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# Comparative Analysis of Biogas Produced from Cow Dung and Poultry Droppings

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**Abstract.** This study involves a comparative analysis of two waste substrates; cow dung and poultry droppings. The purpose of this study was to ascertain which of the waste substrates produces a greater yield of biogas, their individual retention period as well as the percentage of the methane content in the gas generated. The study was divided into two experiments which comprised of a water displacement set up in a laboratory and one 30 L fixed dome digester for each waste substrate. In both experiments waste substrates were mixed with water in ratio 1:1 and operated at a mesophilic temperature condition. In the laboratory, the daily gas yield of the individual substrates in ml was obtained, it was observed that cow dung produced an average of 29.9 ml of biogas per day and the poultry waste produced 60.7 ml per day. A gas analysis was performed to obtain the gas profile of gas produced from the two substrates. As deduced from the analysis, cow dung had a methane and $CO_2$ weight percentage of about 92 wt% and 6.68 wt% respectively, while poultry droppings had about 90 wt% methane and 6.56 wt% $CO_2$.With the aid of a constructed mini gas stove, a flame test was performed, which gave off a blue flame. Hence, the two substrates are efficient for biogas production.

## 1. Introduction

Energy is a necessary requirement for economic development, it clearly improves living conditions and standards in various parts of the world. It is an indispensable part of modern society. Despite the advances in technology, many individuals especially in the rural area of developing countries seek to meet their energy requirements for cooking through traditional means of direct combustion of biomass resources such as firewood, straws, and crop residues [1]. This has resulted in evident environmental, economic and public health issues. Therefore, utilization of a 'green' energy source, which is eco-friendly, one that would improve living conditions, health standards and the environment is necessary in meeting the energy demand, hence the research on biogas.

Biogas is a renewable form of energy that provides a cheap, clean and easily controlled source of energy for diverse purposes [2,3,4]. It gradually replaces fossil fuels and direct combustion of biomass as energy sources, thereby lessening its harmful impact on the environment and human health. The composition of biogas is dependent on the substrate fed into the digester. Generally, biogas comprises of 50-75% $CH_4$, 25-50% $CO_2$ along with traces of some other components such as water vapour $H_2O$, and hydrogen sulphide $H_2S$. Methane is the major constituent of biogas and though the contribution of methane molecules (CH4) to the greenhouse effect is 21 times greater than that of the carbon dioxide molecule, consuming methane in form of renewable energy, reduces its impact on the environment [5]. It has been said that an ideal substrate, is one which is available in large quantities and all year round [6]. Hence, the waste materials to be used in this study are ideal in nature. This research focuses on the design and implementation of a low-cost biogas technology for comparative analysis of cow dung and poultry droppings as sources of biogas.

## 2. Materials and Method

*2.1. Substrate Waste Materials*
The cow dung used in the research was obtained from Eliozu abattoir in Port Harcourt and chicken droppings from Omagwua poultry farm at Rokpokwu. For the purpose of the research, two major experiments were adopted; the main digester experiment and the laboratory water-displacement experiment in which a total solid content (%) test was performed for both substrates. A gas chromatography analysis was also performed on the gas generated from the individual waste substrates to obtain their gas compositions.

2.2. *Total Solid Content (TS %).*
An analysis to obtain the TS% of the individual waste substrate was carried out using a conventional oven drying method. The samples consisted of 20 kg of slurry for each of the waste substrates. The mass of the empty crucible was termed weight A. The slurry was placed in the empty crucible with the total mass constituting weight B. The crucible loaded with the slurry was then heated in an oven set at 105 ℃ for two to three hours after which it was placed in a desiccator to cool at room temperature. The crucible with sample was then weighed again and recorded as weight C. The percentage of TS in the samples were obtained using the formula:

$$\%T.S = \frac{weightC - weightA}{weightB - weightA} \times 100$$

where: Weight A- empty crucible
Weight B- crucible + sample quantity
Weight C- crucible + sample quantity after heating and cooling.

