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USING SOLAR ENERGY TO PRODUCE BIOGAS FROM ANIMAL WASTES

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Abstract

This research work was carried out in the biogas laboratory of the Agricultural Engineering Department, Faculty of Agriculture, Tanta University at Jan. 2015. The main objectives of this research work were to study the possibility of using the stored energy from a solar panel with a heat exchanger to heat the cattle dung solution for a biogas production. Also to investigate the effect of booth the temperature and the hydraulic retention time on the efficiency of anaerobic fermentation. The obtained results show that the highest biogas production was observed in horizontal digester type 12.95 L/day at mixing time of 15 minutes each four hours. and heating at 40 ^{o}C. Meanwhile the lowest was 2.39 L/day in vertical digester type in case mixing time 5min./hr. and heating at 30 ^{o}C. the total biogas productivity was increased by 0.416 from 1.126 (m^3 gas/m^3 manure) in case mixing time of 15 min. /4hr. The biogas productivity was changed by digester type from vertical and horizontal digester. the total biogas energy was increased by 201.2% by increasing temperature from 30 ^{o}C. to 40 ^{o}C. in case mixing time of 15 min. /4hr. at horizontal digester.

Key words: *biogas, evaluate, from vertical and horizontal digester, solar, stored energy*

INTRODUCTION

In Egypt, the annual average of global solar radiation is 5.4-7.1 kW.h/m^2/day, while the annual average solar radiation on full tracking system is 7.5 -10.5 kW.h/m^2/day**.** [8] Biogas technology is a biological process which converts organic materials such as crop and animal residues wastes by an anaerobic fermentation into useful energy. Biogas technology not supplies energy (biogas) and organic fertilizer from renewable waste materials, but also alleviates the problem of waste disposal and pollution control. Biogas system has many advantages.

[7] reported that solar energy is one of the most available forms of energy on the Earth's surface, besides; it is very promising and generous. The earth's surface receives a daily solar dose of 8E+10kW.h, which is equivalent to 500 000 billion oil barrels that is one thousand times any oil reserve known to man. [9] used the collector area about 4m^2 and experimented the volume of water in the storage tank between 100 and 300 l with the mass flow rate between 6 and 12 l/ min. They found that a single solar collector can produce approximately 48-56°C hot water at an average solar radiation of 600-700 W/ m^2 at mass flow rate 0.2 kg/s Also, their results showed that the higher water volume exhibited lower water temperature and the mass flow rate of water had no effect on the water temperature under these conditions. [3] stated that biogas is ‘‘gas rich in methane, which is produced by the fermentation of animal dung, human sewage or crop residues in an air-tight container’’. [5] described biogas as ‘‘a methane-rich gas that is produced from the anaerobic digestion of organic materials in a biological-engineering structure called the digester’’. This definition suggests that biogas is only produced artificially, but this is not the case. It is believed that the scope of their definition may perhaps have been limited by their comparison of artificial production-processes, thus ignoring the natural occurrence of biogas. [4] stated that, A variety of digester types exists for the anaerobic treatment of organic wastes. The selected type depends on operational factors, including the nature of the

waste to be treated, e.g. its solid content. [11] stated that the heat requirements of digesters are used to: (i) raise the temperature of the incoming sludge to that of the digestion tank; (ii) compensate for the heat losses through the walls, floor and roof of the digester; (iii) make up the losses that might occur in the piping between the source of heat and the tank. [6] stated that, Solar water heaters are more and more used worldwide, and the evacuated-tube designs are the most popular due to their simplicity and better overall performance over their flat-plate counterparts, especially in adverse weather conditions. Many evacuated-tube designs have been developed and are being used among which the water-in-glass design is very popular because of its low cost and simple manufacturing and installation procedures. Another design uses a heat-pipe system with an intermediate fluid used to carry the heat from the heating elements to the tank. The objectives of the present research were to: Design an engineering unit to produce biogas from crop and animal wastes suit the farmer.

2- Use solar energy as a heating source during anaerobic fermentation to maximize biogas quantity under different engineering parameters.

MATERIALS AND METHODS

The main experiments were carried out during seasons 2014 and 2015 in the biogas laboratory of the Agricultural Engineering Department, Faculty of Agriculture, Tanta University.

Animal waste (Cattle dung). The source of cattle dung obtained from the dairy farms. Table 1 showing the chemical analysis of cattle dung which was used to feed the biogas digester.

Table 1. Chemical analysis of cattle dung.

