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Biogas Production from Kitchen Wastes by Anaerobic Digestion

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Abstract: This paper aimed to study the biogas production from kitchen wastes mixed with cattle dung. A vertical bench scale biogas digesters were constructed. Each three of them were replicates and their average biogas yields were recorded. The mixing ratios were 75%, 50% and 25% of kitchen wastes to the total slurry. The pH, alkalinity and temperature were measured during the experiments. It was found that digestion process was sensitive to temperature changes. Also, the pH and alkalinity were increasing over time. Moreover, it was found that the mixing ratio of 75% kitchen wastes to the total slurry enhanced the biogas production by 17.3% in comparison to the ratio of 25% kitchen wastes.

Keywords: Biomass, Waste, Biogas, Methane

I. INTRODUCTION

This study focuses upon the case of Saudi Arabia kingdom, where kitchen wastes collected as in material and methods chapter can be utilized for energy demand. The kitchen wastes seems to be a problem in many countries, while in other countries is recognized as an environment friendly source of power rather than being a burden on the environment. Anaerobic digestion is an appropriate option to Saudi warm weather not only to reduce the daily accumulated wastes, but also to decreasing of emitted bad odors and generate electricity to overcome the shortage.

The current study will handle the biogas production technology from kitchen wastes to explain the feasibility of biogas production. In addition to that, the study will focus on the feasibility of biogas production in Saudi Arabia.

Due to the rapid depletion of the conventional energy resources combined with the alerting raise of air pollution and environmental issues caused by the increasing demand of the modern human societies, it became necessary to research for alternative renewable energy resources. Among these resources is biogas, which many researchers see as the hope of the future.

The study aimed, primarily, to investigate the current status of wastes for the best production of biogas by anaerobic digestion and the feasibility from biogas yield in Qassim and production of methane with high characteristic quality.

The overall objectives of this study were to characterize the anaerobic bio degradability potential of kitchen wastes to determine the most suitable conditions for biogas and methane production to solve a fuel and energy problems.

The most important advantages of methane gas over other type of gasses are the following [1-3]:

1) It is used to produce relatively cheap energy in the form of electricity, which can be used for lighting, machinery… etc. In addition, it can be used to produce energy in the form of heat, which can be utilized in many ways such as cooking.
2) Relaying on methane to produce energy is beneficial to the environment since it reduces the greenhouse effect that leads to climate change.
3) Farmers can benefit from the farming and animal waste to produce biogas and agricultural fertilizers as byproduct. Moreover, it would help them secure their domestic needs of gas by using methane, which is a good alternative to liquefied gas.

II. MATERIALS AND METHODS

A. Biogas Digester and Feedstock

A nine bench-scale of cylindrical biogas digesters (vertical type) as shown in Figure 1 was constructed and installed at the biogas laboratory of the College of Engineering, Qassim University, Saudi Arabia.

Each one of these digesters were fabricated from a plastic of 400 mm long and 4 inches diameter with total capacity of five litres approximately and actual digestion volume of 3.7 litres. To follow up the digestion processes, the digester was equipped by two orifices; one for releasing the produced gas and the other for the ignition test, pH and temperatures measurements. Released gas volume was collected in gasholder and determined.

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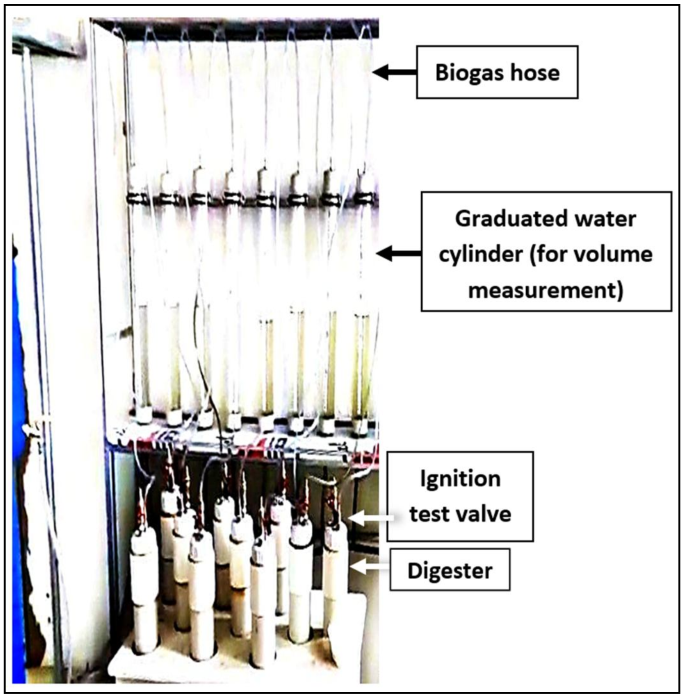

Fig. 1 vertical bench-scale of cylindrical biogas digesters and their ratios.

