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Impact of Concentration of Cow MANURE ON Biogas Production

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ABSTRACT

In Libya, there are multiple sources of pollution, one of which is animal waste. The anaerobic digestion (AD) of organic wastes to produce biogas has the advantage of producing valuable, renewable energy while reducing the environmental impact of these wastes. Cowmanure have the potential to produce biogas due to their high organic content. This study aimed to study different concentrations for the feedstock (1:1 and 2:1 cow manure: water v/v) to monitor which one gives higher biogas production. A plastic tank with a capacity of 72 liters and a feedstock volume of 60 liters was used to create a pilot scale. The biogas was analyzed using a GC device at the end of the experiment in the Zawiya Oil Refining Company. The result indicated that the ratio of 2:1 resulted in a biogas production increase of 8.3% more than 1:1, with a yield of 630 g/day for 16 days. Also, the mixture of 2:1 contained 78.71% of methane, while the mixture of 1:1 contained 58% of methane.

Keywords: Biogas, Cow manure, Anaerobic digestion and Renewable energy.

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تأثير تركيز روث البقر على إنتاج الغاز الحيوي

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الملخص

في ليبيا، هناك مصادر متعددة للتلوث، أحدها النفايات الحيوانية. يتمتع الهضم اللاهوائي (AD) للنفايات العضوية لإنتاج الغاز الحيوي بميزة إنتاج طاقة متجددة قيمة مع تقليل التأثير البيئي السلبي لهذه النفايات. يمتلك روث البقر القدرة على إنتاج الغاز الحيوي بسبب محتواه العضوي العالي. هدفت هذه الدراسة إلى دراسة تراكيزين من المادة الأولية (1:1 و2:1 روث البقر: ماء حجم/حجم) لمراقبة أي منها يعطي إنتاجاً أعلى للغاز الحيوي. تم استخدام خزان بلاستيكي بسعة 72 لترًا وحجم مادة خام 60 لترًا لإنشاء مقياس تجريبي. تم تحليل الغاز الحيوي باستخدام جهاز GC في نهاية التجربة في شركة الزاوية لتكرير النفط. أشارت النتيجة إلى أن نسبة 2:1 أدت إلى زيادة إنتاج الغاز الحيوي بنسبة 8.3% أكثر من 1:1، بإنتاجية قدرها 630 جم/يوم لمدة 16 يومًا. كما أن خليط 2:1 يحتوي على 78.71% ميثان، في حين أن خليط 1:1 يحتوي على 58% ميثان.

الكلمات الدالة: الغاز الحيوي، روث البقر، الهضم اللاهوائي والطاقة المتجددة

1. INTRODUCTION

The biogas production from organic waste materials provides a promising renewable energy option [1]. Biogas is eco-friendly and one of the most efficient and effective alternative renewable energy sources [2]. It can be generated from animal manure, such as cow, sheep, and chicken dung, which is difficult to remove from the

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environment and is considered a pollutant [3]. Anaerobic digestion (AD) very important and widely used technologies for treating organic waste and producing biogas [4]. AD is a series of biochemical reactions in which bacteria devour the organic matter and break it into a gaseous mixture without oxygen [5]. The most important product of this decomposition is methane gas, which has a high thermal energy, along with carbon dioxide, hydrogen, and other gases [6]. Achieving stable and efficient production of biogas requires careful consideration of several design and operational parameters [7]. To ensure the optimal performance of a biogas plant, it is crucial to monitor and control several parameters. These parameters include the type of organic materials, their loading and residence time in the digester, as well as temperature, acidity levels, and other relevant variables. Neglecting any of these factors could lead to issues inhibiting the plant's performance [8], [9].

The production of biogas from animal manure, particularly cow manure, holds great potential and advantages. The energy obtained from it is environmentally friendly as it reduces greenhouse gases and other atmospheric emissions. Moreover, it allows for the utilization of livestock waste [10]. In this study, a pilot-scale plant will be designed to test the potential for converting cow dung to biogas and analyze some factors that affect the process.

2. MATERIALS AND METHODS

The first step of this study involved selecting an appropriate site for the work, followed by the design and operation of a pilot-scale system for biogas production. The experiment used a 1:1 and 1:2 volume ratio of cow manure to water. The physicochemical parameters such as pH, temperature, T (˚C), and the weight of the biogas were monitored daily. The sample point for pH measurement is a 0.6-inch-diameter plastic valve, which was installed at a height of 11.4 inches from the bottom of the digester, through which a

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sample was taken from the digester to measure the pH of the mixture during the study period.