Parameter	Percentage
Total solids (Ts %)	13.35
Volatile solids (%from Ts)	75.64
Total nitrogen (%from Ts)	1.21
Organic carbon %	36.54
C\N ratio	30.20
PH	6.65 –7.23

- Solar heating system. The heating required for the bioreactor was performed using a solar collector combined with a heat exchanger the bioreactor volume was 53 liters. Heating this volume of water to 40^0C formed the basis for the solar collector design. Evacuated tube solar collector performance Figure (1) shows the entire system with a standard water-in-glass collector made of 20 evacuated tubes and the storage tank. A circulation pump is used to circulate the working fluid between the collector and the storage tank. The solar storage tank is a 150 liter insulated vessel.

Fig. 1. Evacuated tube solar collector

Fig. 2. The biogas digester are horizontal and vertical shape

-A cylindrical biogas digester
(horizontal and vertical type) are shown in Fig. 2 biogas digester were constructed Each digester was fabricated from stainless steel sheet 1.5 mm thickness, 80 cm length and 40 cm diameter with total capacity of 100 liters and it has a PVC inlet and outlet tube of 76.2 mm (3 in.) diameter for feeding by organic wastes and rejecting the digester materials.

-Total solids (TS) A sample of the fresh cattle dung which used in the fermentation test was oven-dried at temperature of 110 ^{o}C to the constant weight according to the American Public Health Association [1]. digested slurry was treated similarly.

- Volatile solids (TVS) The dried sample from the total solids determination was ignited at temperature of 550 ^{o}C in a furnace overnight to the constant weight. The loss in weight was taken as the volatile solids according to the American Public Health Association [1].

– Organic matter and organic carbon (OM & OC).

The percentage of organic matter was estimated from the percentage of ash (550-600 ^{o}C), using the following equations [2] :

Organic matter (%) = 100 (%) – ash (%)

Organic carbon (%) = Organic matter (%) / 1.8

- Hydrogen concentration ion (pH).
The ph was directly measured in liquid samples using glass electrode pH meter.

- 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 in liter.

- Methane percentage
The daily released biogas was fractioned in a percentage i.e. methane and CO2 percentage using the potassium hydroxide 40% [10].

RESULTS AND DISCUSSIONS

Results of this study indicate that solar energy can be utilized for heating requirements of bio waste reactors at low cost. Heating requirements of a bioreactor are linked to increased production and decreased retention. Electric and diesel heating of such reactors can be avoided using a combined system of solar energy and produced biogas

-Effect of mixing and digester type on biogas production.
Fig, 3 showing the effect of mixing on anaerobic digestion of buffalo dung was evaluated in bench scale digester at 30 ^{o}C, 35 ^{o}C and 40 ^{o}C. Because mixing duration and intensity effect on the performance of anaerobic digestion are contradictory, we used in this study mixing system (5 minutes each one hour and 15 minute each four hours). The effect of digester type was evaluated on biogas production under the different mixing and heating treatments. The digester yield was greatly varied in both vertical and horizontal digester under mixing or heating. The effect of temperature on biogas production shown in Fig. 3. The results revealed that by increasing of temperature from 30 to 40 ^{o}C. at horizontal digester the total biogas production increased from 32.35 to 61.09 L and from 35.25 to 65.96 L. at mixing system 5 minutes each one hour and 15 minute each four hours respectively.

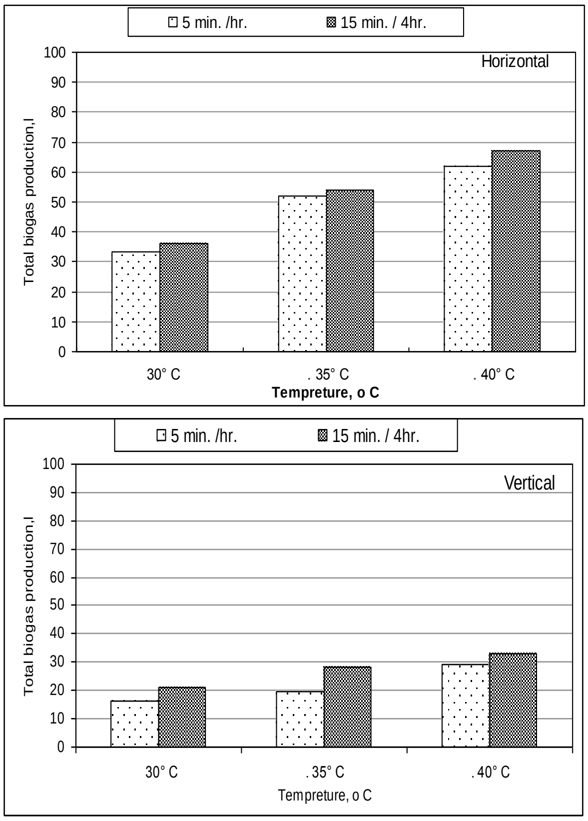

Fig. 3. Effect of temperature on biogas production under different digester type and mixing time.

