Journal of Occupational Safety and Environmental Health
A Publication of the Society for Occupational Safety and Environmental Health

COMPARATIVE ANALYSIS OF BIOGAS PRODUCTION FROM DIFFERENT SOURCES OF COW DUNG

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ABSTRACT
The aim of this study was to compare and analyze the biogas production of cow dung wastes from different sources based on their feed intakes: grass only, grass and supplements, supplements only, and a mixture of cow dung based on grass and large intestine organic matter (from abattoir). The experiment was initiated with the mixture of each of the cow dung substrate and water in a slurry ratio (v/v) of 1:3 and digested for a period of 15 days each. The pH, temperature, nitrate and phosphate constituents of the substrate in the digester were measured before, during and after digestion. The biogas production was observed for each of the experiment. Cow dung substrate (supplements) produced the lowest biogas production with a cumulative volume of 0.355m^3 while cow dung substrate based on grass and intestine organic matter produced the highest cumulative volume of 1.86m^3. It was concluded that cow dung mixed with large intestine organic matter from abattoir should be used as substrate for biogas production on a large scale and should be encouraged for commercial production.
Keywords: Biogas, Cow dung, Substrate, Commercial production

INTRODUCTION
Biogas is a gas produced by anaerobic fermentation of different forms of organic matter and is composed mainly of methane (CH_4) and carbon dioxide (CO_2). For rural and urban areas, properly designed biomas conversion technologies could reduce the economic and environmental cost for cooking and heating and in some cases, provide oppourtunities for economic growth and employment (Looher, 1984). Apart from methane production that could substitute fossil fuel, biogas is also operated as a waste treatment system especially for treating organic wastes. During the past two decades, developing countries and particularly Nigeria has witnessed increased level of waste generation due to population explosion, increased agricultural activities, and growth of industries. Governments and industries are constantly on the lookout for technologies that will allow for more efficient and cost-effective waste treatment (Guruswamy *et. al*., 2003).

Animal wastes are abundant all over the world with Nigeria producing about 227,500 tons of fresh waste each day and about 1kg of fresh animal waste could produce about 0.03m^3 of gas per day (Oyeleke *et. al*., 2003). This shows theoretically that Nigeria can produce 6.8 million m^3 biogas daily which in terms of energy is equivalent to about 3.9 million liters of petroleum. Hence, the use of biogas is capable of providing a source of energy in both rural and urban areas. Biogas can be built by using materials which are locally available in most developing countries (Baki, 2004).

Apart from animal wastes, other substrate sources for biogas production are manure and sewage, residues of crop production (i.e., straw), the organic fraction of the waste from households and industry,

as well as energy crops including maize and grass silage. For commercial biogas production, comparison of different substrates is necessary to choose the best substrate among alternatives for optimum utilization of resources. The aim of this research was to compare biogas production from different substrate sources and recommend suitable one(s) for commercial purpose.

MATERIALS AND METHODS

Collection of Cow Dung Substrates

Cow dung wastes were collected from three different ranches at National Animal Production Research Institute (NAPRI), Zaria,

1st Ranch: Cow dung from cattle fed with grass only

2nd Ranch: Cow dung from Cows fed with both grass and supplements

3rd Ranch: Cow dung from cattle fed with supplements only; and the fourth from Zango abattoir ranch, Zaria

4th Ranch: Cow dung (mostly from grass-fed cattle) mixed with organic matter from large intestine of slaughtered cows

Substrate Preparation and Operation of Digester

The substrate was prepared for each of the different sources of cow dung by mixing 40kg of cow dung with water in the ratio 1:3 w/v, using a scoop, to get an optimal total solid range of 5-10% (Sasse, 1988). The prepared substrate was then transferred, using a funnel, into a digester through the inlet hole. The digesters were then labeled 1st Ranch Digester, 2nd Ranch Digester, 3rd Ranch Digester and 4th Ranch Digester representing digesters corresponding to the respective feed sources. According to Karthik (2012), methane-forming micro-organisms grow slowly, with a doubling time of around 5-16 days. Therefore, the hydraulic retention time was 15 days for each of the experiment. The following parameters were monitored and measured during the digestion process.

Monitoring and Measurement of Parameters

The parameters of interest are Carbon/ Nitrogen ratio, Nitrogen, Nitrate, Phosphate, Temperature, pH, and biogas volume.

Carbon/Nitrogen ratio: The carbon/ nitrogen ratio was determined to know whether the ratio conforms with that stated in the literature for optimum biogas production.

