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EFFECT OF HEATING, MIXING AND DIGESTER TYPE ON BIOGAS PRODUCTION FROM BUFFALO DUNG

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ABSTRACT

Egypt has 3.43 million head buffalo and they produce about 3.5 million-ton/year of dung as air-dried material. The uncontrolled handling and storage of dung causes loss of organic matter, environmental pollution, methane emissive and a bad smell. The anaerobic digestion is one of the common technologies used for recycling organic wastes. Laboratory bench-scale biogas digester 22 liter capacity and 17 liter digestion volume (3 horizontals and 3 verticals type) were used for batch anaerobic digestion system of 95 day hydraulic retention time of buffalo dung 6.30 OTS% to study the effect of temperature, mixing and digester type on biogas production and methane content. The obtained results show that the biogas produced ranged between 104.7 to 468.1 L kg^{-1} organic total solid (OTS) while methane yield ranged between 69.2 to 284.1 L kg^{-1} OTS. The highest biogas yield was observed in vertical digester (468.1 L kg^{-1} OTS) compared to horizontal digester (353.1 L kg^{-1} OTS) in the cases of mixing and heating treatments. Meanwhile, the horizontal digester produced biogas (293.2 L kg^{-1} OTS) more than vertical digester (179.0 L kg^{-1} OTS) without mixing under room temperature. Similarly, the degradation percent of buffalo dung (expressed as organic carbon degradation, %) was increased in vertical digester compared to horizontal digester with mixing and temperature treatments. Consequently, the biogas and methane production were positively correlated with the temperature. Therefore, the maximum biogas yield was recorded in vertical digester with heating and mixing conditions. Maximum enhancement in biogas production over the control could be well correlated with maximum reduction in OTS and C/N ratio of buffalo dung manure.

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Therefore, we concluded that the amount of biogas production was not only depending on the type of digester but also affected by other parameters, i.e. mixing and heating conditions of the digester. The quantitative variations in biogas production were related with OTS, C, N and C/N ratio of the buffalo dung used.
Keyword: *Anaerobic digestion, Batch fermentation, Biogas and methane production, Buffalo dung*

INTRODUCTION

Anaerobic digestion of organic matter with a simultaneous production of biogas is an environmentally attractive way for the treatment of organic waste. Egypt has 3.43 million head buffalo **(FAO, 2001)** and they produce about 3.5 million-ton/year of dung as air-dried material. The uncontrolled handling and storage of dung causes loss of organic matter, pollution and odour problems **(Reinecke *et al.*, 1992)**. **Hamdy (1998)** mention that about 60% of Farmyard wastes are used as fuel by direct burring in low efficiency burners and 20% of the animal wastes are used as organic fertilizer and the rest is lost in handling. **Viesturs *et al.* (1995)** mentioned possible technologies for biomass conversion with energy production, such as thermal processes, hydrolysis, enzymatic hydrolysis and with microorganisms (aerobic and anaerobic). The choice of a certain technique depends on composition of the material as well as the advantages and the drawbacks of such technique. The thermal processes, chemical hydrolysis and enzymatic reactions are not considered for the complexity, high cost and high- tech of such technologies to be applied on farm scale.

Biogas is a form of energy produced when organic material such as buffalo dung is left over from agriculture wastes; also it is a major source of the substrate in a biogas plant. 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. During this process, the important plant nutrients, such as nitrogen, potassium, phosphorous and calcium present in feed material are converted into forms that are much more soluble available to plants than those in the parent compounds **(Ndegwa and Thompson, 2001)**. The buffalo discharge was ranged between 8 to 12 kg/animal/day **(Rofiqul *et al.*, 2006)**, 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% **(Shilpkar *et al*. 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 0.2-0.26 m^3 of biogas **(DGS, 2006)**.

Lehtomäki *et al.* (2007) reported that the ultimate methane yield can be determine in a batch experimental when the biomass fibrously and strongly analyzable. The contents are continuously mixed, which facilitates good distribution of the nutrients and bacteria **(Vandeviviere *et al.*, 2002)**. The organic material is loaded in the digester and digested for the period for 30-180 days hydraulic retention time, which depending on ambient temperature and other factors such as mixing and total solids. This fermentation can be conducted at normal solids content of 6-10 TS% **(Marchaim, 1992)**.

köttner (2003) reported that the process of anaerobic digestion is running at its optimum temperature range of 25 to 38°C (mesophilic conditions), the latter prefer temperatures in the range of 38°C are greater stability of digestion process, easier to control and utilized in about 95 percent of all digesters. Furthermore, a mesophilic treatment at 38°C reportedly destroys 99.9% of pathogens **(Erickson, *et al.*, 2004)**. Other researchers suggested that an increase in the temperature resulted in a reduction of the biogas yield, due to the increased inhibition of free ammonia (NH_3) which increases with increasing temperature **(Angelidaki and Ahring, 1994; Hansen *et al.*, 1999)**.

Kalia and Singh (1998) and **(Shilpkar *et al.*, 2007)** pointed that the C/N ratios of fresh cattle dung and fresh buffalo dung are 38.1 and 29.0, respectively. **Kayhanian and Hardy (1994)** reported that C/N ratios between 25 and 30 as being optimal for anaerobic digestion. However, some investigators argue that the C/N of approximately from 16.8 to 18 is optimal for methanogenic performance if poorly degradable compounds such as lignin are taken into account **(Kivaisi and Mtila, 1998)**.