The results showed that by increasing of temperature from 30 to 40 ^{o}C. at vertical digester the total biogas production increased from 15.44 to 28.15 L. and from 20.23 to 32.25 L. at mixing system 5 minutes each one hour and 15 minute each four hours respectively.

-Effect of mixing and digester type on biogas productivity.

The effect of temperature on biogas productivity shown in Fig. 4. The results indicated that by increasing of temperature from 30 to 40 ^{o}C. at horizontal digester the total biogas productivity increased from 0.364 to 1.01 m^3 gas/m^3 manure and from 0.416 to 1.126 m^3 gas/m^3 manure. at mixing system 5 minutes each one hour and 15 minute each four hours respectively. The results showed that by increasing of temperature from 30 to 40 ^{o}C. at vertical digester the total biogas productivity increased from 0.28 to 0.355 m^3 gas/m^3 manure and from 0.231 to 0.338 m^3 gas/m^3 manure. at mixing system 5 minutes each one hour and 15 minute each four hours respectively.

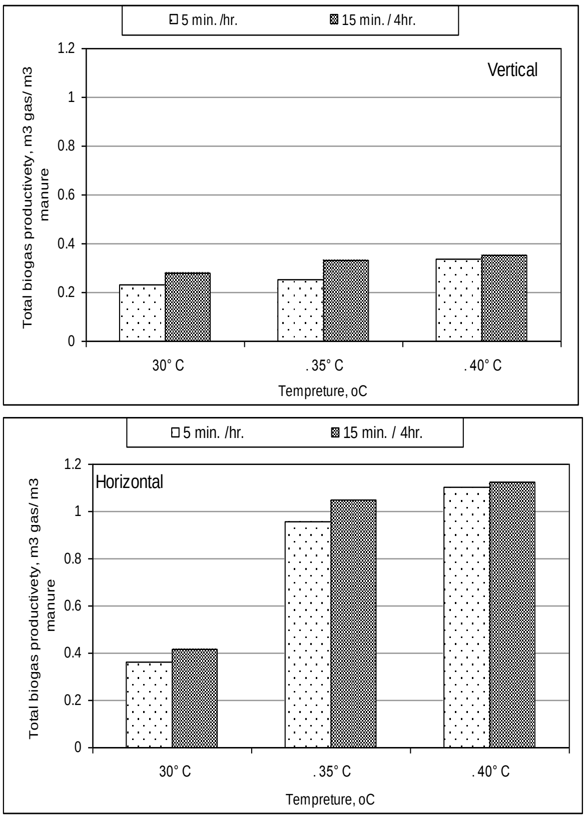

Fig. 4. Effect of temperature on biogas productivity under different digester type and mixing time.

-Effect of mixing and digester type on biogas energy

The results in Fig. 5 showed that in horizontal digester and constant mixing time of 5 minutes each one hour the total biogas energy was 0.380, 0.631 and 0.790 (MJ/day) at 30, 35 and 40 ^{o}C respectively. While, total average biogas energy at constant mixing time of 15 minutes each four hours. 0.415, 0.655 and 0.853 (MJ/day) at 30, 35 and 40 ^{o}C respectively. However The results indicated that In vertical digester and constant mixing time of 5 minutes each one hour the total biogas energy was 0.182, 0.228 and 0.364 (MJ/day) at 30, 35 and 40 ^{o}C respectively. While, the daily average biogas energy at constant mixing time of 15 minutes each four hours. 0.238, 0.336 and 0.417 (MJ/day) at 30, 35 and 40 ^{o}C respectively.