The feedstock specifications are shown in Table 1

TABLE I
AVERAGE COMPOSITION OF EXPERIMENTS COMPONENTS AS (KITCHEN WASTES AND CATTLE DUNG).

Parameters	Kitchen waste	Cattle dung
pH	3.9	6.87
Total solids, TS (%)	8.6	8.1
Volatile solids, VS (g/l)	78	61
VS (% of TS)	92.77	75.3
Organic carbon (% of TS)	53.8	43.7
C:N Ratio	28:1	37:1
Alkalinity (mg/L) as $CaCO_3$	4100	5750

The substrates are mixture of kitchen wastes and cattle dung are shown in Table 2.

TABLE III
MIXTURES OF EXPERIMENTS AND THEIR RATIOS

Mixture	Cattle dung %	Kitchen waste %
1	75	25
2	50	50
3	25	75

Total alkalinity as CaCO3 in mg/L was calculated by Equation 1:

$$\text{Total alkalinity} = \frac{\text{Normality of acid} \times \text{volume of acid used} \times 50 \times 1000}{\text{ml used of sample}} \qquad (1)$$

A thermometer was used check the variation of temperature with time. A pH meter (accuracy of ±0.1 pH) is employed for measuring the pH of the mixture (slurry) periodically.

III. RESULTS AND DISCUSSION

A. pH and Alkalinity

Monitoring of pH shows that the best production of biogas was found at pH 7.0 the kitchen wastes and cattle dung mixtures. This agrees with the results that the optimum pH for anaerobic digesters is ranged from 6.6 to 7.4 [4-6]. The measured pH values for anaerobic digestion of three mixtures at experimental intervals are shown in Figure 2a. The measured pH values for anaerobic digestion of mixture 1 (25% Kit.:75% dung), mixture 2 (50% Kit.:50% dung) and mixture 3 (75% Kit.:25% dung) at experimental intervals are shown in Figure 2a. The pH for mix. 1 started from 5.6 and then increased up to 7.0, for second mix. 2 pH started from 4.8 increased slightly after that decreased to 5.9 and raised again to 7.1, while in the case of mixture 3 the pH started from 4.47 and raised gradualy to 7.3 up to the end. Generally, degradation of substrates starts between day one to five and twelve days for mixture3 and mixture 2, respectively, before it commences the production of biogas in the batch operation. This elevation interprets the high quantity of biogas produced from mixture 3 as we will see it after that in biogas estimation experiments.

It was noted that when the pH value gradually increases, the biogas production increases gradually. It 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 comprise an extremely important parameter. Since, methanogenesis only proceeds at high rate when pH is maintained in the neutral range [7]. Most methanogenic bacteria function optimally at pH 7.0 to 7.2, and the rate of produced gas declines at pH values below 6.3 or exceeding 7.8 [8,9]. The change in pH values for the three experiments at different intervals with hydraulic retention times (HRT) per day are represented in Fig. 2a. It is clear that there is change in pH values for the three experiments at different intervals.

The result of alkalinity has great role for the proper control of pH. For the mixture experiment, total alkalinity at the beginning was 5500 mg/L, reached 6700 mg/L at the end of the experiment. Also, for first experiment, total alkalinity was 4800 mg/L at the beginning reached 5950 mg/L at the end of the experiment. For second mix., the alkalinity was 5900 mg/L at the beginning reached 6810 mg/L at the end of experiment.

These results illustrated in Figure 2b exemplifies and agree that the components most affecting the alkalinity of a digester are the equilibrium between carbon dioxide and bicarbonate and that between ammonia and ammonium, with the most dominant determined by the substrate [10].