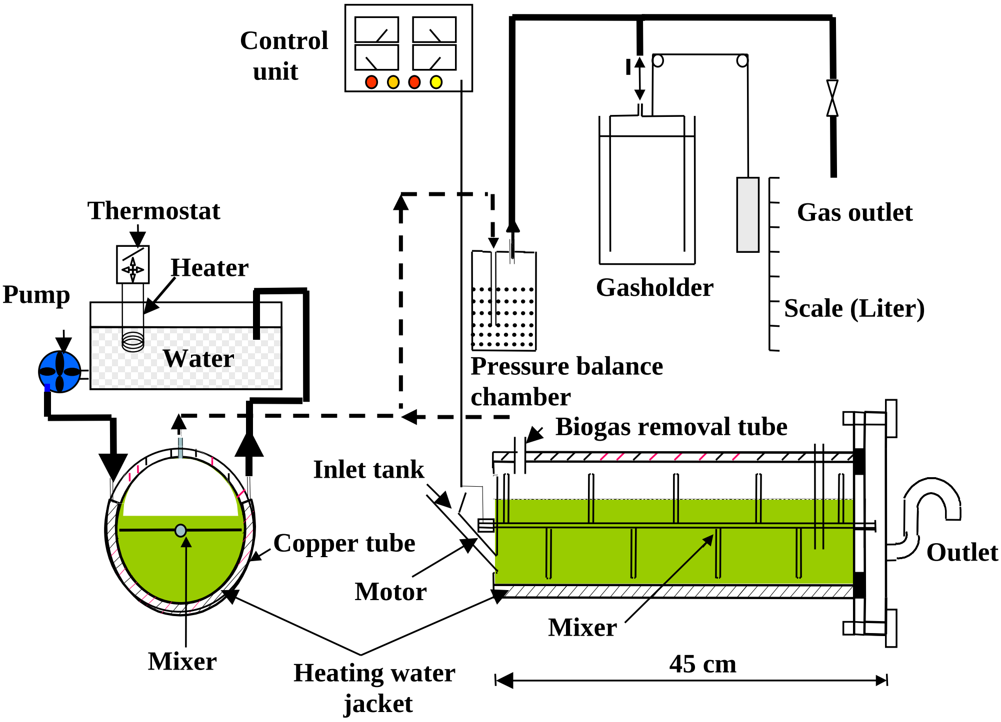
Dolfing (1992) suggested that very rapid mixing disrupts the structure of flocks in completely mixed reactors, thereby disturbing the dystrophic relationships between organisms. An intermediate degree of mixing was found to be optimal for substrate conversion **(Smith *et al.*, 1996).**

The present study aims to investigate the biogas and methane production from buffalo dung under different parameter of mixing, temperature, digester type (*i.e.* vertical or horizontal) using lab bench- scale batch system. The experiment was carried out for a period of 95 days. Biogas production was measured at 24 hr. interval by water displacement method with corresponding environmental temperature, while quantity of methane was checked using 40% potassium hydroxide **(Okeke and Ezekoye, 2006).**

MATERIALS AND METHODS

1. Bench-scale biogas digester

A bench-scale of cylindrical biogas digester (horizontal and vertical type) are shown in Figs. (1) and (2). They are 3 horizontals biogas digesters and 3 verticals biogas digesters, were constructed at the Agricultural Engineering Department, Faculty of Agriculture, Suez-Canal University. Each digester was fabricated from galvanized steel sheet of 1.5 mm thickness, 45 cm length and 25 cm diameter with total capacity of 22 liters and digestion volume of 17 liters and it has a PVC inlet and outlet tube of 50.8 mm (2 in.) diameter for feeding by organic wastes and rejecting the digested materials. To follow up the digestion processes, orifice for releasing the produced gas was provided to the digester and another for the pH-temperatures measurements. Released gas volume was collected in gasholder and determined by using the wetted displacement with a previously calibrated scale in liter.



A: Digester cross section illustrates the heating cycle

B: Longitudinal section illustrates the other components

Figure (1): Schematic diagram of horizontal bench-scale biogas digester.

A hasp mixer was mounted with the biogas digester; and adjusted automatically at 2 minute each one half hour, meanwhile a thermostatic heating unit provided the digester with a pump to adjust and temperature selector.

The bench-scale digesters were used to measure and detect the suitable operating conditions to obtain the ideal biogas production with high methane ratio for the used buffalo dung 8.96 TS% and 6.30 OTS%.