The temperature reading was taken every day using an infrared gun thermometer. Figure 1 below shows the temperature measurement device used for this study.

Figure 1. Temperature Measurement Device.

The retention time (HRT) was also measured to track the duration of gas production. At the end of the experiment, the biogas was analyzed using Chromatography at Zawiya Oil Refining Company.

2.1Site Selection and Design of Digester

This model was designed on a farm in Al-Barnawi area, Al-Zawia city in Libya, due to the proximity of the cow farms to the place of construction, which in turn facilitates the process of transferring cow waste from the farms to the location of the biogas production unit. As shown in Figure 2, the digester was designed from a plastic tank with a capacity of 72 liters, a height of 29.5 inches, and a diameter of 18.3 inches as a main body connected with:

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1. Feed inlet.
2. Gas outlet (main product).
3. Outlet Valve for residue (controlling point) .
4. Sample point for pH Measurement.

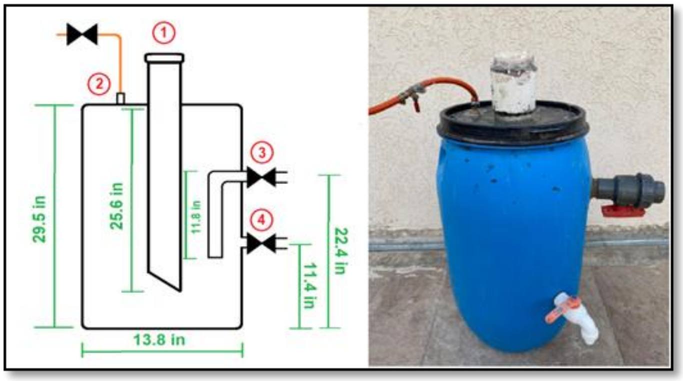

Figure 2. Digester Dimensions

The feed inlet is a plastic tube with a diameter of 3.9 inches, extending into the digester with a length of 25.6 inches and a distance of 3.9 inches from the bottom. The feed inlet was used as an inlet through which slurry was added inside the unit. The gas outlet is used to collect the biogas produced from the unit. It is an outlet connected to a valve to control the biogas exit to the rubber tube. Outlet valves for residue are plastic valves with an inner diameter of 1.4 inches that are used in the fields of irrigation and agriculture because of their high ability to withstand pressure and prevent leakage. In this experiment, this valve was used in the digester, which was installed at a height of 22.4 inches and connected from the inside to a tube with a length of 11.8 inches and at a height of 10.6 inches from the bottom of the digester. The main purpose of installing it on the digester is to control the remains and use it later as fertilizer.

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Figure 3 shows the block flow diagram of the biogas production process. The feed is prepared and mixed well, taking into account the required concentration between waste and water (1:1 or 2:1).

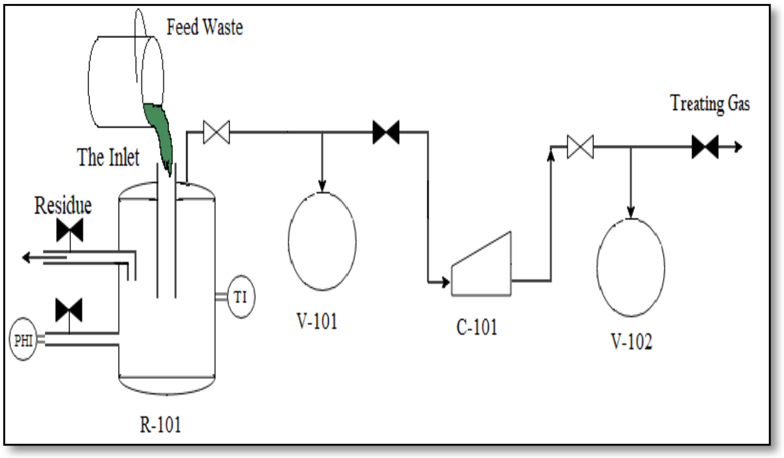

Figure 3. Process Flow Diagram.

The mixture is left inside the digester (R-101) and locked, and after nearly 8 hr, the temperature and pH are recorded three times a day. The gas produced from the digestion is passed to be collected inside the accumulator (V-101), after opening the valve connecting the digester and the gas accumulator. The biogas produced from the decomposition of waste was collected in a car tire. When the tire is filled with approximately 20 to 30 liters of gas, it is emptied by suctioning it using a compressor and transferring it to the container. When the accumulator is full, the gas is compressed inside a container (V-102) using a compressor after closing the first valve. The compressor is automatically operated when the accumulator is full. The suction pressure of the compressor is up to 5 psi while the discharge pressure is up to 250 psi.