For instance, a first mix. Substrate high in proteinaceous wastes is associated with high alkalinity due to the release of amino groups and ammonia production. Therefore, alkalinity is mostly present in the form of carbon dioxide in the gas phase and bicarbonate in the liquid phase. Carbon dioxide is released through the degradation of organic compounds and both CO_2 and ammonia are released through the breakdown of amino acids and proteins. There are some differences among alkalinity value for the first experiment, second experiment, and the last experiment for mixture three.

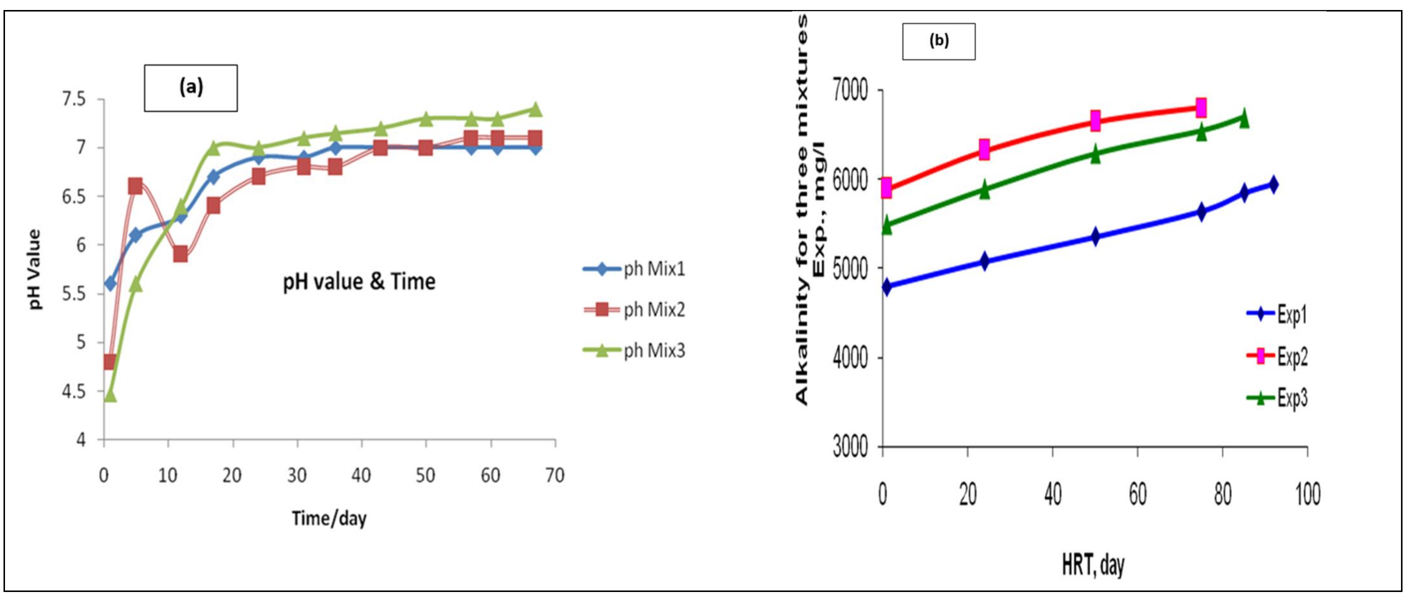

Fig. 2 (a) Change in pH values for three mixtures during exps. time/(Day). (b) Alkalinity monitoring for three mixtures substrates.

B. Temperature Variation

The temperature adjusted at 36 C during all experiments in mesophilic range. Temperature can influence the rate of bacterial action as well as the quantity of moisture in the biogas as moisture content increases exponentially with temperature. Temperature also has an influence upon the concentration of contaminants in biogas. Mesophilic bacteria can withstand temperature fluctuations of ±30 C without noticeable reduction in the production of biogas, but it is important to keep the temperature constant throughout the digestion process. All experiments occurred in mesophilic range because the stability offered by mesophilic bacteria is an important reason for its worldwide use. There is slightly variation with mixture1, 2 and mixture3 experiments as shown in Figure 3.