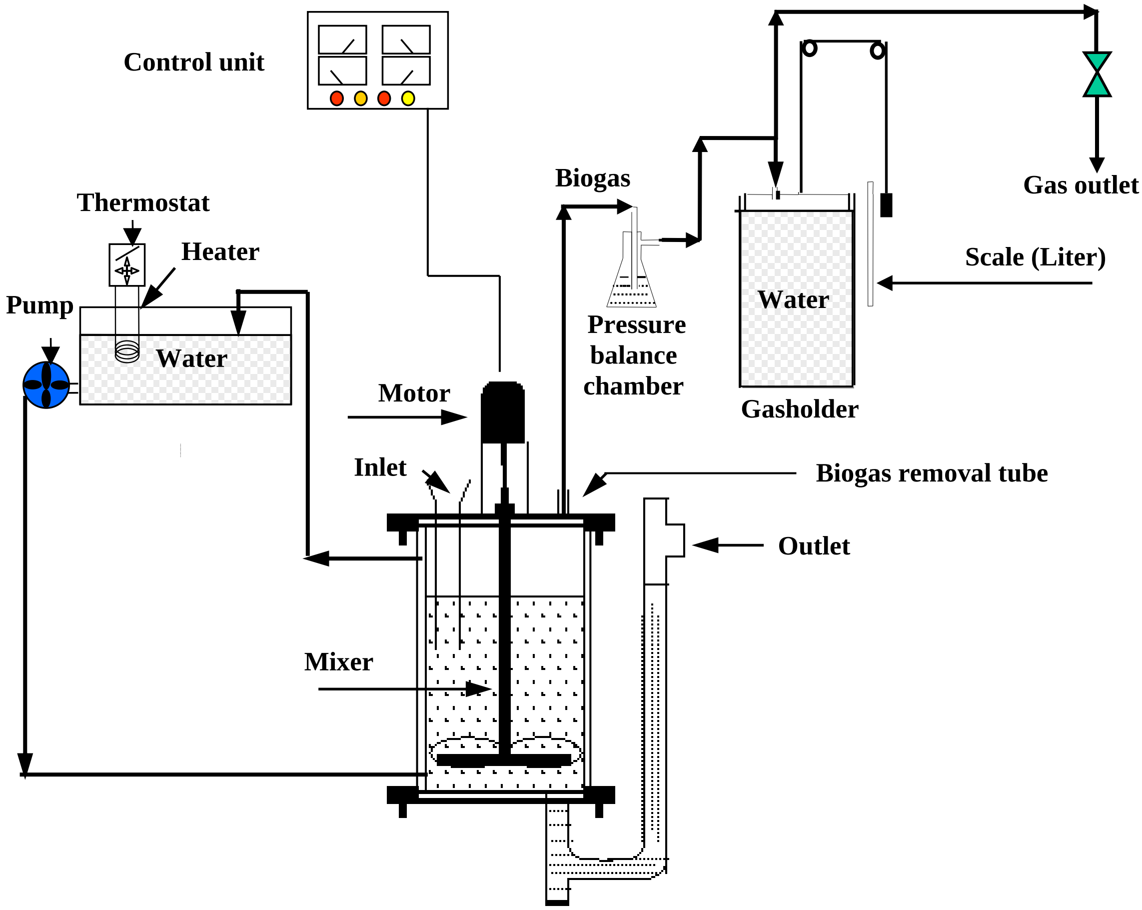


Figure (2): Schematic diagram of vertical bench-scale biogas digester.

The temperature of buffalo dung mixture was adjusted within the mesophilic region (38 ^{o}C). A thermostatic electrical heater and a centrifugal pump, operated by 90-Watt motor, were assembled with an insulated water tank to form the heating unit beside the close cycle serpentine as shown in Fig. (1, A). Copper tube of 7.5 m length, (9.53 mm and 8.3 mm outer and inner diameters) serpentine was coiled around the digester and was insulated using 25.4 mm thick Polystyrene slabs (Foam) to create a stable temperature water jacket around the digester.

2. Analytical methods and Instrumentation

Total solids (TS) and organic total solids (OTS) determination

The total solids percentage (TS%) and its contents of organic total solids percentage (OTS%) for the fresh dung substance also at the outlet orifice were determined in this study. Samples of 80 to 100 grams were used, dried for 24 hours at 105 ^{o}C then the samples total solids were weighted using Ohaus® digital balance till reaching the equilibrium. To determine the organic total solids contents percentage in the dry solids of each sample. The dry solids were dried at 560 ^{o}C in muffle oven; the TS% and OTS% were calculated from the following formula (**DEV, 1971)**:

$$TS\% = \frac{M_{TS}}{M_f} \text{x} 100 \qquad (1)$$

$$OTS\% = \frac{M_{ash} - M_{TS}}{M_f} \text{x} 100 \qquad (2)$$

Where: M_f is the fresh mass, M_{TS} is the mass of total solids and M_{ash} is the ash mass

Meanwhile, the organic total solids (OTS) mass in kg was determined from **Wittmaier (2003)**

$$OTS = M_f \text{ x } OTS\% \qquad (3)$$

Daily biogas production

During the batch fermentations the released gas volume in liter everyday was measured laboratory using the wetted displacement with a previously calibrated scale are shown in Figs. (1) and (2).

Methane percentage

The daily released biogas was fractioned in a percentage *i.e.* methane and CO_2 percentage using the Potassium hydroxide 40% **(Okeke and Ezekoye, 2006).**

Daily methane yield

Daily volume of the methane yield in liter was determined by the multiplication of the daily biogas yield in liter (which was determined from the previous step) by the same daily percentage of the methane.

Degradation ratio

The degradation ratio of organic matter was determined each 5 days along the hydraulic retention time (HRT) 95 day and averaged. It was determined as the percentage of the difference between the OTS from the beginning of the experiments and after five days divided by the OTS at the beginning according to the following equation:

$$DR,\% = \frac{\text{OTS at the begining} - \text{OTS after 5 days}}{\text{OTS at the begining}} \text{x}100 \qquad (4)$$

Digester specific of biogas and methane production

The digester specific of biogas and methane produced was determined in liter/liter.day. The amount of the biogas obtained along the HRT was collected and divided on the period of the HRT to obtain the average daily gas volume in liter/day, which was divided by the digestion volume in liter to obtain the average digester specific gas yield in L/L.d.

Temperature and pH

The temperature also the pH value of the buffalo dung solution inside the bench-scale digesters were regularly daily measured using Jenway pH hand held meter model 370pH/mv. The temperature of buffalo dung inside digester was adjusted within the mesophilic region (38 ^{o}C).

3. Statistical analysis

The SPSS statistical package, version 10.0 (SPSS Inc., Michigan, USA), was used for the statistical analysis. Bivariate correlations analysis was done to establish the significance of differences in both biogas and methane yield as dependent parameters and pH and digester temperature as independent parameters.

