**International Journal of Biochemistry, Biophysics & Molecular Biology**
2020; 5(2): 34-38
http://www.sciencepublishinggroup.com/j/ijbbmb
doi: 10.11648/j.ijbbmb.20200502.13
ISSN: 2575-5889 (Print); ISSN: 2575-5862 (Online)

# Comparative Study of Biogas Production from Anaerobic Co-digestion of Donkey Dung and Swine Dung

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## To cite this article:

Ogala Harrison, Ige Ayodeji Rapheal, Elinge Cosmos Moki. Comparative Study of Biogas Production from Anaerobic Co-digestion of Donkey Dung and Swine Dung. *International Journal of Biochemistry, Biophysics & Molecular Biology*. Vol. 5, No. 2, 2020, pp. 34-38. doi: 10.11648/j.ijbbmb.20200502.13

**Received**: June 16, 2020; **Accepted**: June 30, 2020; **Published**: October 30, 2020

**Abstract:** Production of sufficient sustainable sources of energy, mitigation of green house gas emissions amongst others are the aspiring goals that have led in developing technologies to produce more energy from renewable sources. This study investigated the potentials of an alternative fuel sources for biogas production, it was carried out using donkey dung and swine dung as substrates, further co-digestion of both donkey dung and swine dung was done to differentiate between independent and co-digestion of substrates. Digesters were used to digest swine dung and donkey dung respectively as single substrates as well as to co-digest swine dung and donkey dung. The operating conditions here are pH value 7.2, Temperature 32°C and retention time of 68 days. Effect of seeding with bacteria increases the rate of production and mixing is an essential part that also aids the production of biogas. This work presents the design and construction of biogas digester to treat 500g of swine dung and donkey dung. The digester is capable of producing 0.007m at average working temperature of 32°C. Digester D produces higher volume of biogas. Therefore, from the values of the physic-chemical properties with the sufficient carbon obtained, it will increase the sufficient effective biogas production as an alternative source of energy.

**Keywords:** Biogas, Digester, Production, Dung, Temperature

## 1. Introduction

As demand for energy by man is excessively increasing and there has been a relentless search for the different forms of energy that will meet up with this energy demand [1]. Bio-waste refers to the agricultural waste, forestry waste, livestock manures, the biodegradation part of municipal waste including food and garden waste, treated sewage, organic industrial waste such as paper, textile and compost, which are detrimental to the environment if not manage properly.

Bio-waste is a biomass and thus renewable energy source not only because the energy it produces is obtained from the sun, but because bio-waste can be re-grown over a relatively short period of time through the process of photosynthesis. Chlorophyll in plant captures the sun energy by converting carbon dioxide in the air and water in the ground into carbohydrate, hydrogen and oxygen. When these carbohydrates are burned, they release carbon dioxide and water and thus, energy captured from the sun is release. In this way bio-waste is produced sustainably, meeting current needs without diminishing resources of land's capacity to re-grow bio-waste and capture carbon, the battery will last indefinitely and provide source of low-carbon energy [2].

Bio-waste can be converted to other usable forms of energy like methane gas or transportation of fuels like biodiesel, bio-ethanol, bio-oil, and briquette. Decomposed garbage, agriculture and human waste release methane gas and are called "landfilled gas". Crops like sugar cane and corn can be fermented to automobile fuels, such as bioethanol. Bio-waste can be degraded aerobically to produce biogas and other gases. Biogas is a mixture of methane ($CH_2$), 50 to 70% carbon dioxide ($CO_2$), 30 to 40% Hydrogen ($H_2$), 5 to 10% nitrogen ($N_2$) and 1 to 2% hydrogen sulphide ($H_2S$), water vapor (0.3%). Methane is the major constituent

of biogas and it is a worthily renewable source of energy [3, 4], it is a colorless and odorless gas that burns with 60% efficiency in a conventional biogas store [1].

# 2. Materials and Methods

The materials used were donkey dung and swine dung. The samples were collected in Aliero, Aliero Local Government, Kebbi State, and Northern western Nigeria. The dungs were sun dried for 2-3 days and grounded using mortar and pestle. The dried pulverized samples were stored in tight containers until further analysis.

### *2.1. Substrates Analysis*

Proximate analysis of these substrates was carried out to determine their Total solids (TS), voluble solid (VS), carbon content, nitrogen content, ash content, moisture content, nitrogen/carbon ratio (C: N) ratio and pH before and after digestion process.

#### *2.1.1. Total Solids (TS)*

These are the sums of suspended solids and dissolved solids. The total solids are composed of two components, Volatile Solid (VS) and Fixed Solid. This was determined using [6] procedure.

