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Influence of pH and the Insulation of Reactor on The Biogas Production of Livestock Waste by Batch Anaerobic Reactor

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Abstract: This study presents the improved biogas production by determining the optimum pH and insulation reactor from cow, sheep, and poultry manure (which are the most available in our location). The experiment was carried out in 2000 mL digester put in the water bath at 37 ˚C. The mixing ratio of animal manure and water used was 1:1 in 12 days of Hydraulic Retention Time (HRT). Produced gas was measured by the volumetric water replacement method. The optimum pH will be chosen in the experimental test with different pH ranges in the first phase. Three set-ups were prepared with different pHs (6.5, 7, 7.5). The results showed that the pH had significant effects on biogas yield, where pH7 had the highest biogas production and pH 6.5 is the lowest. The second phase, investigated the effect of the insulation of the reactor on the biogas yield. The biogas was produced from an insulated reactor higher than the photoreactor because of the growth of algae which produces oxygen in the photoreactor. Therefore, it is given that the study which gave a maximum yield of biogas from the batch digestion process might be met the future energy demand.

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تأثير درجة الحموضة وعزل المفاعل على إنتاج الغاز الحيوي لنفايات الماشية بواسطة المفاعل اللاهوائي الدفعي

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ملخص: تعرض هذه الدراسة تحسين إنتاج الغاز الحيوي من خلال تحديد الرقم الهيدروجيني الأمثل وعزل المفاعل لروث البقر والأغنام والدواجن (الأكثر توفرًا في موقعنا). نفذت التجربة في هاضم سعته 2000مل وضع في حمام مائي عند 37 °م. كانت نسبة الخلط لروث الحيوانات والماء المستخدم 1:1 في 12 يومًا من زمن الاحتفاظ الهيدروليك (HRT). تم قياس الغاز المنتج بطريقة الاستبدال الحجمي للمياه. في المرحلة الأولى، سيتم اختيار درجة الحموضة المثلى في الاختبار التجريبي بنطاقات مختلفة من درجة الحموضة. تم تحضير ثلاث عينات بدرجات حموضة مختلفة (7،6.5، 7.5). أظهرت النتائج أن درجة الحموضة كان لها تأثيرات كبيرة على إنتاج الغاز الحيوي، حيث كان الرقم الهيدروجيني 7 أعلى إنتاج للغاز الحيوي وكان الرقم الهيدروجيني 6.5 هو الأقل. في المرحلة الثانية، تم دراسة تأثير عزل المفاعل على إنتاج الغاز الحيوي. كان إنتاج الغاز الحيوي من المفاعل المعزول أعلى من المفاعل الشفاف بسبب نمو الطحالب التي تنتج الأكسجين في الهاضم الشفاف. لذلك فأن الدراسة التي أعطت أقصى إنتاج للغاز الحيوي من عملية الهضم الدفعي قد تلبي الطلب المستقبلي على الطاقة.

Keywords: Improving biogas production, pH level, Photoreactor, Livestock waste, Batch digestion.

1. INTRODUCTION

Fossil fuel is currently the world's main source of energy and is prevalent in forms such as crude oil, hard coal, and natural gas. Such fuels are not renewable energy sources as they were formed over hundreds of millions of years but are consumed at a much faster rate than the rate at which new fossil fuels are being formed. One of the largest disadvantages associated with the use of fossil fuels is that harmful greenhouse gasses such as carbon dioxide are released when it is burnt during energy production processes. This is especially true during the production of electricity via coal-fired power plants [1].

In recent years, the energy sector has received increased attention due to the concern about an oil shortage. Additionally, concerns such as the greenhouse effect and the general depletion of our energy reserves have played a significant role in the debate. This has caused the development of a range of new energy technologies such as wind energy, solar energy, and biomass energy [2,3].

The anaerobic digestion (AD) of biomass to produce biogas is considered to be a model for choosing the best alternative sources of energy for rural areas using the reasoning that it is cheap and can be locally produced and used. Also, the biogas produced can be used for several purposes such as heating, lighting, fuel for cooking, and local or on-the-grid electric power generation [4].