RESULTS AND DISCUSSIONS

1. Biogas and methane production

Biogas, methane yield and percentage were recorded in two type anaerobic digester under the different parameters of temperature and mixing at definite interval throughout the lab experiment. The results show that the biogas yield in vertical digester was between 104.7 to 468.1 L kg^{-1} OTS while the methane yield ranged between 69.2 to 284.1 L kg^{-1} OTS (Table 1). Concerning the horizontal digester, results in Table (1) show that the biogas and methane yield were increased with stirring and increasing temperature comparing to the without mixing under room temperature as a control. It was noticed that the biogas and methane yield were only decreased with mixing treatment. Consequently, the biogas and methane yield was positively correlated with temperature. The same trend was observed in the vertical digester. On the average, the produced biogas during the experiment contained 64.8 and 62.8% methane in the cases of both horizontal and vertical digesters, respectively. The average of methane percentage was fluctuated in two examined digesters under mixing and heating treatment. The highest percentage of methane (66.2 and 66.1%) was recorded in horizontal and vertical digester in the cases of mixing with heating and mixing without heating treatments respectively. Since the highest amount of biogas yield was observed in vertical digester (468.1 L kg^{-1} OTS) compared to horizontal digester (353.1 L kg^{-1} OTS) in the cases of mixing and heating treatments respectively. On the other hand, the horizontal digester produced biogas yield (293.2 L kg^{-1} OTS) more than vertical digester (179.0 L kg^{-1} OTS) without mixing and heating. Therefore, we suggested that the amount of biogas yield was not only depending on the digester shape but also depending on the mixing and heating the raw material. In this regard, many previous researches have suggested that the biogas production during anaerobic digestion is related to temperatures. However, different results have been reported **(Hansen *et al.,* 1999 and Chae *et al.,* 2008)**. **El-Mashad *et al.* (2004)** suggested that the digestion temperature has an influence on the ultimate biogas and methane yield as well as the methane content. In the mesophilic temperature range, 25-35 ^{o}C, the better biogas and methane were produced. In addition, the biogas yield did not linearly increase with increasing temperature. Other researchers suggested that an increase in the temperature resulted in a reduction of the biogas yield, due to the increase inhibition of free ammonia (NH_3) which increase with increasing temperature **(Angelidaki and Ahring, 1994; Hansen *et al.*, 1999)**

Table (1): Biogas and methane production under the different temperature and mixing treatments of the vertical and horizontal digesters

Digester shape	Treatments	Temperature**, °C	Biogas, L kg^{-1} OTS	Methane, L kg^{-1} OTS	Methane**, %
Horizontal	Control*	24.7	293.2	190.0	64.8
	Mixing under room temperature	25.1	171.2	109.0	63.7
	Heating and mixing	38.7	353.1	233.7	66.2
Vertical	Control*	24.9	179.0	112.4	62.8
	Mixing under room temperature	24.5	104.7	69.2	66.1
	Heating and mixing	38.1	468.1	284.1	60.7

*: Under room temperature

******: Mean values of temperature and methane percentage

2. Effect of mixing and digester type on the digester specific biogas yield

The effect of mixing on anaerobic digestion of buffalo dung was evaluated in bench scale digester at 38 ^{o}C. Because mixing duration and intensity affect on the performance of anaerobic digestion are contradictory, we used in this study the stable mixing system (2 minute each one half hour). The effect of digester type was evaluated on biogas yield under the different mixing and heating treatments. The digester specific biogas yield was greatly varied in both vertical and horizontal digester under mixing or heating. Fig. (3) shows that the digester specific biogas yield L/L.d was increased by 70% in horizontal digester compared to vertical digester under the room temperature. The same trend was observed in case mixing treatment under room temperature. The digester specific biogas yield L/L.d by horizontal and vertical digester type in case mixing treatment under room temperature less than in case without mixing under room temperature as a control. The digester specific biogas yield was ranged between 0.06 L/L.d in case mixing treatment under room temperature vertical digester type to 0.27 L/L.d in case of mixing plus heating treatment vertical digester type.

The results indicated that mixing treatment decreasing digester specific biogas yield in both digester type. The importance of mixing in achieving efficient substrate conversion has been reported by several researchers **(Stroot *et al.*, 2001; Kim *et al.*, 2002; Karim *et al.*, 2005; Vavilin and Angelidaki, 2005; Vedrenne *et al.*, 2007)**. The main factors affecting digester mixing are the mixing strategy, intensity, duration and mixer location in the system. However, the effect of mixing duration and intensity on the performance of anaerobic digesters are contradictory. Adequate mixing was shown to improve the distribution of substrates, enzymes and microorganism throughout the digester **(Lema *et al.*, 1991)** whereas inadequate mixing was shown to result in stratification and formation of floating layer of solids **(Chen *et al.*, 1990)**. In general, the obtained results show that the mixing treatment under room temperature decrease the biogas yield (Table 1) and digester specific biogas yield L/L.d Fig. (3). These results agree with **Kaparaju *et al.* (2007)** who found that the vigor mixing would result in delaying and lowering methane production.