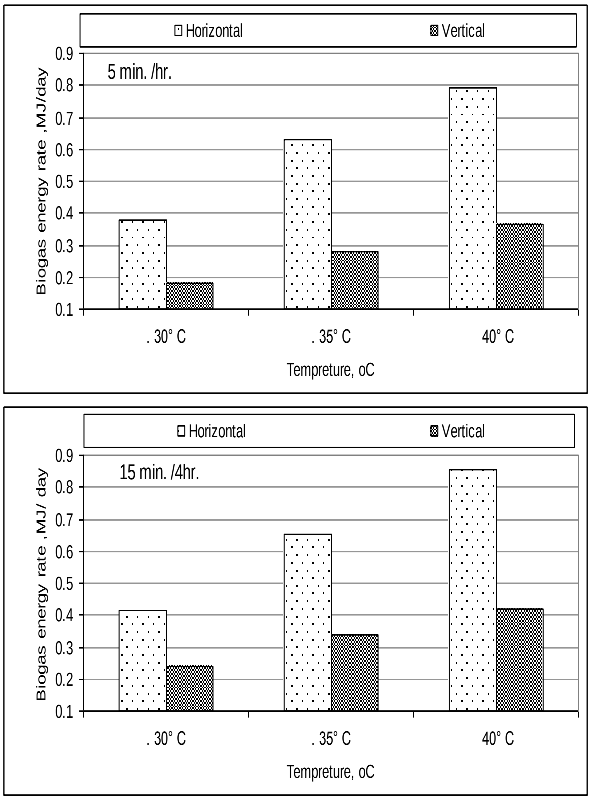

Fig. 5. Effect of temperature on total biogas energy under different digester type and mixing time.

- Effect of mixing time and temperature on pH value

The measured PH value for the anaerobic digester of buffalo dung in vertical and horizontal digester at experimental intervals are shown in Fig. 6. pH values not greatly affected by mixing in both vertical and horizontal digester.

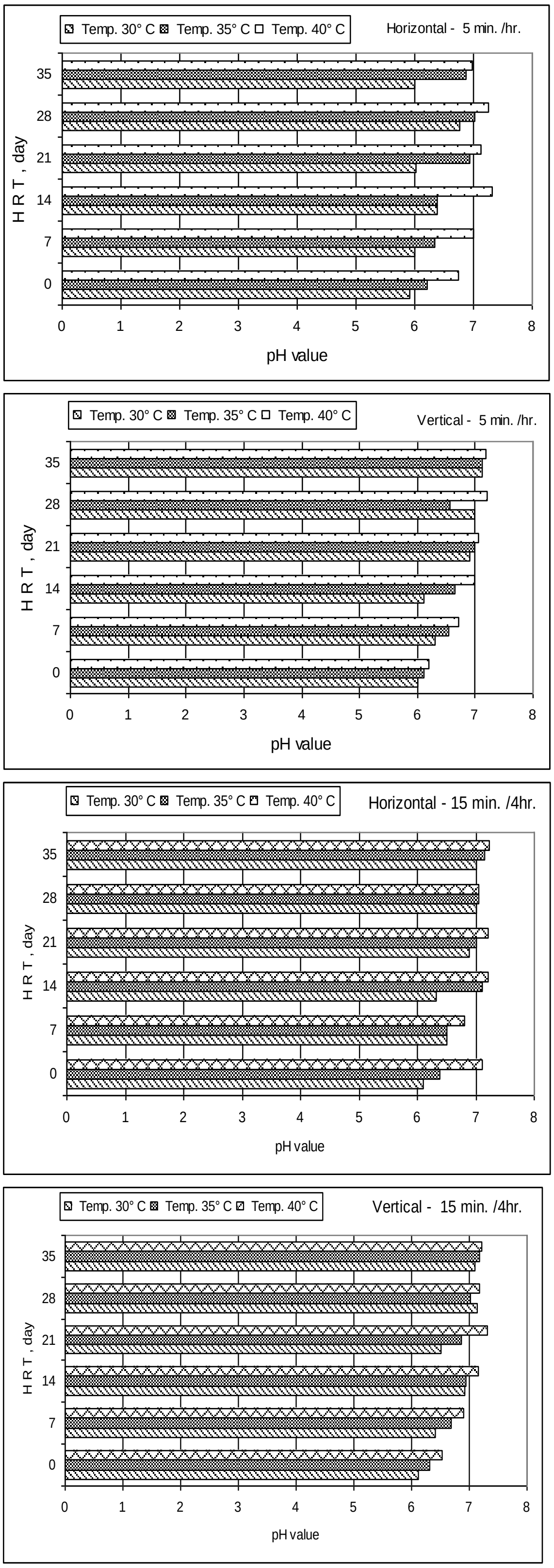

Fig. 6. Effect of (HRT) on pH values under different temperature and different digester type