*2.3. Digester Design*
The digester design adopted for this study is a simple on-ground digester type (Figure 1). It is designed to operate at a mesophilic temperature range. The digester system is formed with a plastic gallon with a capacity of 30 kg and a tyre tube as its storage chamber. The digester design is structured to have an influent inlet, gas flow line and a storage chamber. It is connected in a manner such that during anaerobic digestion process gas formed in the digester is released through the outlet valve and then flows along the gas flow line in to the gas storage chamber or can be connected directly to the mini gas stove for use. The design is such that the effluent also referred to as the digestate formed after digestion process has ended, has an outlet from which it is removed and can then be used as organic fertilizer for crop growth.

**Figure 1.** Fixed digester design.

*2.4. Preparation of Influent: Slurry Mixture and Digester Loading*

*2.4.1. Substrate 1 (Fresh Cow Dung).* About 10 kg of fresh cow dung was measured out for the purpose of the experiment. It was mixed with water to reduce the percentage of total solid content (TS%) in the ratio 1:1.

10 kg cow dung + 10 kg of water = 20 kg of slurry

The slurry was transferred into the digester with the aid of a funnel while a head space was made in the digester where the gas formed would reside temporarily. The inlet was tightly sealed and gas outlet valve was closed to ensure absence of oxygen in the digester and to avoid leakage of gas formed.

*2.4.2. Substrate 2 (Poultry droppings).* The poultry droppings contained saw dust (lignin) which indicates a higher TS%. It was then mixed with water in the ratio 1:1 and transferred into a digester.

10 kg poultry droppings + 10 kg water = 20 kg slurry

*2.5. Laboratory Experiment (Water Displacement)*

This experiment was carried out to obtain the gas yield and gas volume measurement of the waste substrates daily. A 500ml flask was used as the digester while a 400ml flask of served as the water tank and a measuring cylinder was used as the water collector. With the aid of a rubber hose, the digester was connected to the side of the 400ml flask (water tank), while a longer rubber hose was inserted through the top of the 400ml flask to the bottom giving a little allowance. The other end of the was directed into the 50ml measuring cylinder which serves as the water collector.

This experiment was designed such that the volume of water which was displaced, represents or equals the volume of biogas formed within the period of time. The set-up is shown in Figure 2. The waste substrates were mixed with water as expressed below:
225 g of cow dung + 225 ml of water.
225 g of poultry droppings + 225 ml of water.

The individual sample measured slurry were fed into the 500 ml flask, allowing anaerobic digestion (AD) process to commence while monitoring and recording the gas yield for residence period of 7 days. The set up was placed in an area easily accessible to sunlight to ensure that temperature of the mesophilic range is reached.

**Figure 2**. Water displacement setup: Slurry in flask, water in 400ml flask and measuring cylinder.

*2.6. Gas Analysis*

The biogas was analyzed by gas chromatography (GC) technique for molecular composition using GPA 2286 (Figure 3) as the standard test method at Laser laboratory. Gas chromatography (GC) technique involves the use of a gaseous mobile phase to transport sample components through either packed columns or hollow capillary columns containing a polymeric liquid stationary phase. With the aid of the GC machine, the percentage composition and gas profile of individual waste substrates was obtained.

**Figure 3.** Gas chromatography machine GPA 2268.

## 3. Results and Discussion

### *3.1. Total Solid (%) Result*

Using the formulas indicated below, the total solid content as well as the moisture content for the individual substrates were obtained and presented in Table 1:

$$\%T.S = \frac{weightC - weightA}{weightB - weightA} \times 100$$

The moisture content was also calculated using the equation below and presented in Table 2:

$$\%\ \text{Moisture content} = 100 - \left(\frac{weightC - weightA}{weightB - weightA} \times 100\right)$$

**Table 1**. Values to obtain TS(%).

| Weight (grams) | Cow dung (g) | Poultry (g) |
|---|---|---|
| Weight A | 31 | 31 |
| Weight B | 51 | 51 |
| Weight C | 40.5 | 44.5 |

**Table 2**. Composition result of individual substrate.

| Composition | Cow dung (g) | Poultry (g) |
|---|---|---|
| Total solid (%) | 47.5 | 67.5 |
| Moisture content (%) | 52.5 | 32.5 |