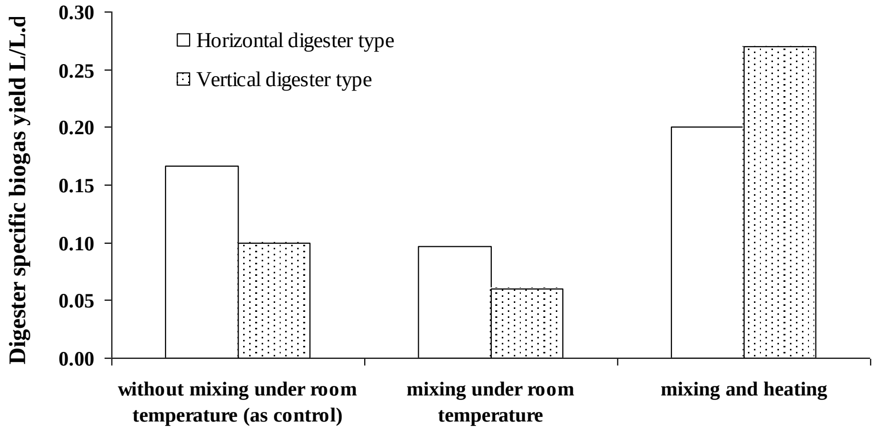


Figure (3): Digester specific biogas yield L/L.d.

The measured pH values for the anaerobic digestion of buffalo dung in vertical and horizontal digesters at experimental intervals are shown in Fig. (4). The pH values in the horizontal digester with mixing and heating treatments are slightly higher compared to under room temperature without mixing as a control. In addition, pH values not greatly affected by mixing in both vertical and horizontal digesters compared to control. The pH values were ranged from 6.98 to 7.24 and from 7.07 to 7.28 in horizontal and vertical digesters, respectively.

The pH is known to influence enzymatic activity, because each enzyme has a maximum activity within a specific and a narrow pH range. The pH of the digestion liquid material and its stability as well comprises an extremely important parameter, since methanogenesis only proceeds at high rate when pH is maintained in the neutral range. Most methanogenic bacteria function optimally at pH 7 to 7.2, and the rate of methane production declines at pH values below 6.3 or exceeding 7.8 **(Bitton, 1994; Van Haandel and Lettinga, 1994)**.

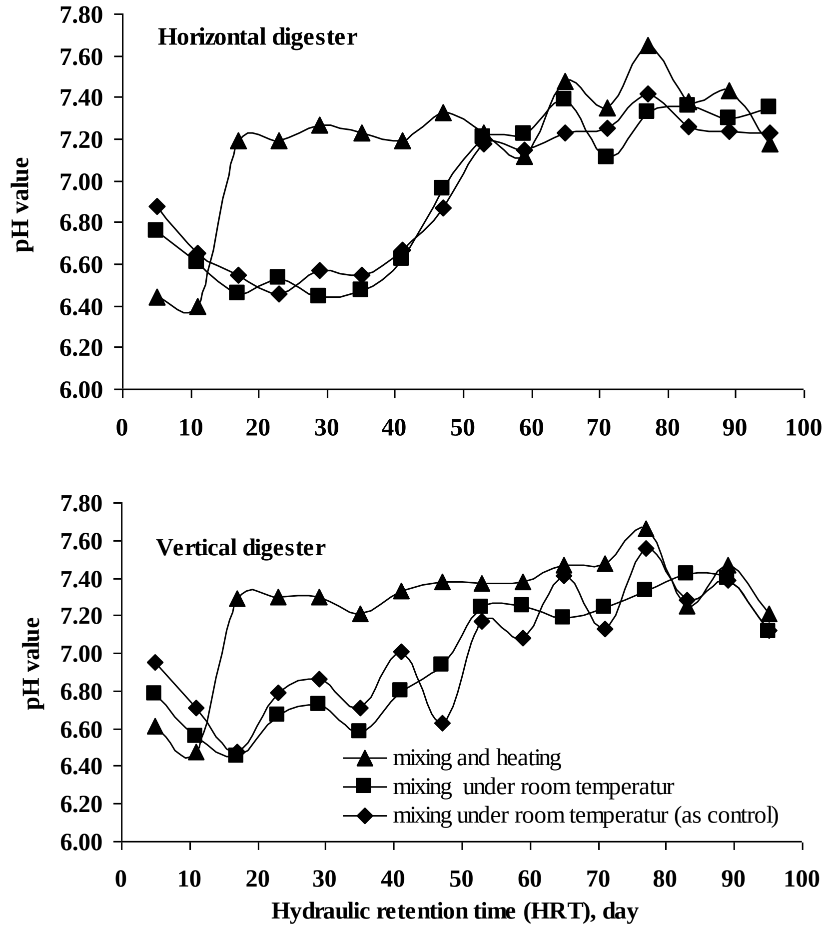


Figure (4): Change in pH values in anaerobically digested buffalo dung as affected by digester shapes and different mixing and heating at different intervals

3.3. Degradation of organic carbon

The decomposition of buffalo dung under anaerobic digestion was highly response to temperature level, mixing intensity and digester type. As shown in Fig. (5), the degradation percent of buffalo dung (expressed as organic carbon degradation, %) was increased in vertical digester compared to horizontal digester with mixing and heating treatments. Similar trend was observed with the mixing treatment under room temperature. On the other hand, under room temperature without mixing, the degradation percent was similar in both vertical and horizontal digesters.