Equation (1) was used to calculate the percentage total solids.

$$TS\ (\%)=\frac{(W1-W2)x100}{(W3-W3)} \quad (1)$$

where,

%TS=Percentage total solid
W1=Weight of dried crucible + dried residue
W2=Weight of crucible
W3=Weight of wet sample (substrate) + crucible

#### *2.1.2. Volatile Solids (VS)*

The volatile solids are organic portion of TS that biodegradable anaerobically. This parameter was determined using the procedure of Sunneer at *et al*., [5].

Equation (2) was used to calculate the percentage volatile solids.

$$VS\ (\%)=\frac{(W1-W3)x\ 100}{(W1-W2)} \quad (2)$$

Where, W1=weight of dish + dried sample at 75°C (g),
W2=weight of dish (g),
W3=weight of dish + sample after ignition at 550°C (g) and D=weight of dish + wet sample (g).

#### *2.1.3. Determination of Moisture Content*

The determination was carried out for both substrates and digestates. For all samples, clean and dry Petri dish was weighed ($W_0$). 2.0g of each sample was taken and placed in the Petri dish such that the total weight of the loaded sample dish would be ($W_b$). The loaded dish was then placed in Gallen Kamp Oven and adjusted to a constant temperature of 105°c for 24 hours. The dish will then be removed from the oven and placed in the desiccators to cool. When it cooled, the dish with its content was weighed, to obtained ($W_a$). The moisture content was evaluated using Masséetal., [7] procedure.

$$\%moisture=\frac{W_a-W_b}{W_s} \quad (3)$$

Where $W_b$=Mass of sample and dish before drying
$W_a$=Mass of sample and dish after drying
$W_s$=Mass of the sample taken

#### *2.1.4. Determination of Ash Content*

This was carried out for both substrates and digesters. Porcelain crucibles was washed and dried for each sample and weighed as ($W_1$). A 2.0g of respective sample was weighed into crucible as ($W_2$) and placed in lenthon furnace and was heated at $600^0$C for 3 hours.

The furnace was switched off and then allows the crucible to cool. Thereafter, the sample was removed from the furnace and placed in desiccators to further cool down at room temperature. The percentage ash content was determined using the procedure of Murtoetal., [8].

Equation (4) was used to calculate the percentage ash content.

$$\%AC=\frac{W_2-W_3x100}{W_2} \quad (4)$$

Where,
AC=Ash Content
$W_3$=Weight of crucible and sample after heating
$W_2$=Weight of crucible and sample before heating

#### *2.1.5. Determination of Total Carbon*

Total carbon was determined according to Walkely Black methods as described by Karki *et al.,* [9].

#### *2.1.6. Determination of Total Nitrogen*

Two grams of each powdered sample in an Ash fewer filter was dropped into 500$cm^3$ kjeldahl flask. Three grams of digesting catalyst (selenium) and 10ml conc. $H_2SO_4$ was also dropped into the kjedahl flask. The sample will digest until a clear green colour is obtained. The digestion was allowed to cool and was diluted into 100ml with distilled water. 20ml of diluted digest was measured into 500ml kjeldahl flask containing ant-bumping chips and 40ml of 40% NaOH was slowly added by the side of the flask. A 250ml conical flask containing a mixture of 50ml 20% boric acid and 4 drops of mixed indicators was used to trap the ammonia being liberated. The conical flask and the kjeldahl flask was then placed on the kjeldahl distillation apparatus with the tubes inserted into the conical flask and kjedahl flask. The flask was heated to distil out the $NH_3$ evolved. The distillate was collected into the boric acid solution, when the boric acid turned green, it was allowed for 10 minutes to complete distillation of the ammonia present in the digest. The distillate was then titrated with 0.1M HCl.

Calculation: %Nitrogen ($N_2$)=14xMxVtxTVx100/Weight of Sample (mg) xVa (5)

Where,
M=Actual Molarity of Acid
TV=Titre Volume of HCl used
Vt=Total Volume of Diluted Digester
Va=Aliquot Volume Distilled [10]

### *2.1.7. Determination of Carbon to Nitrogen (C: N) Ratio*

This was determined using the [10] procedure by dividing the value of total carbon by the value of total nitrogen.

### *2.2. Fermentation of the Slurry*

Preparation of fermentation slurry was done by addition and vigorous mixing of total solid with an equivalent amount of water needed for maximum yield. The water content for each sample was determined using the recommendation for better biogas production as reported by Sadaa, *et al,* [11], that is, a total solid (TS) of 8% in the fermentation slurry. This was the basis for the determination of the amount of water to be added for any given mass of total solid. Hence, the proportion of total solid in the slurries was the same in all the digesters.