*3.2. Water Displacement Experiment*

The daily gas volume for 7 days was obtained using the water displacement experiment, where the volume of gas was equivalent to the volume of water displaced through the rubber hose into the measuring cylinder (water collector). The quantity of cow dung and poultry dropping slurry, and volume of containing vessels used are as follows:

| | |
|---|---|
| Volume of digester | 500 ml |
| Volume of water tank | 400 ml |
| Volume of slurry | 450 ml |
| Head space in digester | 50 ml |

*3.2.1. Substrate I- Cow Dung.* As seen in Figure 4, the daily gas production rapidly increases and then peaks on the fourth day, after which the volume of gas produced steadily declines. It is observed that the total volume of biogas produced from cow slurry after 7 days is about 188.5 ml. While the average quantity of biogas produced is 29.9 ml/day.

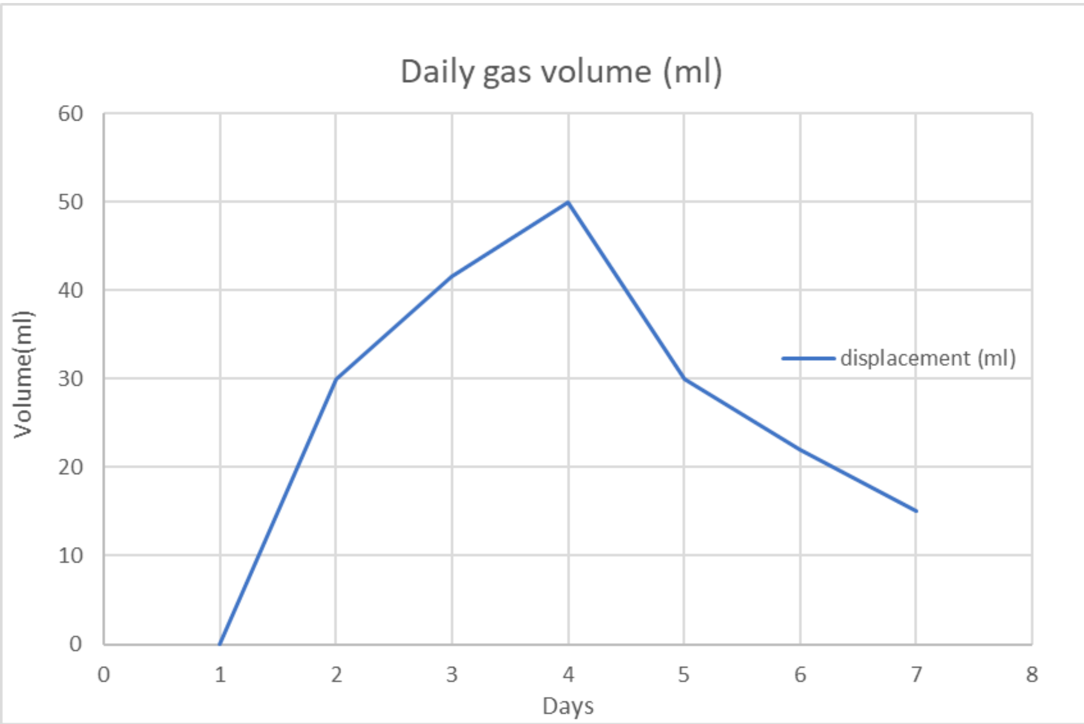


**Figure 4**. Daily gas yield of cow dung for 7 days (Substrate I).

*3.2.2. Substrate II- Poultry Droppings.* The total volume of biogas produced from poultry waste slurry is about 425 ml with an average biogas production of about 60.7 ml/day. It is observed in Figure 5 that the gas yield pattern for poultry droppings differs from that of the cow dung. Here, gas formation occurred so rapidly in the first two days, giving off all the gas generated from AD process. It then dropped, allowing for further digestion process to take place which subsequently resulted in a rapid gas yield once more, after which gas yield gradually declined. This suggests the different retention and residence time possessed by both substrates.