Carbon: The organic carbon in each sample was determined by using Walkey-Black method. 0.032g of sample was weighed into a conical flask using a weighing balance and 5ml, 10ml, 100ml of potassium dichromate, sulphuric acid and distilled water were added in turn after which 3 drops of phenalthroline was also added and the solution was swirled. The solution was then titrated with ferrous ammonium sulphate solution with a white background. Percentage Carbon was calculated thus:

$$\%Carbon = [(blank\ titre - actual\ titre)\ x\ 0.03x\ 100\ x\ f]/w \quad (1)$$

where,

Blank titre = volume used to titrate a blank sample Actual titre = volume used to titrate each sample

f = correction factor =1.32

w = weight of the sample used (gram)

Nitrogen: The nitrogen in each of the sample was determined using the Kjeldahl method. 0.2g of each of the substrate was measured in each digestion tube and 5 g of kjeldahl catalyst mixture was later added to each of the samples, mixed well and left for 20 minutes. Also, 20ml of concentrated sulphuric acid was added to each sample and left for another 15 minutes. The samples were then digested using digesting blocks for 2 hrs and the solution was allowed to cool till the next day. By using a volumetric flask, 100ml of distilled water was added to each of the digested solution and then 10ml of each of the solution was pipetted and transferred into a distiller and 10ml of sodium hydroxide and few zinc granules were added and closed to commence distillation. 20ml of Boric Acid (2%) was introduced into conical flask and placed at the bottom of distillation condenser for each

test. 50ML was collected from each distillate and titrated with 0.01N H_2SO_4 acid using mixed indicator. The percentage nitrogen is calculated as:

$$\%Nitrogen = \frac{[0.014\ x\ (actual\ titre - blank\ titre) x\ 10{,}000\ x 0.025]}{(w\ x\ Alequote\ distilled)} \quad (2)$$

where,

Blank titre = volume used to titrate a blank sample

Actual titre = volume used to titrate each sample

w = weight of the sample used

Nitrate: Nitrogen is one of the macro-nutrients that supply the basic cellular building block for anaerobic bacteria growth and it is measured in solution as nitrate. Nitrate was analyzed by using a H183200 Multi-parameter photometer. The cuvette in the instrument was removed, opened and filled with 6ml of sample and then closed. The cuvette was placed into the instrument compartment and then the instrument was calibrated. The cuvette was removed and 5 drops of phenol disulphonic acid was added and the cap was replaced and then shook vigorously for 10 seconds. The cuvette was inserted into the photometer and nitrate was determined by using the H183200 Multi-parameter photometer.

Phosphate: Phosphorus is another macronutrient necessary for anaerobic bacteria growth and it is measured as phosphate in solution. Phosphate was analyzed by using H183200 Multi-parameter photometer. The cuvette in the instrument was opened and filled with 10ml of each of the sample and then closed. The cuvette was placed into its holder and the lid was closed and the instrument was calibrated and then HI 937130 (powdered reagent-l packet) was emptied into the solution. The cuvette was shook for 2 mins and inserted into the photometer to determine phosphate.

***pH*:** pH is measured because it reflects the alkalinity or the concentration of fatty acids in digesters. The concentration, either acidic or basic, has effects on the reaction rate of anaerobic bacteria in digesters. The pH of each sample was determined using HI183200 Multi-parameter photometer.

Temperature: Anaerobic digesters are normally operated at either mesophilic temperatures (30-40^{o}C) or moderately thermophilic temperatures (50-60^{o}C), allowing optimal growth of the bacteria involved in the breakdown of the organic matter (Sandra, 2014). It is essential for efficient operation to control temperature since reaction rates drop off considerably as temperature falls below 35°C and there is also a sharp drop off in activity at temperatures above 45^{o}C, as mesophilic bacteria become inhibited by the heat. Hence, the temperature was monitored so as to account for the reaction rates in the digesters, which is noticed in the quantity of biogas. The daily temperature of each experimental set up was measured with the use of thermometers.