Animal manures can be used as sources of biomass-based conversion processes, especially in bio-energy and bio-fertilizer production. Today, developed countries tend to decrease the number of farmers but increase the number of animals. This trend is also transforming livestock production in developing countries [5]. Livestock contributes to nearly 40% of the total agricultural production in developed countries and 20% in developing countries, supporting the livelihoods of at least 1.3 billion people worldwide since 34% of the dietary protein supply comes from livestock [6].

The specific amount of cattle manure per animal relies on many aspects such as feeding regime, stage of the process, type of production system, etc., and the method of housing used [7]. Livestock activities have an environmental impact when manure is not effectively managed [8,9]. On the other hand, animal manure is considered an attractive natural resource for renewable energy production, and can also replace industrial fertilizers and improve soil fertility [10,11].

AD can take place at psychrophilic temperatures below 20 C but most reactors operate at either mesophilic temperatures or thermophilic temperatures, with optima at 35 C and 55 C, respectively. The methane yields that are obtained at a temperature range of 15 – 20°C is about 26 – 42% of the yields achieved at 35°C [12]. The percentage of methane in biogas produced under thermophilic conditions (55°C) is on average 2% higher when compared with biogas produced under mesophilic conditions(35°C). It has been shown that temperature has almost no effect on the ultimate methane yield of beef cattle manure for temperatures between 30 and 60°C [13].

The pH levels and alkalinity are significant factors in the AD process. Alkalinity is necessary to control the pH and acts as an inhibitor of acid formation during acidogenesis. The methane-producing bacteria (methanogens) are sensitized to pH variation and operate between 6.5 and 7.8. The carbon dioxide content and the consumption and production of volatile acids in biogas affect the pH. Minor levees in alkalinity can exist when organic acids concentrate in the digester due to the introduction of large amounts of organic acids through the feed source of the digester or failure to mask the acids into methane in the process of methanogenesis. To maintain constant pH levels, sodium bicarbonate (pH buffer) can be added as a buffer, or a material with a high storage capacity, such as food scraps or dairy manure, can be added [14].

In a study evaluating the influence of diet and the period on the AD of cows, Orrico et al [15] observed that only the diet had an effect under the digestion process. The authors observed that the proportion with the highest amount of concentrate (40% roughage and 60% concentrated) led to greater efficiency in the gas production compared to the 60% roughage and 40% concentrated diet with a biogas production potential of 420 mL/g.

Barros et al. [16] evaluated the biogas production in an Indian digester with a capacity of 7 m^3, using cow manure as substrate. In the two-month period, the researchers observed a cumulative production of 5.025 L. In addition, Weber [17] while studying the biogas production from cow manure by using a vertical continuous digester, with a capacity of 20 m^3, observed the production of 396.850 L of biogas in four months.

Several studies to develop strategies to increase biogas production and methane yield have shown that the co-digestion of organic wastes, such as animal manure combined with industrial, agricultural, and municipal wastes, is a viable option [18]. However, the low rate of biodegradation of fibrous wastes, such as manure, proves that an anaerobic digestion process for biogas production based solely on these substrates may be difficult, whereas the addition of substrates with lower fiber contents facilitates a more rapid initiation and increase in the biogas yield.

Previous studies have investigated the use of cow manure that was co-digested with different wastes to increase biogas production and methane yields. Cunsheng et al. [19] reported that co-digestion of cattle manure with food waste in batch mode at an optimal ratio of 2:1 (manure: food waste) increased methane production by 41%, from 2624 ml to 3725 ml, compared to mono-digestion. Benali et al. [20] Effect of solid concentrations on anaerobic digestion of cow manure. This research aims to determine the optimum water dilution which will produce a high biogas yield. Three batch set-ups; CM1, CM2, and CM3 of uniform amounts of cow manure were prepared with different water dilution conditions. The results of accumulated biogas yield at the end of an experiment were 5.38L, 3.96L, and 3.4L for CM2, CM1, and CM3.

Benali et al. [21] comparative study of biogas production from cow, chicken, and sheep manure, this research aims to determine the best sample from animal waste for the production of biogas, where the study has proven that the maximum value of biogas production for chicken manure is followed by sheep and cow respectively.