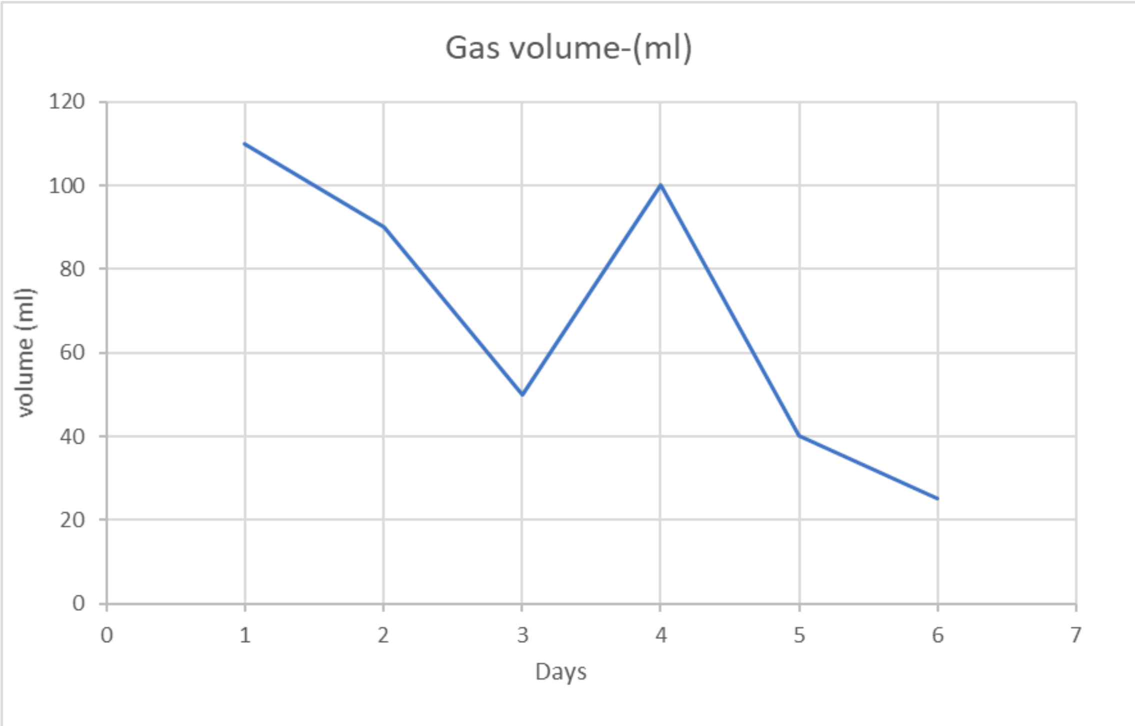


**Figure 5**. Daily gas yield of poultry droppings for 7 days (Substrate II).

*3.3. Gas Analysis Result*

The analysis result was obtained with the aid of a gas chromatography machine. It shows the constituents of the gas produced from the individual waste substrates. The gas profiles of each substrate are presented in the following tables and figures (Tables 3 and 4, and Figures 6 and 7). Tables 3 and 4 also show the mole and weight percentage of the various constituents of biogas generated from the two substrates.

**Table 3**. Composition of biogas sample (cow dung).

| Component | Mole% | Wt% |
|---|---|---|
| $CH_4$ | 96.63 | 91.97 |
| $N_2$ | 0.81 | 1.35 |
| $CO_2$ | 2.56 | 6.68 |
| Total | 100 | 100 |
| Sample Properties | - | Wt% |
| Molecular Weight (g/mole) | - | 16.85 |
| Gravity [air=1] | - | 0.582 |

**Table 4**. Composition of biogas sample (poultry droppings).

| Component | Mole% | Wt% |
|---|---|---|
| $CH_4$ | 96.10 | 91.24 |
| $N_2$ | 1.33 | 2.20 |
| $CO_2$ | 2.52 | 6.56 |
| Total | 100 | 100 |
| Sample Properties | - | Wt% |
| Molecular Weight (g/mole) | - | 16.91 |
| Gravity [air=1] | - | 0.584 |