***Biogas Volume*:** The volume of biogas yield was measured and recorded on a daily basis. The experiment was observed for a period of 15 days under a mesophilic condition. The volume of biogas was calculated as follows:

$$Volume\ of\ gas\ (m^3) = \pi r^2 h \quad (3)$$

Where,

π = constant

r = radius of the cylindrical container

h = height increase of the cylindrical container

RESULTS AND DISCUSSION

The results of carbon/nitrogen ratios of the substrates are presented in Table 1. Cow dung substrate based on grass (i.e., 2nd ranch) had the highest carbon/nitrogen content (29.06%) while cow dung substrate, based on supplement only (i.e., 3rd ranch) has the lowest carbon/nitrogen content (20.36:1). All of the substrates had carbon/nitrogen ratio within the range of 25-30:1, for optimum biogas production, observed in the literature (Dioha *et. al.*, 2013; Maishanu and Hussani, 1991).

Table 1: Carbon/Nitrogen Ratio (C/N)

Parameters	1st ranch	2nd ranch	3rd ranch	4th ranch
C (%)	41.57	42.13	40.82	49.54
N (%)	1.53	1.45	2.01	1.75
C/N Ratio	27.26	29.06	20.36	28.31

The results of the Nitrate analyses are as shown in Figure 1. The figure reflects that Cow dung substrate based on grass only (i.e., 1st ranch) and the substrate from Zango abattoir (4th ranch) had have nitrate more than the desirable amount of 50mg/l stated by Tugtas (2012) while substrate based on grass and supplement indicate nitrate level slightly lower than the desirable limit. This indicates that there is enough nutrients for bacteria activities in these reactors which is a function of increased biogas production. However, substrate based on supplement only reflects inadequate nitrate level of 20-32mg/l which might lead to low biogas production.

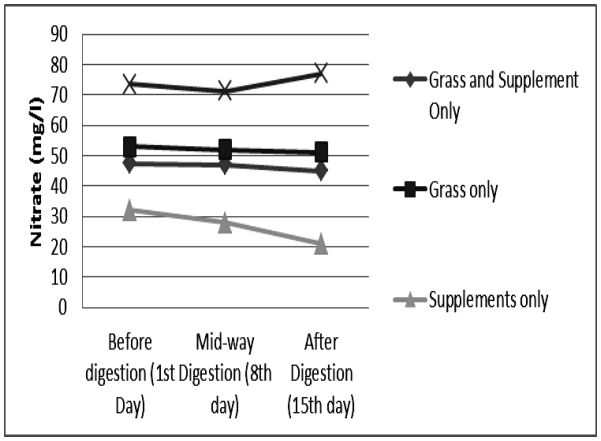

Figure 1: Line graph of nitrate variation of different substrates

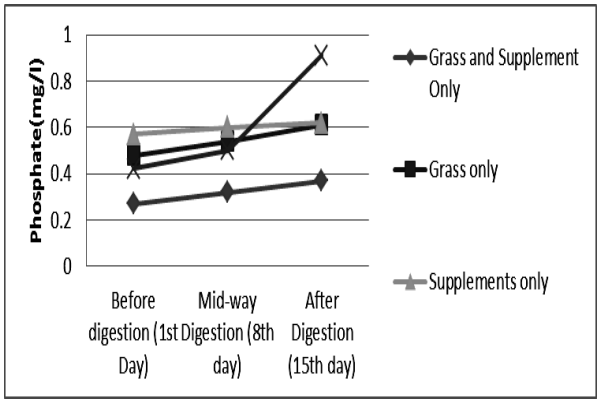

Figure 2: Line graph of phosphate variation of different substrates.

The results of phosphate variation in the digesters are presented in Figure 2. It is observed that all the substrates had phosphate in quantities lower than the maximum desirable limit of 10mg/l indicated in the study of Tugtas (2012). Consequently, there might be no significant adverse impact on gas production.

The results of variation in pH of each of the substrates before, mid-way and after digestion are presented in Figure 3. The pH range for substrate from grass only (i.e., 1st ranch), supplements and grass (2nd ranch) and Zango abattoir (4th ranch) are within the acceptable range of 6.5-8.0 (Tugtas, 2012) while substrate based on supplement only reflect a progressive decrease in pH from 1st day to the 15th day. This implies that the substrate was easily degraded which caused a sudden increase in acid content. Consequently, the microbes were adversely affected and might reduce the volume of biogas produced.