In Libya, even if the production of biogas started in the last few years, still there is too much need to optimize the biogas resources. This experimental study provides strong evidence that the concept of improving biogas yield by painting the reactor with black color and determining the optimum pH of cow, sheep, and poultry livestock manure.

2. EXPERIMENTAL SET-UP AND PROCEDURE

The experimental set-up was made to study the effect of pH and the insulation of the reactor on the biogas production of cow, sheep, and poultry manure. The reactor made of a plastic bottle of 2 liters capacity was used for set-up. The schematic of the biogas production unit is shown in Figure 1. The reactor was linked with the displacement bottle and water collector. Rubber tubes were used to link the reactors and the displacement bottles.

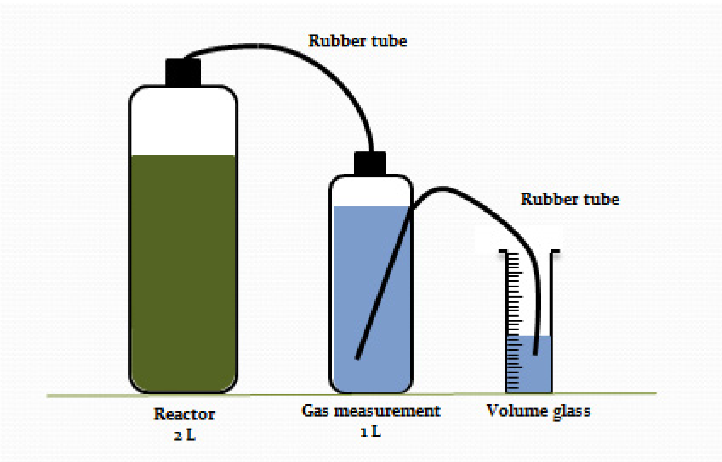

Figure (1). Biogas production unit.

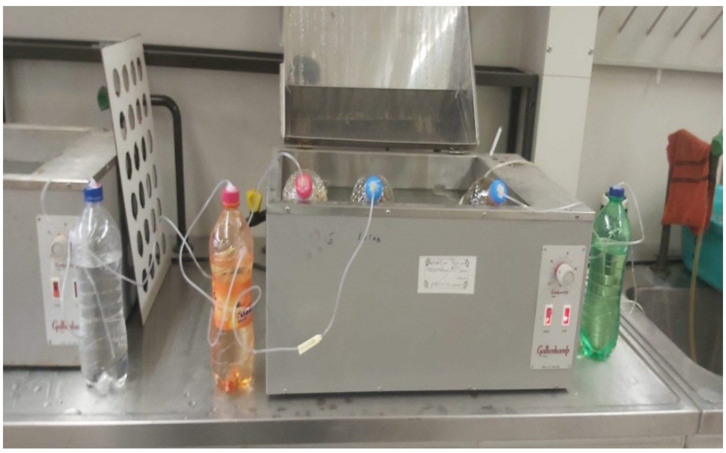

Figure (2). The water bath laboratory

The digestion process was done in the water bath at 37°C as shown in Figure 2. The three reactors were operated in batch type and fed manually.

3. RESULTS AND DISCUSSION

In this research work, Phase I and phase II of the experiment were carried out using fresh manure of poultry (PM), cow (CM), and sheep(SM). Phase I was conducted to verify the effect of pH on biogas production, while phase II Investigated the effect of insulation of digester on biogas production. The characteristics of the experiments are shown in Table 1.

Table (1). The details of the experiment.

Mass of manure	560 g
Volume of water	560 ml
Temperature	37 ^{0}c
Hydraulic retention time	12 days
Measurement of biogas production	Daily (24hr)

3.1. Phase I

The substrates have been tested for the effect of pH on biogas production. Figure 3A, B, and C. shows the daily biogas yield over 12 days retention period from PM, CM, and SM at various pH conditions.