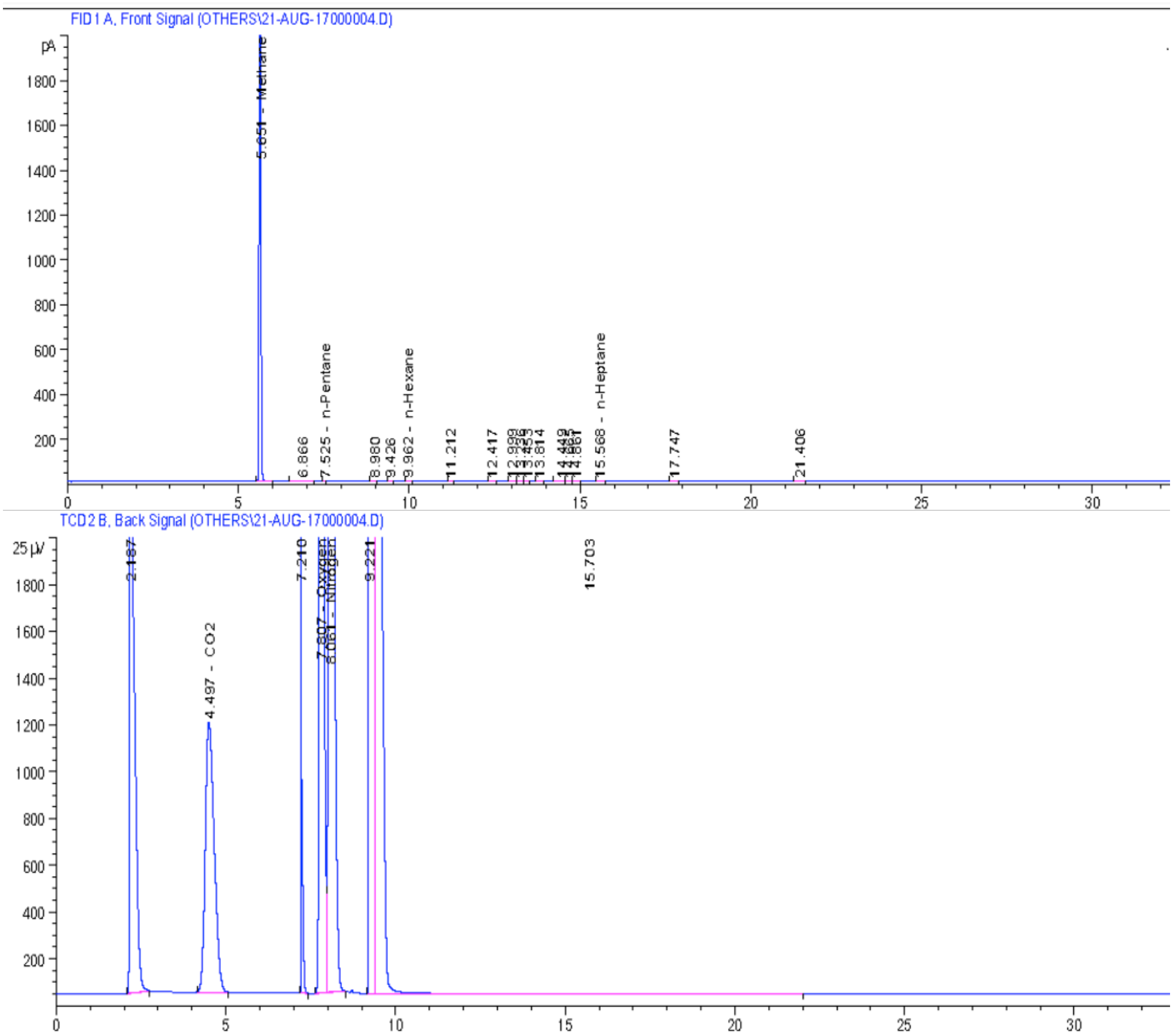


**Figure 6**. Gas profile of substrate I (Cow dung).

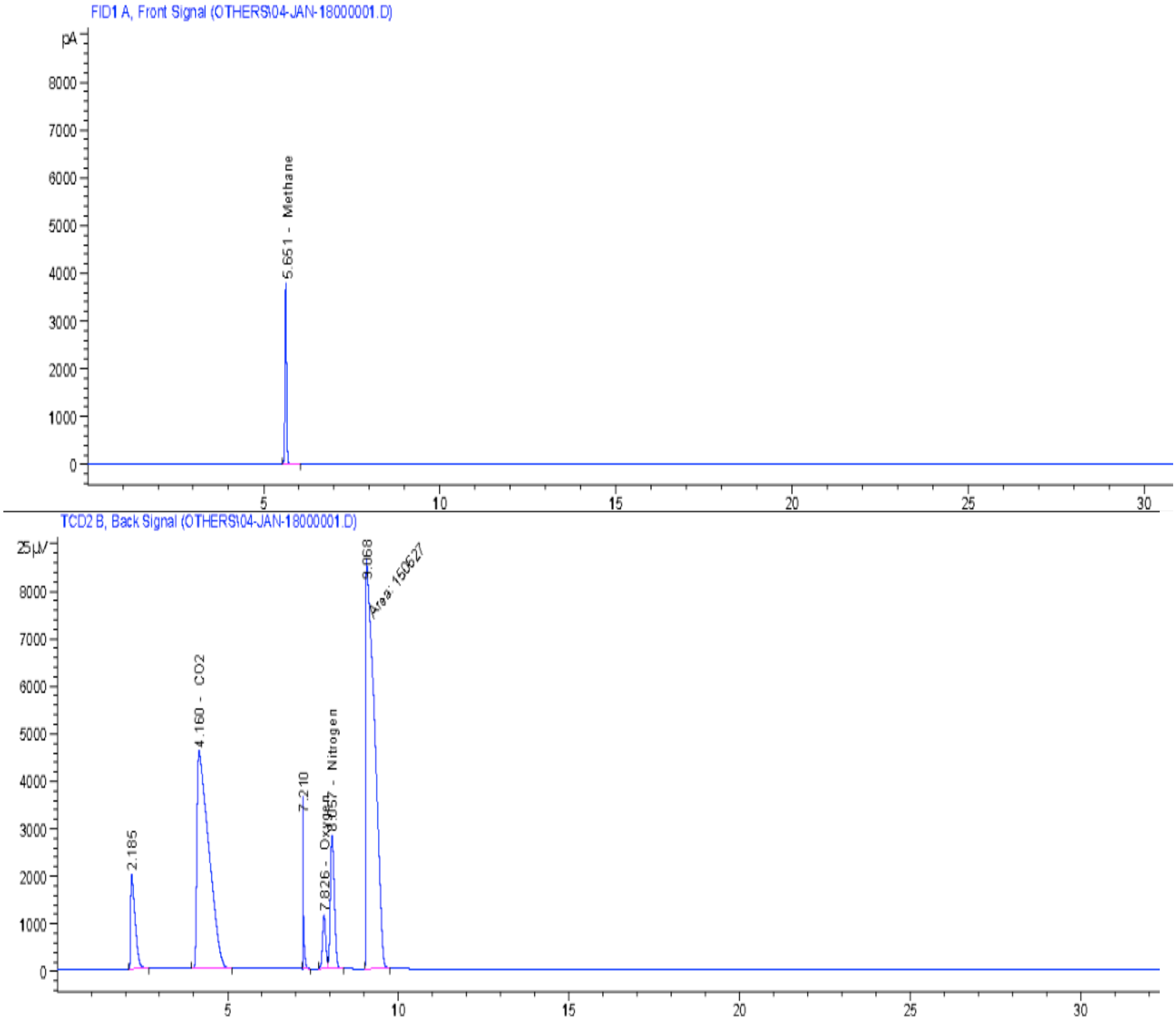


**Figure 7**. Gas profile of substrate II (poultry droppings).

Figures 6 and 7 show the peak levels of the various constituents of biogas generated from cow dung and poultry waste respectively. Methane being the major constituent is present and of a higher peak in cow dung than in poultry waste, as estimated from the graphs above.

## 4. Conclusion

This research has been useful in revealing vital information on the gas obtained from the anaerobic digestion process, the gas yield pattern, the gas volume per day and gas profile of generated gas. The research shows that both substrates are good for production of biogas although they differ in terms of their gas profile and yield rate patterns. It was shown from the laboratory experiment that cow dung takes a longer retention time of about 7 days after being placed in the digester before it begins to produce biogas unlike the poultry droppings which has a retention time of just about 3 days. The results obtained from the gas chromatography analysis, shows that cow dung has a higher percentage of methane than poultry droppings, although it yields gas slower and in a short period after the start time of the anaerobic digestion process than the poultry droppings.

## 5. Acknowledgement

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