



ORIGINAL RESEARCH ARTICLE

BIOGAS PRODUCTION AND NITROGEN RECOVERY FROM CATTLE AND CHICKEN DUNG THROUGH ANAEROBIC DIGESTION.

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ARTICLE INFORMATION

Received: 3rd July 2024
Reviewed: 14th February 2025
Accepted: 16th February 2025

Keywords:

Anaerobic digestion
Biochemical methane potential
Cattle dung
Chicken dung
Biogas production

ABSTRACT

This study was conducted to determine the biochemical methane potential (BMP) of cattle and chicken dung through anaerobic digestion. Essentially, manure from animal waste could be a valuable resource in the production of high-grade organic fertilizer. To achieve this, chicken and cattle dung were collected at Ramat polytechnic farms in Maiduguri for the assessment. All samples were prepared and the digestates analysed to determine the nutrient composition using Atomic Absorption Spectrophotometer (AAS), UK, 2005. Thereafter, the nitrogen (N) content was measured using Kjeldal method. This process was observed for seven (7) days. Finally, the water displacement method was adopted to measure the amount of biogas produced. The results show that at a ratio of 2:3 cattle to chicken dung, the highest gas yield was 117 mg/l on the first (1) day and the lowest gas yield was 53 mg/l using the blank sample on the seventh (7) day. Nevertheless, using blank sample and ratios of 1:1, 2:3, and 3:2, the amounts of nitrogen compounds in the substrates prior to and following digestion were 1.17, 1.66, 2.45, and 2.39 mg/l and 2.17, 2.66, 3.25, and 3.19 mg/l, respectively. Consequently, it is evident that the production of biogas and biofertilizer from agricultural waste has the potential to be a promising technology in low-income society.

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1.0 Introduction

Effective waste management and recycling are essential for maintaining a healthy environment and mitigating pollution. Animal manure particularly from cattle and chicken dung poses significant environmental challenges if not managed properly. Improper handling can lead to pollution, odors, pest infestations, and eutrophication (Castrillon et al., 2017). However, manure can be converted into valuable resources through anaerobic digestion, producing high-quality organic fertilizer rich in nutrients and compounds (Li et al., 2021). While also reducing the environmental impacts associated with manure disposal. Manure typically contains hemicellulose, cellulose, lignin and essential nutrients, making it an ideal substrate for biogas production and nutrient recovery. Animal manure can be converted into biogas, a renewable energy source, by anaerobic digestion. The main components of biogas are carbon dioxide (CO₂) and methane (CH₄), with typical concentrations of 50–70% (CH₄) (Kumar et al., 2018). A clean burning fuel that can be used for heating, cooking, and electricity generation can be produced by anaerobic digestion, which can extract up to 90% of the biogas found in animal manure (Robert et al., 2020). For the treatment of nutrient-rich cattle and chicken manure, anaerobic digestion is an appropriate technique that can produce biogas and biofertilizer. Excreta, hair and feathers, feed and water spills, processed waste, wastewater bedding, wood shavings, and composted manure are all components of cattle and chicken dung. Manure is a great way to get nutrients for crops to grow and be productive. However, a number of variables, including animal species, diet, digestibility, proportions of protein and fiber, age, housing conditions, and stage of production, can affect its qualities and characteristics. The solid content, size, and composition of manure solids are crucial for collection, storage, handling, and utilization (Li et al., 2021). Nitrogen is an essential nutrient for plant growth and its extraction from animal manure can provide a valuable fertilizer for agriculture, cattle and chicken dung are rich in nitrogen with typical concentration ranging from

1.5 to 4.5 % ((Kumar et al., 2018). This study aims to investigate the biochemical methane potential of cattle and chicken dung using different ratios and their physico-chemical compositions.

2. Materials and Method

2.1 Materials

In this study, the materials and equipment used includes the following Scotch bottles, Bath with Temperature Control, Coke or Stopper, Pipe for Gas Outlet, Cow dung (Inoculum), Dung of Chickens, Water, Atomic Absorption Spectrophotometer (AAS) Buck Scientific 210VGP, UK, 2005, Potassium hydroxide, Sulphuric acid copper and Tetraoxosulphate (VI) acid concentrate.

2.1.1 Sample Collection and Preparation

Cattle and chicken dung were obtained at Ramat Polytechnic Agricultural Farm in Maiduguri, Borno state. It was packaged in a plastic container and then taken to the laboratory for examination.