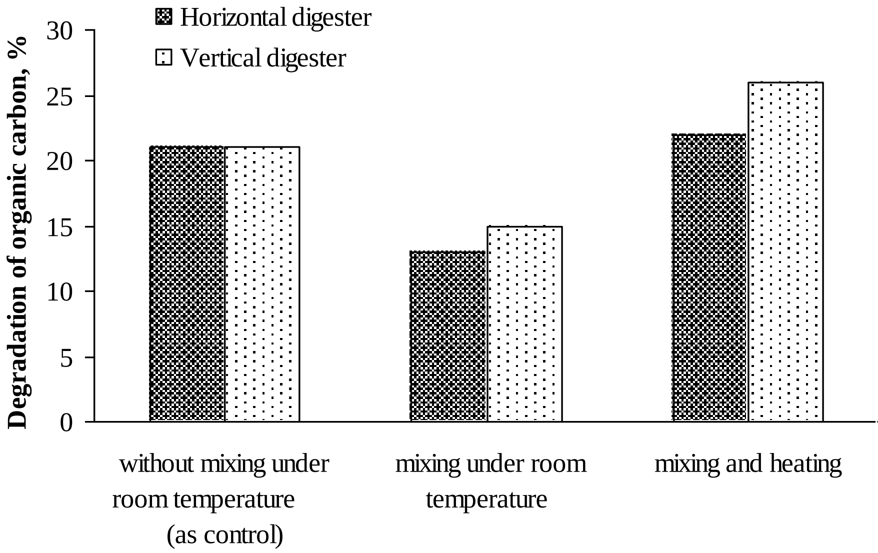


Figure (5): Effect of digester shapes, mixing and heating on organic carbon degradation of buffalo dung.

The C/N ratio is used as an index of the decomposition rate, *i.e.* suitability of organic feeds for methanogenic bacteria. Fig. (6) shows the C/N ratio for the different treatments during the hydraulic retention time.

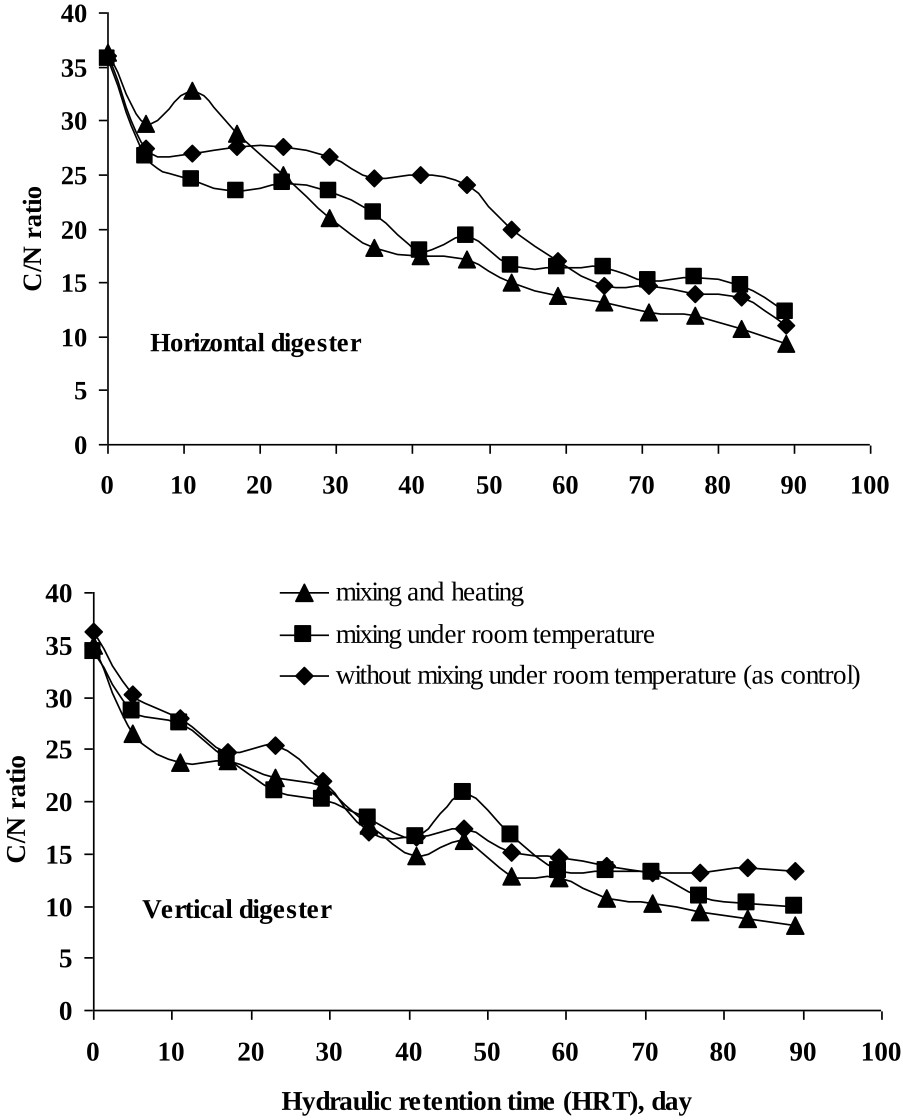


Figure (6): Periodical changes in C/N ratio for raw material during anaerobic digestion time course.

The results revealed that there are differences in the declining of C/N ratios. Generally, increasing anaerobic digestion period resulted in a highly decreasing in C/N ratio in all treatments of buffalo dung material. The lowest C/N ratio was recorded in vertical digester with heating and mixing treatments. On the other hand, total nitrogen concentration in buffalo dung at different anaerobic digestion was increased from zero day until end of experiment. Total nitrogen ranged from 1.92 to 2.07% and from 1.66 to 1.83% in horizontal and vertical digesters, respectively.

As well as, the result indicated that the mixing and heating treatments increase the degradation rate of buffalo dung in both vertical and horizontal digesters through the reduction of OTS as shown in Fig. (7).