The pH of the slurry was measured before and after digestion.

***Table 1.*** *The Procedures taken during Mounting of the Digesters are as follows;*

| Digesters | Content (gram) | Volume of water (litres) |
|---|---|---|
| Digester A | A (500g) | 3000mls |
| Digester B | B (500g) | 4000mls |
| Digester C | C (300g and 200g) | 3200mls |
| Digester D | D (200g and 300g) | 3600mls |

### *2.3. Experimental Design*

A hole was bored on the lid of the can by a machine (chissle). One end of the hose pipe (which served as a delivery tube for the gas) was inserted into the hole bored on the lid, epoxy steel gum was then applied around the hole to ensure that no air seep into or out of the digester.

The animal dung (slurry) was then feed into the digester (Can) and then was covered with the lid which has already been connected to the hose pipe. Gum was applied around the circumference of the can lid to ensure an airtight condition which is necessary for anaerobic digestion.

The plastic bowls was filled with water and measuring cylinder containing water was then inserted into the plastic bowls filled with water avoiding bubbles of air. The retort stand was used to hold the measuring cylinder vertically in the bowls. The other end of the hose pipe was introduced into the water basin and passed through the measuring cylinder for the collection of gas produced. The volume of the water displaced is proportional to the volume of biogas generated.

The mode of loading was a discontinued feeding (batch feeding). This simply means loading the digester was at once and maintaining a closed environment throughout the retention period. Four different digesters was prepared for loading. These digesters were labelled as follows:

Digester A –Swine Dung only
Digester B – Donkey Dung only
Digester C – Swine (300g) and Donkey Dung (200g)
Digester D – Swine (200g) and Donkey Dung (300g)

## 3. Results

***Table 2.*** *Proximate Analysis of the Substrate before Anaerobic Co-digestion.*

| PARAMETERS | SUBSTRATE A | SUBSTRATE B |
|---|---|---|
| Total Solid | 97.0 | 93.5 |
| Volatile Solid | 44.9 | 45.0 |
| Total Nitogen | 5.5 | 35.0 |
| Total Carbon | 6.5 | 9.8 |
| Ash Content | 28.0 | 43.5 |
| Moisture Content | 18.5 | 18.1 |

***Table 3.*** *Result of Proximate analysis of the Digestate after Anaerobic Digestion.*

| Parameters | Digester A | Digester B | Digester C | Digester D |
|---|---|---|---|---|
| Total solids | 98.5 | 96.5 | 98.0 | 96.5 |
| Volatile solids | 61.0 | 53.5 | 72.0 | 40.0 |
| Total carbon | 8.0 | 5.0 | 2.03 | 2.61 |
| Total nitrogen | 6.5 | 9.8 | 0.91 | 1.37 |
| Ash content | 26.5 | 21.5 | 6.5 | 7.5 |
| Moisture content | 3.0 | 6.5 | 4.5 | 3.5 |

***Table 4.*** *Result of PH of the slurries and digestate before and after anaerobic digestion.*

| PH | Digester A | Digester B | Digester C | Digester D |
|---|---|---|---|---|
| Before | 8.00 | 8.23 | 8.12 | 8.20 |
| After | 9.45 | 8.93 | 9.02 | 8.92 |

***Table 5.*** *Result of cumulative weekly biogas production with temperature for the four digesters.*

| Time (weeks) | Temperature (°C) | Digester A (ml) | Digester B (ml) | Digester C (ml) | Digester D (ml) |
|---|---|---|---|---|---|
| 1 | 34 | 361 | 147 | 1221 | 372 |
| 2 | 34 | 2880 | 2314 | 4624 | 4650 |
| 3 | 34 | 4851 | 5108 | 5464 | 5908 |
| 4 | 36 | 3467 | 3527 | 4470 | 4943 |
| 5 | 34 | 4022 | 3644 | 3175 | 5672 |

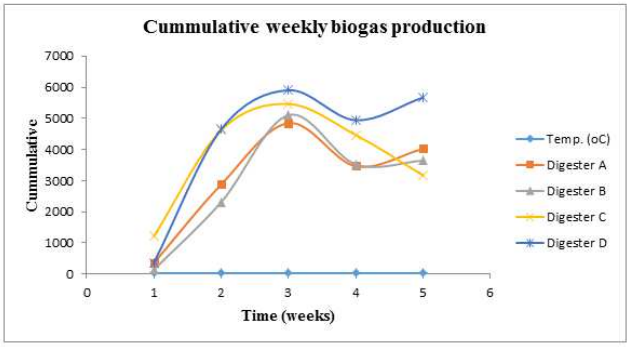


***Figure 1.*** *Graph Cummulative Weekly Biogas Production.*

## 4. Discussion

The results of total solid (TS) for the sample A and B before digestion were 97.0% and 93.5% respectively. After

the anaerobic digestion, there was an increase in the values of total solid for the two substrates. The values are 98.5% and 96.5% respectively for digester A and B. Digester C and D have the following values 98.0% and 96.5% respectively.