2.1.2 Preparation of Slurry

In this study, both cattle and chicken dung were prepared according to Angelidaki et al., (2004) and (2009). The percentage of the methane in the substrate was calculated using BMP. Before the slurry was put into the digester tank, it was thoroughly mixed to obtain an air-free sample to remove trapped air in the waste. The slurry was put into the digester and all contaminants were removed.

2.1.3 Set Up of Digester

Two 500 ml scotch bottles were filled to the brim with 225 ml of inoculum (sludge) and a corresponding volume of substrate, leaving 50 ml available for the biogas head space. The ratio of substrate biomass to inoculum was maintained at 1:1, 2:3, and 3:2. Then, two blank bottles with 225 ml of inoculum and 450 ml of tap water added were utilized as controls. Before the stopper was applied, all bottles were flushed with 100% nitrogen gas (N) for one minute to remove any air from the head space. After that, the digester was kept in an incubator with water at a temperature that was mesophilic and at the neck of the bottle. Every day for one minute, each digester was shaken in the water bath until the biogas production stopped, which took seven (7) days. Using a graduated measuring cylinder and the water displacement method, the biogas production was monitored. The Buck Scientific 210VGP Atomic Absorption Spectrophotometer (AAS), UK, 2005 was then used to analyze the digestate, to ascertain the potentials of nitrogen (N) following the BMP test. All duplicate was conducted in triplicate.

2.2 Water Displacement Laboratory Experiment

The purpose of this experiment was to measure the waste substrates' daily gas yield and volume. A measuring cylinder served as the water collector, a 400 ml flask as the water tank, and a 500 ml flask as the digester. The 400 ml flask (water tank) was connected to the digester using a rubber hose, and a longer rubber hose was placed through the top of the flask to the bottom, providing a tiny allowance. The 100 ml measuring cylinder, which acts as the water collector, received the water opposite end. The volume of water that was displaced in this experiment is intended to be equivalent to or represent the volume of biogas that was produced over the course of the experiment (see Figure 1). Water was added to the waste substrates as follows:

1. 225 ml of water plus 225 g of cattle dung.
2. 225 ml of water plus 225 g of chicken dung.
3. Digester capacity: 500 ml
4. Water tank capacity: 400 ml
5. Slurry volume: 450 ml and 6. 50 ml head space in the digester

The 500 ml flask was filled with the measured individual sample slurry, allowing the anaerobic digestion (AD) process to begin while the gas yield was monitored and recorded over the course of the seven-day residence

period. The setup was positioned in a spot that was readily exposed to sunlight in order to guarantee that the mesophilic range 25°C to 40°C was reached.



Figure 1: Digester setup

2.2.1 Digestion Method

The substrates were broken down before being analyzed. A precise weight of 1g of the prepared sample was placed into the Kjeldal flask and filled with 1kg of potassium sulphate, 8g of copper sulphate, and 20ml of concentrated tetraoxosulphate (VI) acid, and thoroughly mixed. The content of the flask was heated for four hours until the mixture turned clear (blue green in color). Thereafter, the heating was stopped, and the mixture was carefully cooled.

2.2.2 Distillation

20 ml of the digested mixture was measured into a distillation flask, and 10 ml of 60% sodium hydroxide (NaOH) was carefully added by the side of the flask so that the solution is sufficiently alkaline. 20 ml of 4% boric acid was added to the flask. The digested mixture was then transferred into a conical flask, and 100 ml of distilled water was added and mixed. The receiver tube's tip was positioned slightly below the surface of the standard when the distillation apparatus was put together. Until all the ammonia was concentrated into the receiving flask, the contents were heated on a heating mantle.

2.2.3 Titration

0.1N hydrochloric acid was added to the receiver flask and titrated until a color shift occurred. Without testing the materials, a blank determination was performed with all the reagents in the same amounts. It was then combined with 2 ml of concentrated hydrochloric acid (80% HCL) and heated to 100 degrees Celsius to dry it out. Additionally, it was filtered with 5ml of 20% nitric acid using 10µm Whatman filter paper and transferred into a 100ml volumetric flask. At this point, the extract is prepared for analysis with the analytical device. The Buck Scientific 210VGP Atomic Absorption Spectrophotometer (AAS), UK. (2005) was used to measure nitrogen (N).