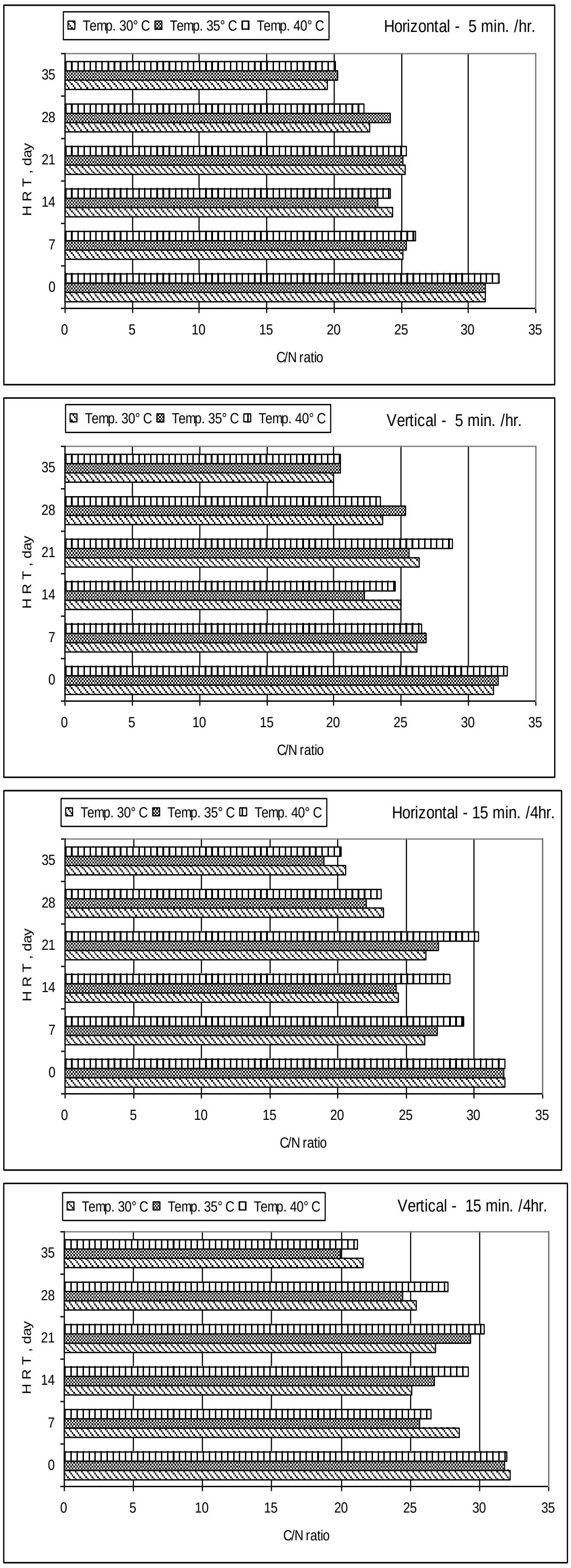

Fig. 7. Effect of (HRT) on C/N ratio under different temperature and different digester

The pH values were ranged from 5.91 to 7.23 and 6.01 to 7.21 in horizontal and vertical digester, respectively. The pH is known to influence enzymatic activity, because each enzyme has maximum activity within a specific and a narrow PH rang. 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.

- Effect of mixing time and temperature on C/N ratio

Generally, increasing anaerobic period resulted in a highly decreasing in C/N ratio in all treatments of buffalo dung materials. The lowest C/N ratio (19.46) was recorded in horizontal digester with heating of 30 ^{o}C and mixing time of (5min. / 1h.) However The results evident that the higher C/N ratio (32.84) was recorded in vertical digester with heating of 40 ^{o}C and mixing time of (15min. / 4h.)

The results in Fig. 7 showed that there are differences in the declining of C/N ratios.

CONCLUSIONS

The highest biogas production was observed in horizontal digester type 12.95 L/day at mixing time of 15 minutes each four hours. and heating at 40 ^{o}C.

Meanwhile by increasing temperature from 30 oC. to 40 oC. the biogas productivity was increased by .069 from 0.188 (m^3 gas/m^3 manure/day in case mixing time of 15 min. /4hr. - The pH values were ranged from 5.91 to 7.23 and 6.01 to 7.21 in horizontal and vertical digester, respectively. the daily average biogas energy was increased by 106.67% by increasing temperature from 30 to 40 ^{o}C. in case mixing time of 15 min. /4hr. at horizontal digester.

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