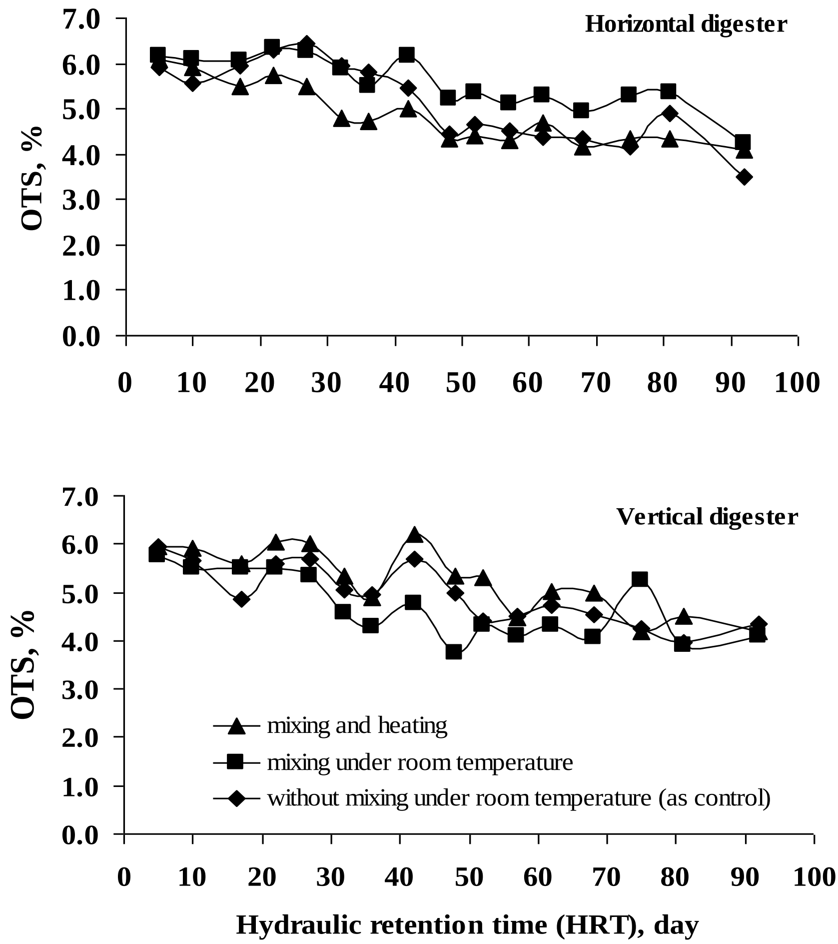


Figure (7): Organic total solids for horizontal and vertical digesters at experimental intervals

The previous results agree with **Iannotti *et al.*,** (1993) who found that total carbon content decreased as CO_2 evolved while total nitrogen content remained constant. Thus, the decrease in the C/N ratio reflected the degradation process during anaerobic digestion. Maximum enhancement in biogas production over the control could be well correlated with maximum reduction in OTS and C/N ratio of buffalo dung after 95 days digestion. **Demirci** and **Demirer** (2004) using broiler and cattle dung as a substrate for biogas production have reported a similar observation.

Correlation analysis was used in order to evaluate relationships between the biogas and methane production and temperature and pH at different treatment in this study (Table, 2). Significant correlations were observed between biogas and methane yield and temperature and pH in case mixing and control in both vertical and horizontal digesters. No significant correlations between biogas yield and temperature and pH except in mixing and temperature treatment in case vertical digester found correlation between biogas yield and pH. The same trend was record in case methane yield.

Table (2): Significance levels of the correlation between the different treatment and biogas, methane percentage, pH value and temperature

Digester type	Parameter	Control (Without mixing under room temperature)			(Mixing under room temperature)			(Mixing and heating)		
		Biogas yield, L/day	Methane, %	T, °C	Biogas yield, L/day	Methane, %	T, °C	Biogas yield, L/day	Methane, %	T, °C
Horizontal	T, °C	0.408**	0.339*	-	0.498**	0.528**	-	ns	ns	-
	pH	0.531**	0.671**	0.732**	0.753**	0.851**	0.722**	ns	0.382*	-
Vertical	T, °C	0.546**	0.561**	-	0.641**	NS	-	ns	ns	-
	pH	0.589**	0.657**	0.714**	0.798**	0.401*	0.786**	0.426**	ns	0.675**

* Correlation is significant at the 0.01 level (2-tailed)

** Correlation is significant at the 0.05 level (2-tailed)

Therefore, we concluded that the amount of biogas produced was depending on not only the type of digester but also the presence of some parameters such as mixing and heating in the digester.

CONCLUSIONS

The study conducted to the following:

- The highest biogas yield was observed in vertical digester type 468.1 L kg^{-1} OTS in cases of mixing and heating treatments. Meanwhile, the lowest was 104.7 L kg^{-1} OTS in vertical digester type in cases mixing under room temperature
- The biogas production was positively correlated with the temperature and mixing. The biogas yield L kg^{-1} OTS was increased by 106.2% in cases mixing and heating treatments in horizontal digester type compared to mixing under the room temperature in the same digester type meanwhile, increased by 347.0% in vertical digester type in the same treatment.
- Effect of digester type, the biogas yield L kg^{-1} OTS was increased by 63.7% in horizontal digester type compared to vertical digester type in treatment without mixing under room temperature meanwhile, increased by 63.5% in horizontal digester type compared to vertical digester type in treatment mixing under room temperature.
- The biogas production was negative correlated with the mixing under room temperature. The biogas yield L kg^{-1} OTS was decreased by 41.6% in cases mixing under room temperature compared to without mixing under room temperature in horizontal digester type meanwhile, decreased by 41.5% in vertical digester type in the same treatment.
- Degradation ratio was 21% in horizontal and vertical digester type in treatment without mixing under room temperature, meanwhile the degradation ratio increased by ١٥,٥% and ١٣,٦% in vertical digester type compared to horizontal in treatment mixing under room temperature and mixing with heating respectively.