Gas production was increasing on the first days and then decline with the passage of days. On the first day of PM produced 741 ml, 722 ml, and 641 ml at pH 6.5, 7, and 7.5 respectively, while in the CM produced on the first day 653ml,610ml and 515 ml at pH 6.5, 7, and 7.5 respectively, Finally, the SM produced 386ml,387ml, and 363ml at pH 6.5, 7 and 7.5 respectively.

The result showed that PM produced the highest biogas production at each pH level, followed by CM, and the lowest by SM.

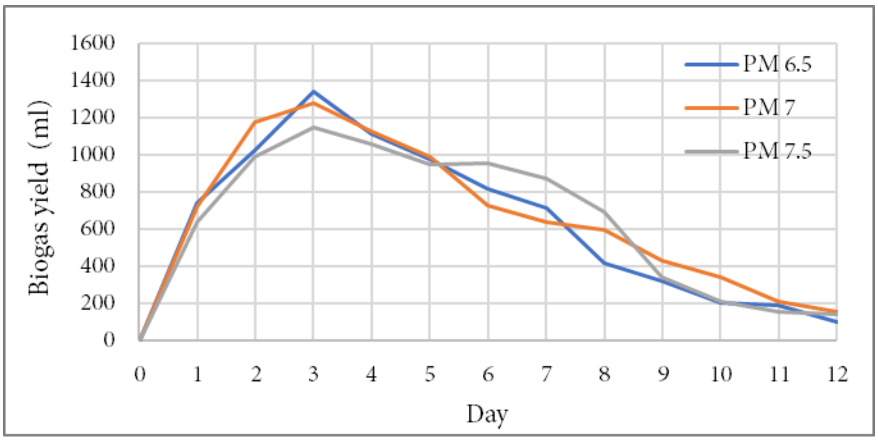

Figure (3-A). Daily biogas yield from PM.

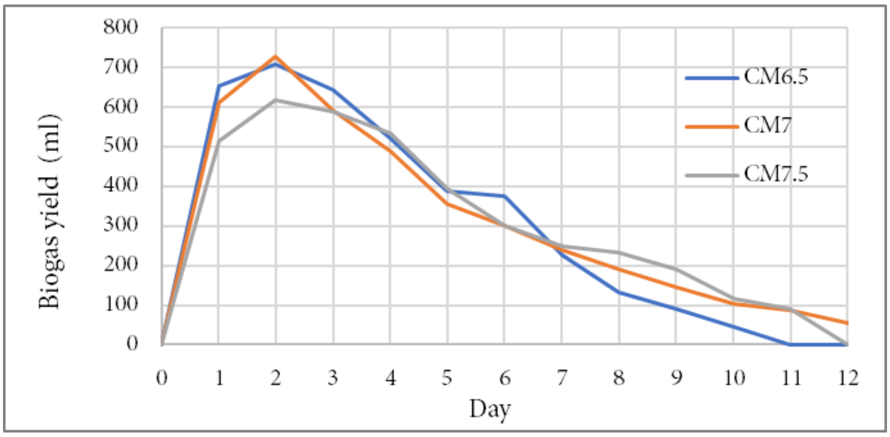

Figure (3-B). Daily biogas yield from CM.

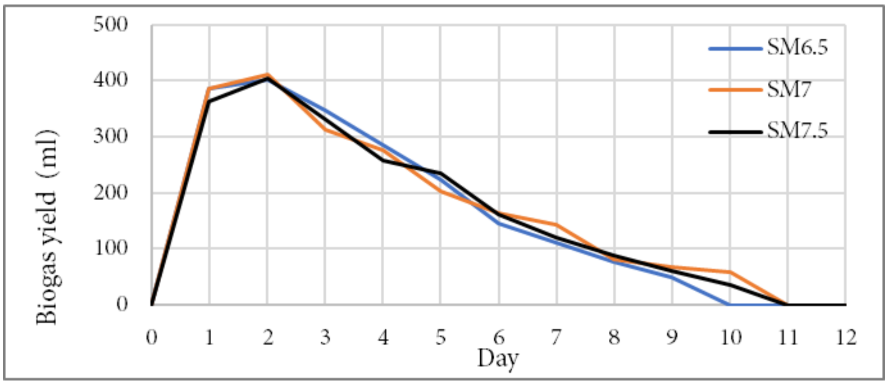

Figure (3-C). Daily biogas yield from SM.