3. Results and Discussion

The physico-chemical characterisation of the substrate is presented in Table I. The physicochemical properties of the two substrates (cattle and chicken dung) show that the substrates are suitable for co-digestion. Furthermore, it revealed that both substrates have similar characteristics. Interestingly, while the chicken dung was found to have consisted of higher composition of COD, Vs, NH₃-N, TN, PO₄³⁻, P and C/N than the cattle dung, the cattle dung has higher composition of Ts and FOG than the chicken dung. This study is in agreement with the results reported by Angelidaki et al., (2009), Mohammed et al., (2018) and Cabrita et al., (2023).

Table I. Physico-chemical parameters of substrates

Parameters	Cattle Dung	Chicken Dung
COD (mg/L)	8000 ± 3	19,600 ± 3
pH	8.85 ± 0.1	9.23 ± 0.1
Vs (%)	76.23 ± 2	86.25 ± 2
Ts (%)	89.55 ± 2	77.42 ± 2
NH ₃ -N (%)	0.26 ± 0.001	0.37 ± 0.001
TN (mg/L)	3611 ± 3	12,510 ± 3
FOG (mg/L)	2100 ± 2	1620 ± 2
PO ₄ ³⁻ (mg/L)	232 ± 0.01	631 ± 0.01
Protein (mg/L)	1340 ± 3	5620 ± 3
C/N	16.45 ± 2	20.23 ± 2

3.1. Average Daily Gas Yield

Figure 2 shows the average volume of methane produced during the seven (7) days of digestion. It was observed that from the beginning to the end of the digestion significantly increased from 53 mg/L to 77 mg/L for the blank sample, 67 mg/L to 101 mg/L for the 1:1, 64 mg/L to 117 mg/L for the 2:3 and 66 mg/L to 93 mg/L for the 3:2 ratios respectively.

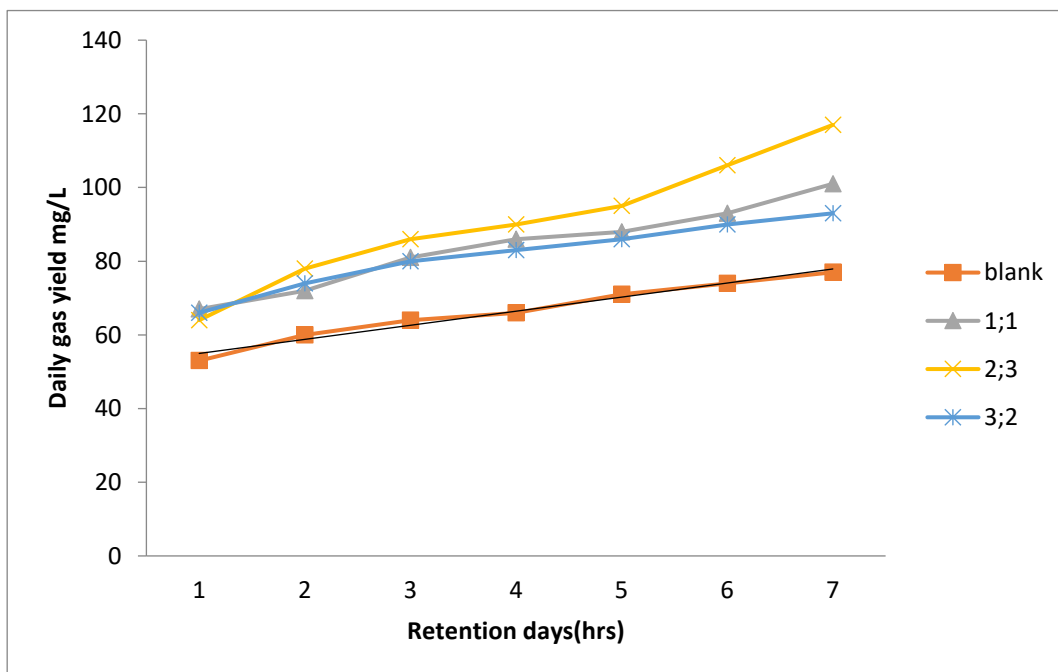


Figure 2: Average daily gas yield in 7 days

As observed from the total volume of biogas generated during the digestion. It shows that co-digestion of cattle and chicken dung produced between 53mg/l -117mg/l in the blank sample while) and ratio 2:3 mix ratio respectively. The most biogas produced at day seven (7) during the experiment appeared to give the best result. However, the co-digestion of chicken and cow dung using mix ratio of 2:3 produced higher biogas volume than that of 1:1, 3:2, and blank, at 117,101, 77, and 53 mg/l, respectively. A similar study was conducted by Mohammed et al., 2019 who demonstrated biogas production from a blend of chicken, pig, and cow manure in a ratio of 1:1:1with corresponding Nitrogen levels of 272N/ml, 167N/ml, and 80.5N/ml. Similarly, Ojo, (2021) conducted research and reported that the volume of biogas produced from a blend of 1:1 ratio of chicken to pig manure was 323ml and 528ml respectively. Thus, biogas produced can be used to generate renewable green energy in the form of electricity and heat via a combined heat and power engine.