The sample B has the highest value compared to the other sample B. After the anaerobic digestion, there was an increase in the result of the volatile solid for the two digesters. The values are 61.0% and 53.5% for digester A and B respectively. The values for digester C and D are 72.0% and 40.0% respectively. The increase in the values is as a result of the high volatile solid that has been converted to biogas.

There was a decrease in the value of total nitrogen in the samples as a result of the bacteria that have utilized the nitrogen for their metamorphic growth process. This was in line with earlier submissions by various researches.

After the anaerobic digestion, the values of Ash content were 26.5% and 21.5% for digester A and B respectively. Digester C and D have the following values 6.5% and 7.5% respectively. There was a decrease in the value of Ash content of the substrates after the anaerobic digestion. Similar report was presented by Yavini *et al*., [12].

Substrate A has the higher moisture content before digestion. After the anaerobic digestion, the values of moisture content were 3.0 and 6.5 for digester A and B respectively Digester C and D have the following values 4.5 and 3.5 respectively. the moisture content values are compare well with 74.8% digestate sample as reported by Dabrowska et al., [13].

pH is an important factor that affects anaerobic digestion as reportedbyNeczaj*etal*., [14] the values of the pH before the anaerobic digestion of the four (4) slurries are 8.00, 8.23, 8.12 and 8.62 for digester A, B, C and D respectively. It has been reported that anaerobic bacteria required a neutral environment and thus a pH ranging from 6.4-7.2 is needed for optimum biogas production as described by Aremu & Agarry [15]. There was an increase in the pH of the digestate after the anaerobic digestion. The values obtained are compare well with 7.2 pH of solid fuel used for biogas production as reported by Soliu, *et al*., [16].

After the anaerobic digestion, the values of total carbon were 8.0 and 5.0 for substrate A and B respectively. Digester C and D have the following values 2.03 and 2.61 respectively. There was a decrease in the values; this might be as a result of biogas formation.

The temperature range throughout the retention periods is within 34-36°C which is optimum for biogas production under mesophilic condition. this also validate the temperature range cited by Babatola, [17], At low temperature, microorganism become inactive and rate of gas production drops but resumes when the temperature is favorable.

In Digester A (swine dung) only, biogas production started on the 4th day of the retention period because it takes more time for swine dung to decompose after which gas is being produced by producing 90ml of biogas. This is expected because biogas production rate in batch condition is directly equal to specific growth of methanogenic bacteria (Babatola 2008). The Digester A may be attributed to its high value of pH value which was slightly above the optimum pH range cited by Ubalua (2008) (6.9-7.3 & 6.4-7.6 respectively).

In Digester B (donkey dung), biogas production began on the 5th day of the retention period by producing 60ml of biogas. A peak production of 1,160ml was recorded on the 22nd day of the retention period and thereafter reduced each day till the 50th day of retention period. After this, there was a slow production till the end of the retention period.

In Digester C (swine and donkey dung 300g-200g). The biogas production began on the 5th day of the retention period with 100ml of biogas produced. This was similar to the work of Ubalua (2008) stated that the production of biogas from mixture of gasses created from methanogenic bacteria which break down the organic matter in an anaerobic condition. The production increased daily till a peak of average production of 4470ml on the 5th week of production, thereafter it was observed that as the temperature increases, there was a good production. Digester C has a great potential in biogas production revealed from its value of volatile matter, carbon content and total solid. Swine dung was classified among the best substrates for bio-digestion.

In Digester D (donkey and swine dung 300g and 200g). The production began on the 3rd day of the retention period by producing 40mls of biogas. The production subsequently increases and decreases day by day. The highest production was recorded on the 3rd and 4th week with the value of 1300ml and 1130ml. Digester D produces higher volume of biogas compared to digester B. This was as the result of improved nutrient provided by donkey dung, there was a reduction in the startup time.

# 5. Conclusion

Biogas production from anaerobic co-digestion of swine and donkey dung was established in this research work to be feasible of mesophilic temperature range and this gives positive attribute towards a search for sustainable renewable energy source (SRES) to substitute the fast depleting fossil fuels. Digester D produces higher volume of biogas. This was as the result of improved nutrient provided by donkey dung and has the best neutral pH, there was a reduction in the startup time.

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