °C	Retention time (day)	Biogas (Liter/ day)	Cumulative (Liter)
Buffalo waste	Wet (20% ST)	55	60	4.54	477.0
		45	45	5.73	257.85
		35	30	7.95	238.50
	Dry (40% ST)	55	60	2.67	160.20
		45	45	3.78	170.10
		35	30	4.85	145.50
	Mean			**4.92**	**241.525**
Feeding buffalo waste	Wet (20% ST)	55	60	2.06	123.60
		45	45	2.57	115.65
		35	30	3.32	99.60
	Dry (40% ST)	55	60	1.27	76.20
		45	45	1.89	85.05
		35	30	2.43	72.90
	Mean			**2.26**	**95.50**
	LSD 0.05			**0.08**	**1.11**

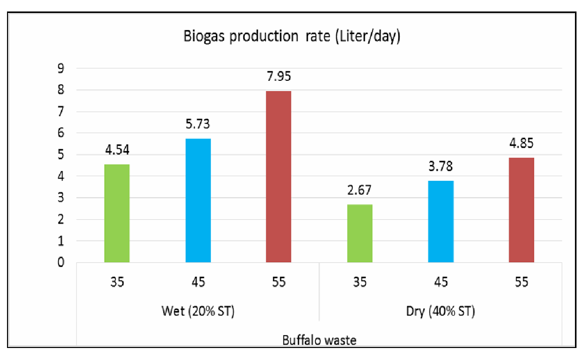


Fig. 5 : Effect of buffalo waste, fermentation conditions and temperature on biogas production.

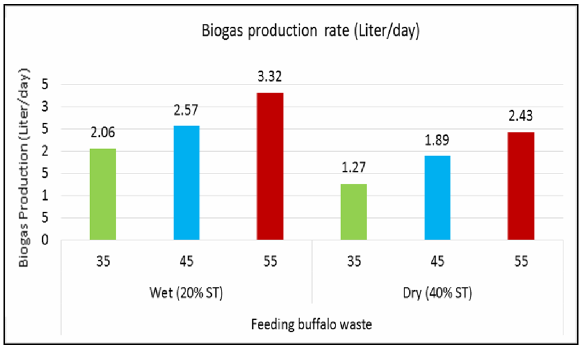


Fig. 6 : Effect of feeding buffalo waste, fermentation conditions and temperature on biogas production.

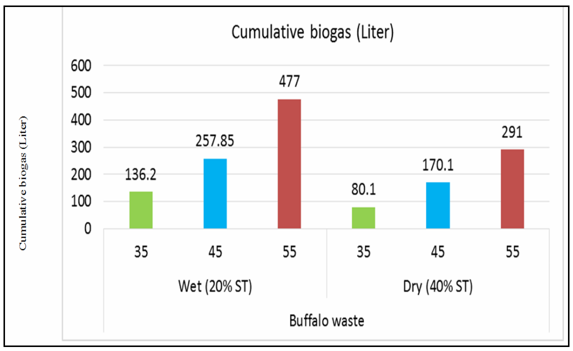


Fig. 7 : Effect of buffalo waste, fermentation conditions and temperature on cumulative biogas production.

Effect of Waste Type

The buffalo wastes gave the highest biogas production rate at different temperatures and fermentation types compared with the feeding buffalo wastes as showed in Figs. (6, 7 and 8).

The highest biogas production rates for buffalo wastes of wet fermentation was 7.95, 5.73, and 4.54 liter/day at temperature of 55, 45, and 35 °C temperature ˚C respectively, while was 3.32, 2.57, and 2.06 liter/day for feeding buffalo wastes at the same temperatures, respectively.

The highest biogas production rate for dry fermentation of buffalo wastes was 4.85, 3.78, and 2.67 liter/day at temperature of 55, 45 and 35 °C temperature ºC respectively, while was 2.43, 1.89 and 1.27 liter/day for feeding buffalo wastes at the same temperatures respectively.

The lowest retention time was 30 days for wet fermentation of buffalo wastes at temperature of 35 ºC, while the highest retention time was 60 days for dry fermentation of feeding buffalo wastes at 55°C temperature.