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الملخص العربي

تأثير التدفئة والتقليب و نوع المخمر على إنتاج الغاز الحيوي من روثِ الجاموسِ

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يوجد في مصر ٣,٤٣ مليون رأس جاموس تنتج حوالي ٣,٥ مليون طَن / سنة روث جاف هوائياً ويؤدي تداول وتخزين هذه المخلفات دون معالجة إلي فقد المادة العضوية وتلوث البيئة وانتشار الروائح الكريهة، ويعتبر التخمر اللاهوائي أحد طرق معالجة المخلفات العضوية لإنتاج الغاز الحيوي (البيوجاز).

أجريت دراسة معملية علي روث الجاموس بالوحدة التجريبية للغاز الحيوي بقسم الهندسة الزراعية - كلية الزراعة - جامعة قناة السويس في ستة مخمرات (ثلاثة مخمرات أفقية وأخري رأسية) مصنعة من الحديد المجلفن بسمك ١,٥ مم و متساوية القطر ٠,٢٥ متر و الارتفاع ٠,٤٥ متر بحجم كلي ٢٢ لتر وحجم تخمر ١٧ لتر.

تم تغذية المخمرات بمخلفات الجاموس بنسبة ٦,٣٪ مادة جافة عضوية نظام تغذية مرة واحدة تحت ظروف تشغيل درجة حرارة الغرفة وبدون تقليب ككنترول للتجربة في مخمر أفقي وأخر رأسي، ودرجة حرارة الغرفة مع التقليب دقيقتين لكل نصف ساعة في مخمر أفقي وأخر رأسي، ودرجة حرارة ثابتة في مدى بكتريا الميزوفيليك ٣٨م^{o} مع التقليب دقيقتين لكل نصف ساعة في مخمر أفقي وأخر رأسي.

تم تقدير النسبة المئوية للمادة الجافة العضوية OTS معملياً في المادة المتخمرة لروث الجاموس لحساب نسبة تحلل المادة العضوية خلال وقت الاستبقاء ٩٥ يوم كما تم تقدير نسبة الكربون/النيتروجين C/N وقياس رقم الأس الهيدروجيني pH ودرجة الحرارة في المعاملات تحت الدراسة.

تم قياس كمية الغاز الحيوي ونسبة الميثان اليومية المتحصل عليها للمعاملات المختلفة وتم حساب كمية الغاز الحيوي و الميثان باللتر المتحصل عليها من كل واحد كيلو جرام مادة عضوية جافة.

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وقد توصلت الدراسة إلى النتائج التالية:

- أعلي كمية غاز حيوي منتجة كانت ٤٦٨,١ لتر/ كيلو جرام مادة عضوية جافة في المعاملة التسخين علي درجة ٣٨م^{o} مع التقليب في المخمر الرأسي بينما كانت أقل كمية منتجة ١٠٤,٧ لتر/ كيلو جرام مادة عضوية في المعاملة علي درجة حرارة الغرفة مع التقليب في المخمر الرأسي أيضاً.

- تأثير التسخين كان طردي زادت كمية الغاز الحيوي في المعاملة التسخين علي درجة ٣٨م^{o} مع التقليب عن المعاملة علي درجة حرارة الغرفة مع التقليب بنسبة ١٠٦,٢٪ في المخمر الأفقي. بينما كانت الزيادة بنسبة ٣٤٧,٠٪ في المخمر الرأسي لنفس المعاملة
- تأثير شكل المخمر، زادت كمية الغاز الحيوي في المخمر الأفقي بنسبة ٦٣,٧٪ عنها في المخمر الرأسي في المعاملة درجة حرارة الغرفة بدون تقليب وكذلك زادت كمية الغاز الحيوي في المخمر الأفقي بنسبة ٦٣,٥٪ عنها في المخمر الرأسي في المعاملة درجة حرارة الغرفة مع التقليب
- تأثير التقليب كان عكسي قلت كمية الغاز الحيوي في المعاملة التقليب علي درجة حرارة الغرفة عن المعاملة بدون تقليب علي درجة حرارة الغرفة في المخمر الأفقي بنسبة ٤١,٦٪ بينما قلت بنسبة ٤١,٥٪ في المخمر الرأسي لنفس المعاملة.
- نسبة التحلل في المخمر الرأسي وفي المخمر الأفقي كانت ٢١٪ في المعاملة بدون تقليب علي درجة حرارة الغرفة بينما زادت بنسبة ١٥,٥٪ و ١٣,٦٪ في المخمر الرأسي بالمقارنة بالمخمر الأفقي في معاملة التقليب علي درجة حرارة الغرفة و التقليب مع التسخين علي التوالي.

يتضح مما سبق أن كمية الغاز الحيوي ومحتواه من غاز الميثان الناتجة من مخلفات الجاموس ليست تتأثر فقط بنوع المخمر سواء أفقي أو رأسي ولكن كذلك بعوامل التشغيل مثل درجة حرارة التخمير والتقليب فضلاً عن العوامل الأخرى مثل نسبة المادة العضوية الجافة، نسبة الكربون/النيتروجين C/N ورقم الأس الهيدروجيني pH في المادة المتخمرة.