3.2. Average Composition of Inoculum before Digestion

Table 2. shows the average elemental composition of substrates obtain from chicken and cattle dung that have been weighed and compared with a blank, 1:1, 2:3, and 3:2 ratios before digestion. The result indicates that the concentration of N in the substrates are 1.17, 1.66, 2.45, and 2.39 mg/L respectively.

Table 2. Average Initial Composition of Inoculum Before Digestion

Parameters (g/ml)	Blank	1:1	2:3	3:2
N	1.17	1.66	2.45	2.39
P	0.80	1.14	1.66	1.64
K	0.39	0.57	0.83	0.79
Ca	2.86	2.94	4.18	3.14
Na	0.26	0.34	0.36	0.35
Fe	0.023	0.026	0.030	0.027
Mg	0.22	0.26	0.32	0.30
Zn	0.18	0.20	0.45	0.30
Si	10.75	14.06	16.04	15.46

A study conducted by Abdulraheem et al., 2018 using sweet potatoes reported that N compound concentrations of was 1.19 and 1.05 mg/l. However, the present in this study, N concentration was observed to be higher compare with the results obtain from their study.

3.3. Average Composition of Inoculum After Digestion

Table 3. shows the average composition of substrates made from chicken and cattle dung compared with the blank, 1:1, 2:3, and 3:2 ratios before digestion. The results show that N concentration in the substrate was 1.85, 2.43, 3.25, and 3.19 mg/L respectively.

Table 3. Average Composition of Inoculum after Digestion

Parameters(g/ml)	Blank	1:1	2:3	3:2
N	1.85	2.43	3.25	3.19
P	1.80	2.14	3.16	2.64
K	1.39	1.57	2.03	1.79
Ca	1.86	1.94	2.55	2.14
Na	0.26	0.34	0.36	0.35
Fe	0.53	0.66	1.03	0.87
Mg	0.12	0.16	0.22	0.20
Zn	0.18	0.30	0.79	0.70
Si	0.75	0.76	1.04	0.86

Similarly, Anthony et al., 2016 and Mohammed et al.,2019 conducted a research and reported the presence of N concentration to be 3.11 mg/L and 0.84mg/L and 2.50mg/L and 2.01mg/L for rice and tea garden production respectively. Also in a similar research by Detpiratmongkol et al., 2014 , the result indicates that N concentration was 2.65mg/L and 2.33mg/L for production of Kalmegh (*Andrographis paniculata* Nees.).

3.4. Comparison of the Average Initial and Final Elemental Composition of Substrate

There is a noticeable increase in the N composition following anaerobic digestion, of the two samples. the comparison is presented in Tables 4. It was clear that the mixing ratios had varying effects on the substrates used for the digestion, as higher values were recorded in co-digestion of the substrates at 2:3 ratio.

Table 4: Comparison of the Average Initial and Final Elemental Composition of Nitrogen (N) in the Substrates

Mixing ratio	Initial (mg/L)	Final (mg/L)
	Nitrogen	
Blank	1.17	1.85
1:1	1.66	2.43
2:3	2.45	3.25
3:2	2.39	3.19

4. Conclusion

This study demonstrated the potentials of cattle and chicken dung as substrates for biogas production and nitrogen extraction. The co-digestion of cattle and chicken dung at a 2:3 ratio yielded the highest daily biogas production, outperforming the 1:1, 3:2, and blank ratios. Similarly, both substrates are rich in nitrogen with concentrations ranging from 1.17 to 3.25 mg/L before and after digestion. The study concludes that cattle and chicken dung are viable sources of bioenergy (biogas and bio-fertilizer). It is noteworthy that the co-digestion of these substrates at a 2:3 ratio has potential for conversion into valuable NPK blend products for organic fertilizer, offering a safe, cost-effective, and sustainable alternative to inorganic fertilizer currently in market.

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