An empty, clean refrigerant gas container, was used to accumulate the biogas produced from the process. The weight of the

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gas obtained from the digestion process is measured daily. The samps of gas were taken in a black rubber balloon that is used in the storage for the gas to be analyzed in the chromatograph device. The size of this balloon is nearly 5 liters. Gas samples are transferred efficiently via a specialized connector to meet measurement criteria.

3. RESULTS AND DISCUSSION

The variations in physicochemical parameters of temperature, pH, and productivity during these experiments are shown in Table 1.

Table 1. Result of parameters (T, pH & productivity) for mixing ratios of 1:1 and 2:1.

Days	Average daily temperature ℃ (Mixture1)	Average daily temperature ℃ (Mixture2)	PH		Productivity (kg/day)	
			1:1	2:1	1:1	2:1
1	31.5	40.6	6.11	6.20	0.022	0.042
2	28.7	40.4	5.96	6.34	0.025	0.08
3	29.8	39.7	5.92	6.49	0.025	0.082
4	32.2	39.1	5.81	6.98	0.028	0.087
5	31.6	47.5	5.95	7.52	0.028	0.088
6	31	42.4	6.02	7.95	0.028	0.088
7	30.2	40.5	6.12	8.20	0.028	0.088
8	31.6	42.3	6.26	8.03	0.028	0.086

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9	31.6	41	6.35	7.96	0.021	0.082
10	29.4	40.7	6.56	7.86	0.017	0.076
11	32.2	42.9	6.60	7.77	0.01	0.072
12		41.7		7.60	None	0.065
13		41.5		7.43	None	0.052
14		39.6		7.20	None	0.032
15		39.6		7.12	None	0.021
16		40.4		6.89	None	0.011

3.1 Productivity and Retention Time

The hydraulic retention time typically exhibits a range of 10 to 30 days, with variations influenced by the prevailing temperature conditions[11]. The findings of this investigation align with the data presented in Table 1, indicating that the retention time for the initial mixture was 11 days, while the second mixture had a retention period of 16 days. Subsequently, gas generation ceased for both mixtures. The extent of deterioration of a substrate is directly proportional to the duration of its exposure to optimal reactor conditions. Nevertheless, it is noted that the rate of reaction exhibits a decline when the residence duration is extended.

According to the data presented in Table 1, the commencement of gas production from the initial mixture occurred on the first day of the retention period. The average biogas yield throughout this

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period was recorded as 0.022 kg/day, with a 1:1 ratio. Subsequently, there is an increase in production to 0.025 kg/day on the second day, followed by a further increase to 0.028 kg/day from the third day through the seventh day. However, the production rate decreases to 0.021 kg/day on the ninth day. On the tenth day, the quantity of biogas generated was recorded as 0.017 kg per day, followed by a subsequent decline to 0.01 kg per day on the following day. The supplementation of additional bovine excrement in the subsequent trial (employing a blending proportion of 2:1) yielded augmented biogas generation and prolonged duration of gas retention. The maximum rate of production observed was 0.088 kg per day, which occurred on day 5 and persisted until the cessation of production on day 16.

3.2 pH and Temperature Analysis Result

3.2.1 pH Result

Table 1 shows the initial mixture had a pH of 6.11 on the first day. This pH value was found to be higher compared to the average pH value of 5.93 observed for the mixtures on days 2 through 5. The maximum gas generation observed for the feedstock consisting of a 1:1 mixing ratio of cow manure was 0.022 kg per day. The pH levels during the study period ranged from 5.81 to 6.60. In the case of the second mixture, which had a 2:1 ratio of cow manure, it was seen that there was a rise in pH levels as well as an increase in gas productivity. The maximum biogas output observed in this study was 0.088 kilogram per day, accompanied by an average pH value of 7.89. The growth of methane-producing bacteria and gas generation is affected by the pH. The low pH, which often occurs as a result of an overload of organic materials, hinders the growth of bacteria[11]. The process of digestion is most effective when the pH level is close to neutral, typically falling within the range of 6.89 to 8.2 [12]. Two-Stage Process for the anaerobic digestion of liquid cow manure and cheese whey, energies, the gas productivity in the

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second combination exhibited a significant increase of around 70.14% compared to the first mixture during 11 days. Throughout the experiment, there was a noticeable increase in pH values, accompanied by a corresponding increase in gas production. Specifically, the gas production rate reached 0.088 kg/day by day 7. In contrast, the initial mixture exhibited a pH of 6.60 and a gas production rate of 0.01 kg/day. After the experimentconcluded, the gas production rate for the second mixture was 0.011 kg/day at a pH of 6.89. The quantity of gas present in the first mixture was lower than that in the second mixture on the final day.