Figure 4. shows the total biogas yield from PM, CM, and SM at various pH conditions. The results showed that the highest amount of gas production was at pH 7, then pH 7.5, and finally at pH 6.5 in all substrates. Where in PM the biogas produced from pH 7 was higher than the gas produced from pH 7.5 by 2.9% and the gas produced from pH 7.5 was higher by 2.3% than the gas produced from pH 6.5, while in CM the gas produced from pH 7 was higher than the gas produced from pH 7.5 by 1.78 % and the gas produced from pH 7.5 was higher by 1% than the gas produced from pH 6.5, Wherein SM the total biogas produced from pH 7 was higher than the gas produced from pH 7.5 by 1.1 % and the gas produced from pH 7.5 was higher by 1.4 % than the gas produced from pH 6.5.

The reason for these results is that the pH of the substrate has a significant effect on biogas production because it affects the activity of bacteria to destroy organic matter in biogas. A low pH in the digester inhibits the activity of microorganisms involved in the digestion process, particularly methanogenic bacteria. Micro-organisms grow best at their optimum growth at neutral pH of 7.0. Growth occurs slowly or not at all below the minimum growth at neutral pH and above the maximum growth at neutral pH.

The AD process is sensitive to pH level, thus changes in pH level can cause the inhibition of biogas production. pH levels that are too high or too low inhibit the growth of methanogenic microorganisms, which then reduces the production of biogas. Methane production occurs in the pH interval between 5.5 and 8.5. The optimum pH level for methanogens to form methane is between 6.7and 7.5. Cattle manure is suitable for AD to produce biogas as it has a pH level of 7.5 which is within the optimal range of pH. The AD process is severely inhibited when the pH level decreases to below 6.5 (acidic) and rises above 8.5 (alkaline).

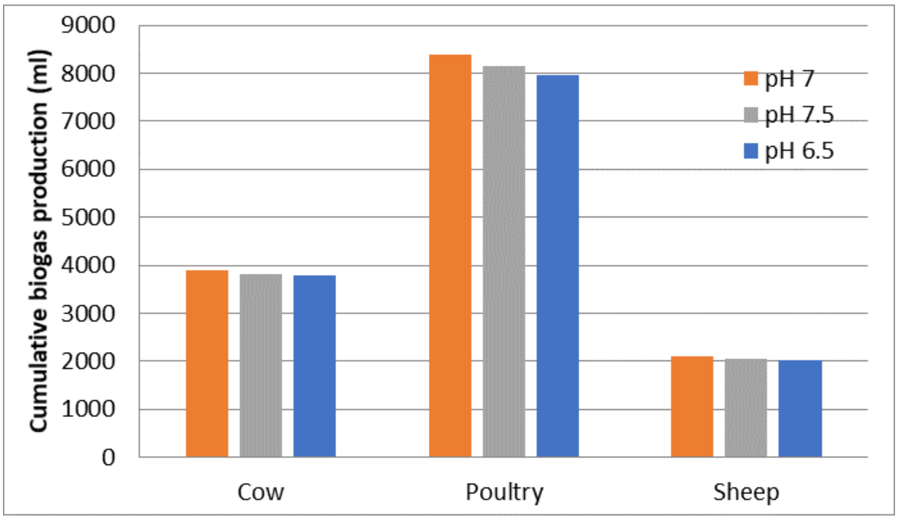

Figure 4.Cumulative biogas yield from PM, CM, and SM.

3.2. Phase II

The results showed that coated reactor with black color and type of manure had a significant effect on biogas yield as shown in Figure 5. PM produced the highest average yield while SM produced the least (Table 2).

Table (2). The effects of insulation of reactor and type of manure on biogas production.

Parameter	Transparent			Black		
Manure type	CM	PM	SM	CM	PM	SM
Temperature (^{0}C)	37	37	37	37	37	37
pH	6.1	5.74	6.54	7.03	5.99	6.67
Avg. daily biogas production(ml)	318	682	177.5	325	711.5	263.33

Figure (5). Shows the average daily biogas production of the black and photoreactor from the PM, CM, and SM. The result shows that the black reactor produced higher biogas than the photoreactor because sunlight encourages the growth of algae which retards biogas production.