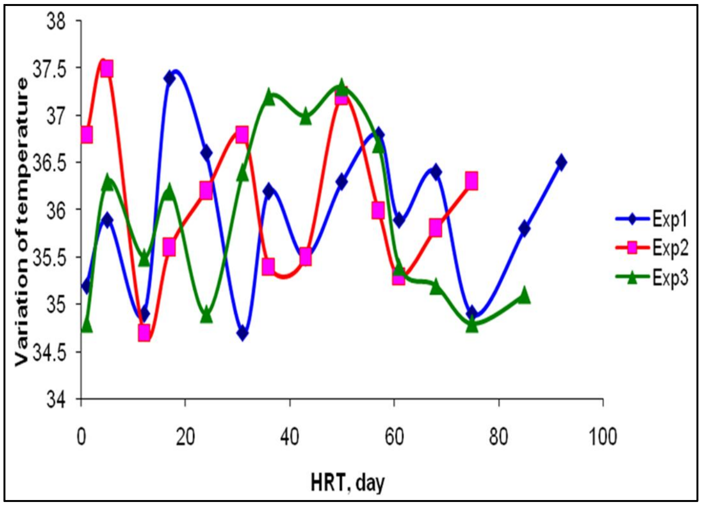

Fig. 3 The variation of temperature at experimental intervals

C. Biogas Production

Biogas yield and percentage were recorded in three experiments with mesophilic conditions. The results show that the average of biogas yield in the first experiment for the mixture of sludge and cattle dung was 49.36 L kg-1 OS. Figure B shows the production of biogas of the three experiments, mix.1, mix.2 and mix.3. Results are represented as the volume of biogas obtained versus the hydraulic retention time (HRT). The spread of the results among test indicate that the biogas production in the three experiments is fairly reproducible or stable, until three experiments get close to the maximum production. The calculation of biogas quantity in case of mix.2 was 52.8 L kg-1 OS. In the mix3 experiment, biogas quantity was 57.91 L biogas/kg OS more than mix.2 and 1 with raised pH during hydraulic retention time.

In Figure 4, we notice that in case of (Experiment 1), the production of biogas increases at the beginning of the time period, then decreases after 43 days due to degradation of organic matter as in the following degradation experiments. Also, in case of (Experiment 2), the production of biogas reaches highest increase after 43 days and decreases after that. But, in case of mixture3 (75% kichen and 25% cattle dung (Experiment 3), in the beginning of the time period, the production of biogas increases, then decreases after 50 days after reaching the highest biogas production.

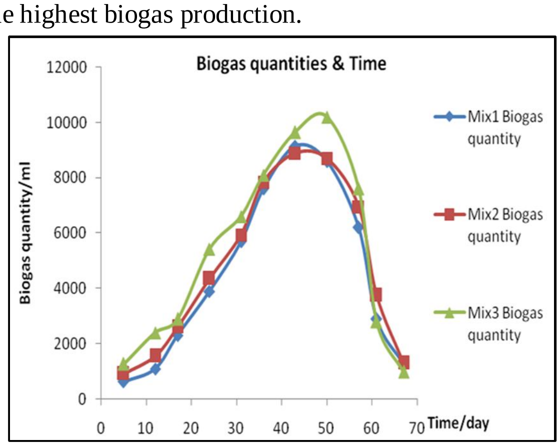

Fig. 4 The comparison of biogas quantities results/ ml for the three mixtures during exp. time/day.

It was also observed that biogas production was actually slow at starting and the end of observation. This is predicted because biogas production rate in batch condition is directly equal to specific growth of methanogenic bacteria [11]. During the first 12 days of the mix.1 experiment of observation, there was less biogas production and mainly due to the lag phase of microbial growth. Whereas, in the range of 5 to 12 days of observation; biogas production increases substantially due to exponential growth of methanogens. Details in Table 3.

TABLE IIIII
BIOGAS MEASUREMENTS DETAILS

	Substrate	Mixture1	Mixture2	Mixture3
Runs	Time (days)	Biogas (ml)	Biogas (ml)	Biogas (ml)
1	1	0	0	0
2	5	640	915	1270
3	12	1100	1550	2400
4	17	2300	2600	2900
5	24	3900	4350	5420
6	31	5700	5930	6600
7	36	7600	7850	8100
8	43	9150	8900	9650
9	50	8600	8700	10200
10	57	6200	6950	7600
11	61	2900	3750	2800
12	67	1270	1300	976
Totals		49360	52795	57916

IV. CONCLUSIONS

Nine bench scale biogas digesters were built. They had 4 inches diameter with 40 cm length and total digestion volume of 3 L. Three mixing ratios of kitchen with cattle dung were used. The kitchen wastes were 75%, 50% and 25% by volume to the total slurry; which produced biogases of 57.9 L, 52.8 L and 49.4 L, respectively. During the experiments, the temperature was set to 36 C. However, uncontrollable variations were occurred which significantly affected the digestion process. It was noticed that both the alkalinity and pH were increasing as the reaction takes place.