3.2.2 The Temperature Result Analysis

Temperature is a crucial factor in biogas production via fermentation. Figure (4 and 5) shows the relationship between the yield and ambient temperature for both mixtures with different temperatures. The pilot scale was incubated at the temperature of the weather where it was summer. The temperature was ranged from 29.4 to 47.46° C during the experiment period. The highest production of biogas for the first and second mixtures was indicated with the highest temperature (32 and 47.46 ˚C).

Temperature and substrate quality are key factors for stable anaerobic digestion. Microbial communities are affected by them, along with biochemical conversion pathways, reaction kinetics and thermodynamics [12]. The process of digestion can occur in environments with different temperatures. Psychrophilic digestion occurs between 10-25°C, mesophilic at 25-45°C, and thermophilic at 50-58°C. Thermophilic digestion requires a short retention time due to an increased degradation rate with higher reactor temperature. At the same time, high temperatures can kill most bacteria in the digester due to increased ammonia levels. When the nitrogen-rich substrate is exposed to high temperatures, most of the nitrogen converts to ammonia, which inhibits microbial activity in the digester, thereby reducing biogas production. In this study, we

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can note that the temperature was in the mesophilic range, which ranged from 32 and 47.46 ˚C.

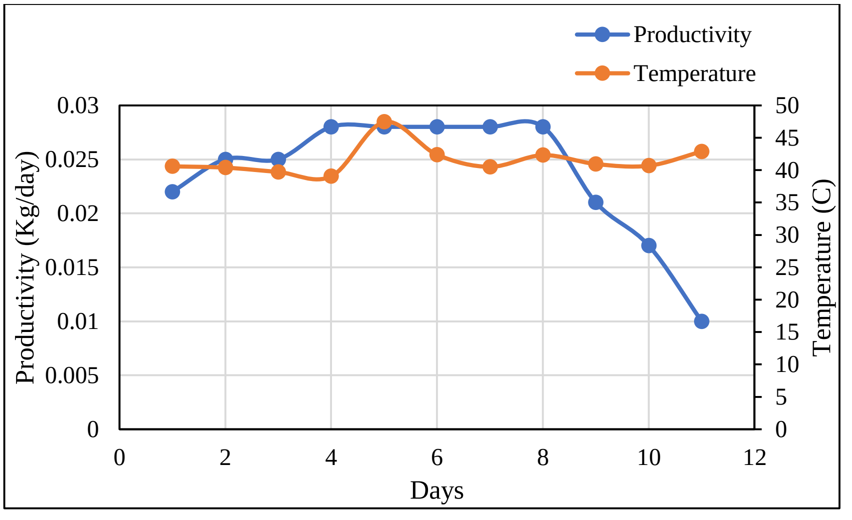

Figure 4. Temperature and Productivity Values Vs Days for The Mixing ratio of (1:1)

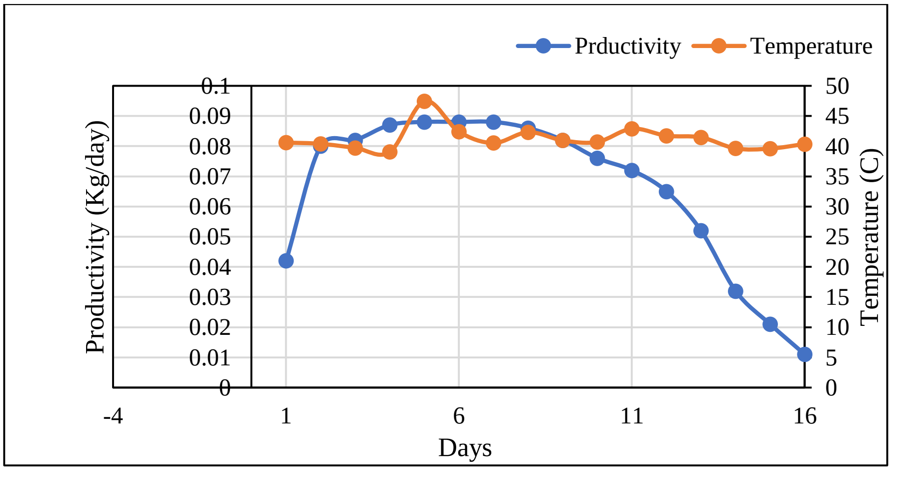

Figure 5. Temperature and PH values vs. days for Mixing ratio of (2:1)

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3.3 Biogas Productivity

Figure 6 illustrates a comparative analysis of the initial and subsequent gas mixtures in terms of productivity. During the study period, it was observed that the second combination exhibited a larger gas yield compared to the first mixture. The inclusion of cow waste in the composition resulted in an augmentation of gas production, and the rate of digestion became faster in contrast to the rate of biogas generation for the two mixtures. Figure (6) displays the respective daily biogas production quantities of 578 g/day and 630 g/day for the first and second mixes. The inclusion of cow manure in the mixture resulted in a gas production increase of 8.3% compared to the mixture without cow manure.