Figure 5-A. shows the daily volume of biogas produced from PMB and PMT within the retention period of 12 days. In the case of PMB, 1000 ml of biogas was produced on the first day, then it started to increase on the second day as it produced 1100 ml. On the third day, it produced 1150 ml. The highest biogas production was recorded on the 4th day at 1580ml, and the gas production reached 181 ml on the 12th day. In the case of PMT, 540 ml of gas was produced on day 1, then it started to increase on day 2 as it produced 900 ml.

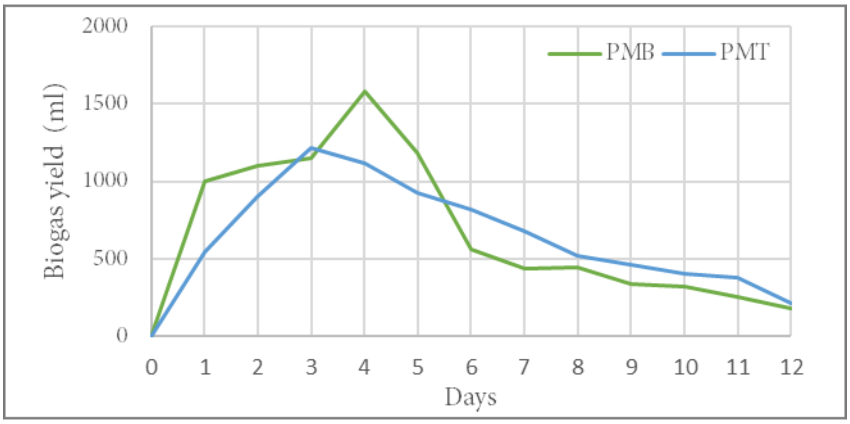

Figure (5-A). Biogas yield during digestion in PM.

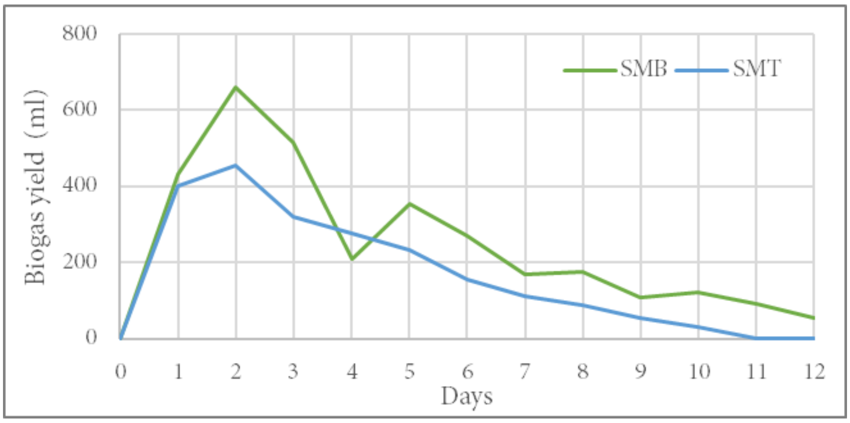

Figure (5-B). Biogas yield during digestion in CM.

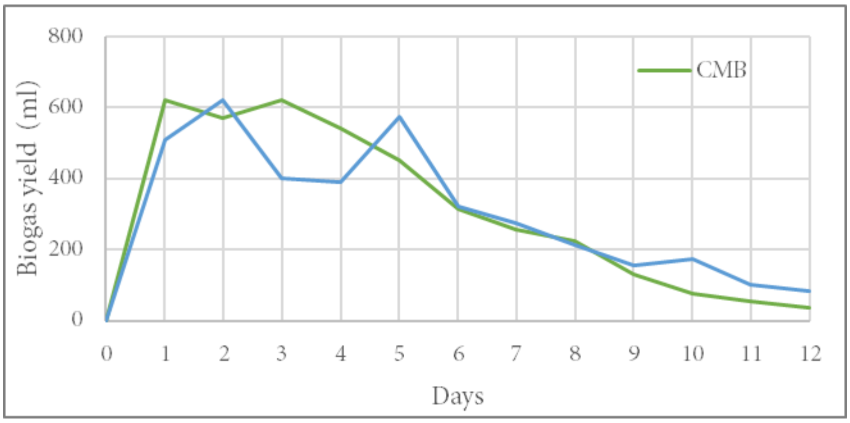

Figure (5-C). Biogas yield during digestion in SM.