It was observed that the daily and cumulative biogas production for buffalo wastes was higher than feeding buffalo wastes for all experiments. This may be due to the buffalo wastes consist of cow manure, which is semi digested residue of plant matter which has passed through the animal's gut. The resultant matter is rich in minerals and bacteria, while feeding buffalo wastes consists of the undigested remains of food in the kitchen, so that fermentation microorganisms needs more time to digest the organic matter in feeding buffalo wastes to produce biogas. So it is better to produce the biogas from buffalo wastes.

Effect of Fermentation Type

The obtained results showed that, the wet fermentation gave higher biogas production rate, cumulative production and shorter retention time as compared with the dry fermentation for all temperatures and wastes. The highest biogas production rate was 7.95 liter /day with wet fermentation of buffalo wastes and temperature of 55ºC, while the lowest value was 1.27 liter/day with dry fermentation of feeding buffalo wastes at 35°C temperature. The highest and lowest cumulative biogas productions were 477 and 72.9 liter and they occurred at the same conditions and wastes, respectively as showed in Table (2).

On the other hand, the wet fermentation gave the shorter retention time of 30 days at buffalo wastes and temperature of 55ºC compared with 60 days at feeding buffalo wastes and 35°C temperature.

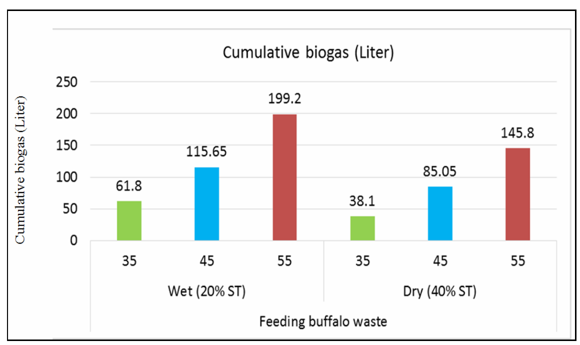


Fig. 8 : Effect of feeding buffalo waste, fermentation conditions and temperature on cumulative biogas production.

Effect of different studying factors on biogas components:

The biogas components are dependent on the type of feed stocks and to some extent on the technique used in the fermentation process. The effects of temperature, waste types and fermentation type on biogas components were evaluated and the obtained results are listed in Table (2) and Figs. (9, 10, 11 and 12).

Table 2 : The effect of different temperatures, buffalo waste, fermentation types on biogas components

Waste type	Fermentation Conditions	Temp (°C)	Biogas components CH_4 (%)	CO_2 (%)	H_2S (ppm)
Buffalo waste	Wet (20% ST)	35	62.34	37.66	20.45
		45	63.87	36.13	31.63
		55	65.78	34.22	12.12
	Dry (40% ST)	35	62.56	37.44	21.82
		45	63.54	36.46	32.51
		55	64.21	35.79	11.23
Mean			**63.72**	**36.28**	**21.63**
Feeding buffalo waste	Wet (20% ST)	35	55.57	44.43	34.67
		45	54.34	45.66	22.49
		55	53.26	46.74	26.34
	Dry (40% ST)	35	48.38	51.62	33.25
		45	51.69	48.31	25.37
		55	52.45	47.55	28.91
Mean			**52.62**	**47.39**	**28.51**
LSD 0.05			**0.07**	**0.05**	**0.32**

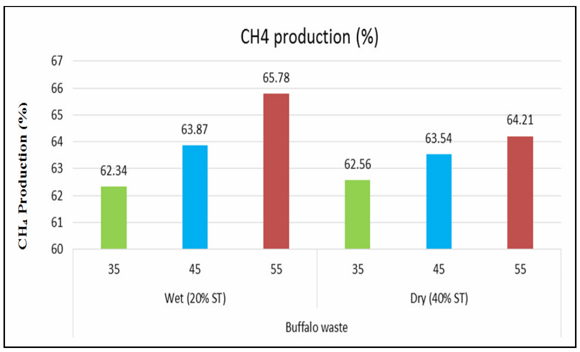


Fig. 9 : Effect of buffalo waste, fermentation conditions and temperature on methane production.