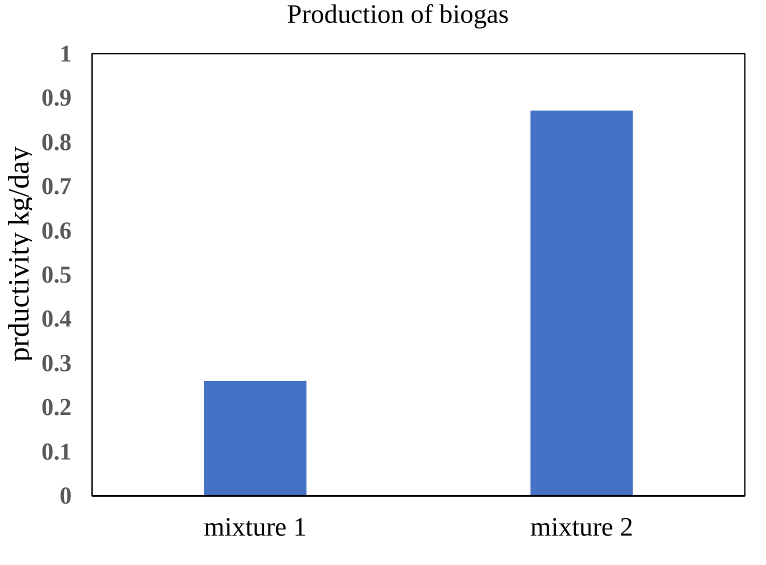

Figure 6. Total Amount of Biogas Productivity in the First and Second Mixture.

Based on the data presented in Figure 6, it is evident that the cumulative productivity was assessed throughout a study period of

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11 days. By employing a consistent calculation method, the annual productivity for mixture 1 was determined to be 8.63 kg/year, whereas mixture 2 exhibited an annual productivity of 28.90 kg/year.

3.3.1 Biogas Analysis Result

The sample for organic content analysis of biogas was collected upon completion of the experiment. The sample was obtained from within the gas balloon and afterward subjected to analysis in the laboratory of the Zawia refinery, utilizing a gas chromatography (GC) instrument. This apparatus exclusively quantifies the hydrocarbon constituents, including C_1 and other gaseous compounds. The biogas analysis findings for both combinations are presented in Table 2. The combination with a ratio of 2:1 consisted of 78.71% methane and 21.29% other gases, while the mixture with a ratio of 1:1 consisted of 58% methane and 42% other gases.

Table 2. The Hydrocarbons Composition of the Biogas.

mixture	Methane%	Other Gases%
1:1 ratio	58	42
2:1 ratio	78.71	21.29

From the literature review, methane represents about 50 to 75% of the total biogas. This study was applied to produce small quantities of biogas on a small scale. The size of the digester unit used for this study is 72 L, which is too small compared with the recommended proper size of 960 L, which should be constructed to get productivity equal to the amount of natural gas used by consumers, which is 12 kg by weight. For the difference in temperature between day and night and for the cold weather in the winter, we recommend preparing a tank burial beneath the earth to keep the temperature high enough for bacterial activities.

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4. CONCLUSION

In this study, a pilot unit has been made for the registration and generation of biogas with a volume of 72 L. From the study of the mixing ratio between cow dung and water, the main findings are that the mixing ratio of 2:1 releases more biogas than the mixing ratio of 1:1. Cow manure was a suitable substrate for biogas, especially with the addition of extra cow manure. The mixing ratio of 2:1 indicated that adding extra cow manure increased biogas production, where the highest rate was 0.088 kg/day on day 5, with a pH value of 7.52 and an ambient temperature of 47.5 °C. The analysis of the biogas produced indicated that the mixture with 2:1 contained 78.71% and the mixture with 1:1 contained 58% of methane. The biogas system and cost calculation are economically feasible for farmers, providing another source of energy to heat their farms and bio-fertilizers for agricultural purposes, saving them money.

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