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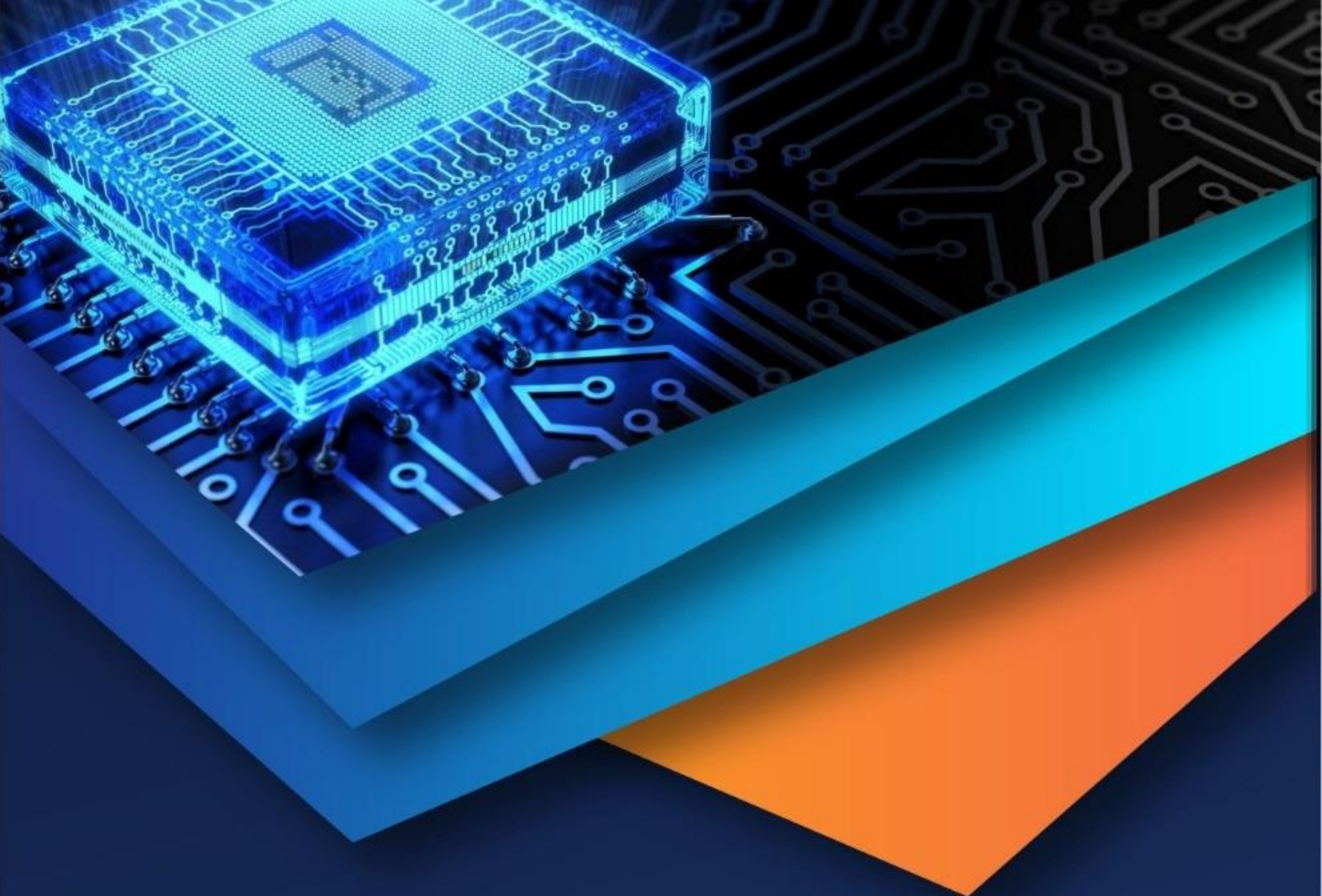

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