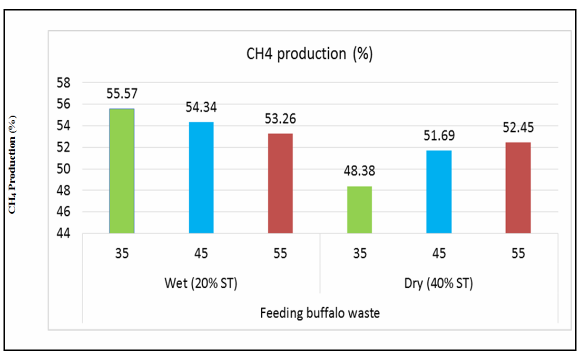


Fig. 10 : Effect of feeding buffalo waste, fermentation conditions and temperature on methane production.

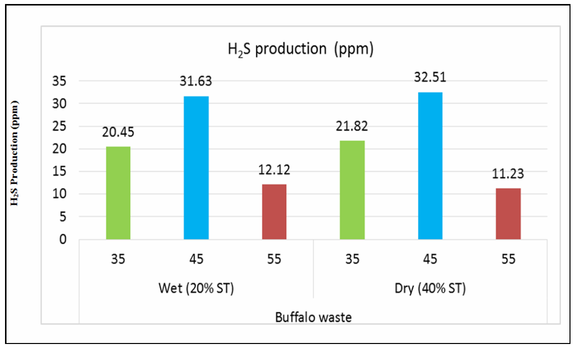


Fig. 11 : Effect of buffalo waste, fermentation conditions and temperature on Hydrogen dioxide production.

It was observed that the highest methane percent was 65.78% at wet fermentation of buffalo wastes with temperature of 55ºC, while the lowest methane percent was 48.38% at dry fermentation of feeding buffalo wastes with 35°C temperature. On the other hand, the methane percentage in biogas production from buffalo wastes was higher than that production from feeding buffalo wastes. In addition, the wet fermentation process was giving higher methane content as compared with dry fermentation process. The results also, clear that there is no significant difference in methane content at different fermentation temperatures but there was slight increase in methane content at temperature of 60 ºC as compared with the other two temperatures.

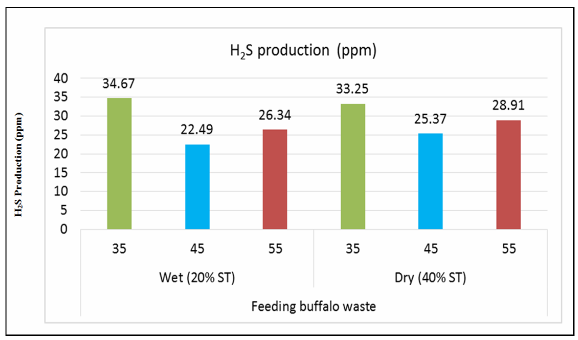


Fig. 12 : Effect of feeding buffalo waste, fermentation conditions and temperature on Hydrogen dioxide production

Conclusions

This research work was done to evaluate the biogas production and its components under different fermentation conditions under two types of wastes (buffalo and feeding buffalo) at three levels of temperature (55, 45 and 35ºC) and three retention times using wet and dry fermentation. This research was carried out at Abu-Ghaleb village, North of El-Giza governorate to: evaluate the biogas production and its components from buffalo and feeding buffalo wastes, increase the production of biogas and decrease the hydraulic retention time.

The highest production rate of the biogas was obtained in the longest period at 55 °C. This may be due to the high growth rate of bacteria leading to fermentation and rapid decomposition, thus helping to produce biogas in the shortest possible time. The lowest temperature is 35 °C The lowest rate of biogas production compared to the upper temperature 45, 55 °C This may be due to the lack of activity of microorganisms in the low temperature and therefore we conclude that there is a relationship between the temperature and the rate of production of biogas and there is a relationship between the ratio Moisture and fermentation Production of biogas and its components, therefore it is possible to recommend the use of buffalo fattening waste at high temperatures and in the presence of a high moisture content to produce the biogas and its components better.

In general, the following conclusions can be summarized:

1- The best temperature was 55ºC, which gave the maximum biogas production rate (7.95 liter/day), cumulative (477.0 liter) and methane percentage (65.78%) and minimum retention time (30 days). Followed by temperature of 45ºC and 35ºC temperature, respectively.
2- The best fermentation type was wet fermentation (20% ST), which gave the highest biogas production rate and cumulative and minimum retention time as compared with dry fermentation (40% ST).
3- The buffalo waste gave the highest biogas production rates and cumulative and minimum retention time compared with feeding buffalo wastes.

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