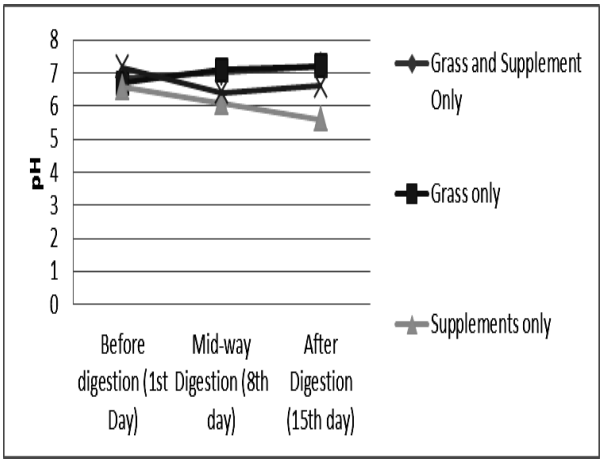

Figure 3: Line graph of pH variation of different substrates.

The average daily temperature variations of the reactions in the digesters are presented in Figure 4. It can be deduced that the average temperature range fell between 31.68^{0}C and 40^{0}C which signifies that the conditions inside the digesters were mostly mesophilic. Mesophilic bacteria have an optimal temperature for growth between 30-40^{o}C and consequently mesophilic digesters are usually operated at temperatures around this range (Sandra, 2014). From 11th to 15th day, the temperature in the 4th digester (for Zango abattoir substrate) drop below the observed average and recommended range, and the consequent effect is seen in a slight drop in

biogas production as discussed in the next section.

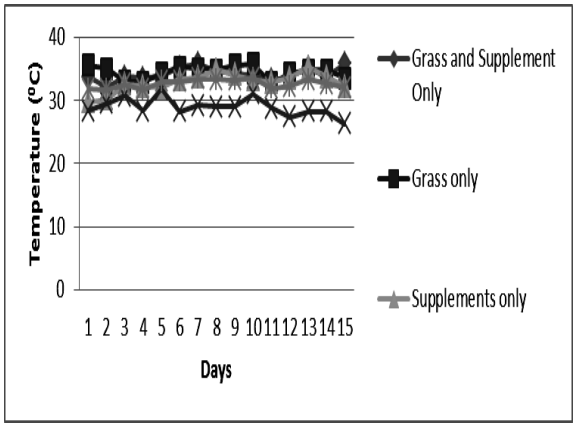

Figure 4: Line graph of temperature variation of different substrates

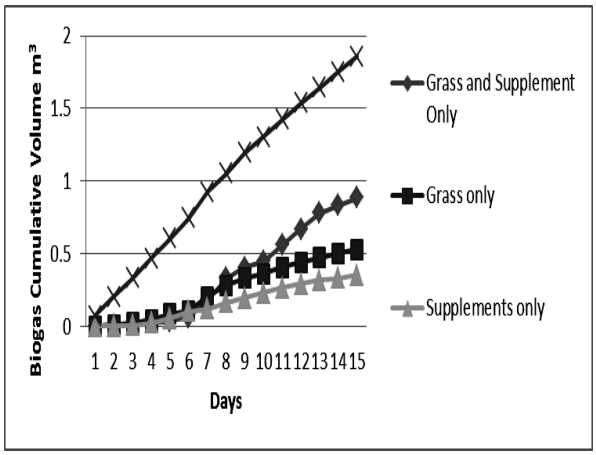

Figure 5: Line graph of cumulative biogas production from substrates

The results of cumulative volume of biogas produced form the substrates are presented in Figure 5. It is observed that cow dung substrate from Zango abattoir produced the highest compared to the rest of the other cow dung substrates after the period of digestion. Nevertheless, it is observed that there is a slight drop in the upward increase in biogas cumulative volume from 11th day to 15th day as a result of reduced temperature. The cumulative volume of cow dung substrate based on grass and supplements superseded that of cow dung substrate based on grass on the 8th day to become the next high cumulative volume while cow dung substrate based on supplement had the least cumulative volume produced. This might be as a result of reduced pH which signifies the presence of acid content as discussed before.

CONCLUSIONS

The following conclusions and recommendations have been drawn from the study:

i. Biogas production from cow dung can be influenced by cattle feed intake
ii. Cow dung substrate based on grass and animal intestinal organic content produced the highest volume of biogas than substrates from cow dung based on grass only, grass and supplement, and supplement only
iii. Temperature below 30^{0}C reduces the activities of anaerobic bacteria in digesters and consequently hinders biogas production.
iv. pH influences biogas production in agreement with past investigations; pH lower than 6.5-8.0 reduces the volume of biogas generated.
v. Cow dung substrate based on grass and cattle intestinal organic content have the potential to generate high volume of biogas and could be encouraged for commercial production on a large scale
vi. Establishment of anaerobic digesters in abattoirs should be encouraged to control and improve waste handling.

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