On day 3 it produced 1220 ml, which is the highest biogas production. The gas production continued to decrease until it reached 212 ml on the12th day. Figure 5-B. shows the daily volume of biogas produced from SMB and SMT within the retention period of 12 days. In the case of SMB, the highest biogas production was recorded on the second day at 660 ml.

In the case of SMT, the highest biogas production was recorded on the second day at 453ml.

Figure 5-C. shows the daily volume of biogas produced from CMB and CMT within the retention period of 12 days. In the case of CMB, the cumulative biogas production was 3900ml. In the case of CMT, the cumulative biogas production was 3817ml.

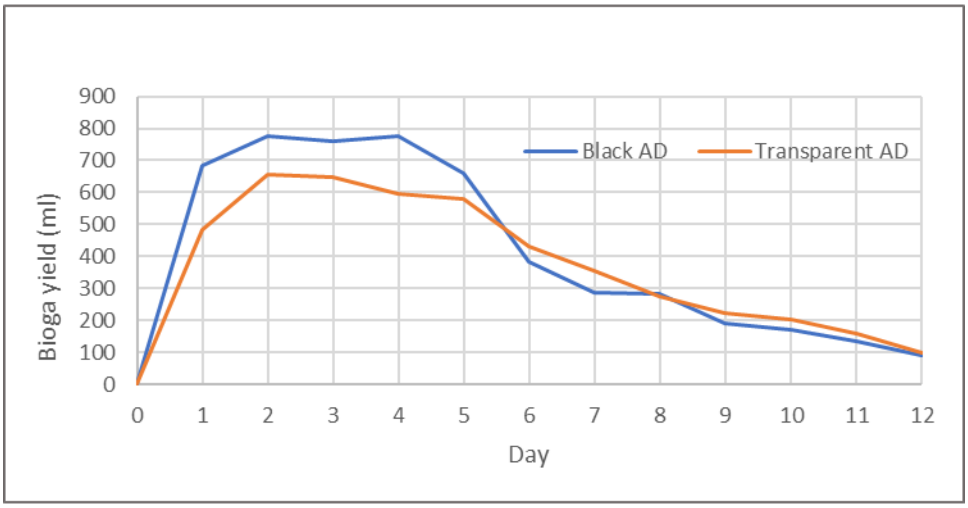

Figure 6. Average biogas yield in the Black reactor and Transparent reactor of three different types of animal manure (PM, CM, and SM).

Figure 6 shows that the black anaerobic digester is better than the transparent anaerobic digester. That is because the fungi growth increases when light enters the anaerobic digester.

This growth produces oxygen inside the reactor. Numerous problems thereafter arise to the activity of anaerobic bacteria responsible for biogas production, and because of that, biogas production decreases. These results are corresponding to the results of Oladoye C.T, et al [22].

4. CONCLUSION

The results showed that the pH scale had an important effect on biogas yield, where the slurry neutral had the highest biogas production and the slurry acidic is the lowest. Phase II proved the Insulation of the reactor to light had a significant effect on biogas yield. Therefore, it is recommended to the researchers not use a transparent reactor.

If it is transparent, paint it black because it keeps the temperature steady, and sunlight encourages the growth of algae which retards biogas production.

In addition, the animal species' effect on biogas production where the highest biogas production was recorded on PM and then CM and SM respectively.

5. RECOMMENDATIONS

In the future, an experiment would be expanded for including all types of animal manure. In addition, study the effect of feeding on biogas production between farms and barns.

6. ACKNOWLEDGEMENTS

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