

Biogas production from blends of fonio husk and donkey dung via anaerobic digestion for sustainable development

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Abstract

There is growing public concern over potential impact on environmental quality caused by animal wastes. Anaerobic digestion, a biological conversion process can be used to obtain energy from biological wastes. This study explored the production of biogas from co-digestion of fonio husk and donkey dung using anaerobic biological conversion. The digesters were labeled as; digester A –Fonio husk only, digester B - donkey dung only, digester C – Fonio husk (300g) and Donkey Dung (200g), digester D – Fonio husk (200g) and donkey dung (300g). Proximate analysis of the substrates before and after digestion were determined such as total solids (TS), volatile solid, carbon content, nitrogen content, ash content, etc., and pH before and after digestion process. The biogas produced during this period was collected by water displacement method and subsequently measured. The results showed that Fonio husk in bio-digesters A and B gave a cumulative average biogas volume of 4972 ml and 5222 ml (week 3) while pig dung in bio-digesters C and D gave a cumulative average biogas volume of 5564 ml and 5978 respectively (week 3) within three weeks of fermentation. The digester is capable of producing 0.007m at average working temperature of 320C. Digester D produces higher volume of biogas as a result of improved nutrient provide by donkey dung as shown in the results obtained from the proximate analysis and has the best neutral pH, there was a reduction in the startup time.

Keywords: Biogas; Digester; Production; Dung; Temperature.

1. Introduction

In Nigeria, agricultural waste generation is raising fast and creating humongous wastes disposal and management difficulties. The very reason is the population increment and cities' expansion (Ojolo et al., 2007). As the need for energy by man is excessively increasing and there has been an unrelenting search for the distinct forms of energy that will meet up with this energy need (Ofoefule et al., 2009). Biomass is an organic matter that is procured from plants, cereals, algae, animal wastes. It is plentifully obtainable due to its accessibility and also that carbon generated is harmless. It is made up of three main parts which are cellulose, hemicelluloses and lignin (Ige et al., 2020).

Biogas can be generated by anaerobic digestion with anaerobic organisms, which digest material inside a closed system, or fermentation of biodegradable materials. Biogas is composed of methane (CH₄) and carbon dioxide (CO₂) and may have small amounts of hydrogen sulfide, moisture and siloxanes (Okolie et al., 2017). The gases methane, hydrogen, and carbon monoxide (CO) can be burnt or oxidized with oxygen. This energy release allows biogas to be used as a fuel; it can be used for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat (Okolie et al., 2017).

Fonio husk is a cereal, which is surrounded by an outer protective covering or the husk like rice (Ballogou et al., 2013). After harvest, the husk is often heaped up to constitute environmental nuisance. This is often the case with post-harvest Agricultural wastes (Ndububa et al., 2016). The utilization of fonio husk for the production of biogas was not very much studied. Agricultural wastes such fonio husk and donkey dung can be transformed into valuable products via anaerobic digestion which provide vital substitute sources of energy for domestic use and small industrial scale. Transforming biomass into biogas through biological conversion aids in eliminating wastes and also makes the environment clean from unacceptable wastes (Ige et al., 2018). It also diminishes greenhouse gas emissions and to attain alternative livelihood to the urban and rural communities (Banconguis, 2007). The selection of the above-mentioned agricultural wastes is owing to the fact that such materials are readily available in abundance at North-West region of Nigeria

Therefore, the focus of this study is to investigate the production of biogas from fonio husk and donkey dung, as a potential alternative source of energy. The objectives of the research were to investigate the effect of the nature of both fonio husk and donkey dung and their co-digestion, on biogas production yield.

2. Materials and methods

The materials used were fonio husk and donkey dungs. The samples were collected in Koko and Aliero towns, Kebbi State, and Northwestern Nigeria. The fonio husks were sun dried for two weeks while 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), volatile 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 calculated using equation in equation (1) (Ukpabi et al., 2017).

$$\text{Total Solid \%} = \frac{A-B}{D-B} \times 100 \quad (1)$$

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

2.1.2. Volatile solids (VS)

The VS are organic portion of TS that biodegradable anaerobically. This parameter was calculated using equation (2) (Ukpabi et al 2017).

$$\text{Volatile Solid \%} = \frac{A-C}{A-B} \times 100 \quad (2)$$

Where A = weight of dish + dried sample at 75°C (g), B = weight of dish (g), C = 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 the equation (3) as reported by Ukpabi et al (2017).

$$\% \text{ Moisture} = \frac{W_b - W_a}{W_s} \times 100 \quad (3)$$

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°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. This was reweighed to obtain (W_3). The percentage ash content was calculated using the following equation (4) as reported by Ukpabi et al (2017).

$$\text{Ash Content \%} = \frac{W_2 - W_3}{W_2} \times 100 \quad (4)$$

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 AOAC, (2000) procedure.

2.1.6. Determination of total nitrogen

Two grams of each powdered sample in an Ash fewer filter was dropped into 500cm³ kjeldahl flask. Three grams of digesting catalyst (selenium) and 10ml conc. H₂SO₄ was also dropped into the kjedahl flask. The sample was digesting 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 were 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 AOAC, (2000).

$$\% \text{ Nitrogen } \text{N}_2 = \frac{14 \times M \times V_t \times TV}{\text{weight of sample}} \times 100 \quad (5)$$

Where M = Actual Molarity of Acid

TV = Titre Volume of HCl used

Vt = Total Volume of Diluted Digester

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 Ituen et al., (2007), 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 samples (slurry) were then feed into the digester (Can) and then were 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 were prepared for loading as shown in Figure 1. These digesters were labeled as follows:

Digester A – Fonio Husk only

Digester B – Donkey Dung only

Digester C – Fonio Husk (300g) and Donkey Dung (200g)

Digester D – Fonio Husk (200g) and Donkey Dung (300g)



Fig. 1: Biogas Production Set-Up (Taken by the Authors).

3. Results

Table 2: Proximate Analysis of the Substrate before Anaerobic Co-Digestion

PARAMETERS	SUBSTRATE A	SUBSTRATE B
Total Solid (mg/l)	83.5	65.2
Volatile Solid (mg/l)	33.8	43.0
Total Nitrogen (%)	6.0	32.5
Total Carbon (%)	7.2	11.4
Ash Content (%)	23.0	45.2
Moisture Content (%)	15.4	21.7

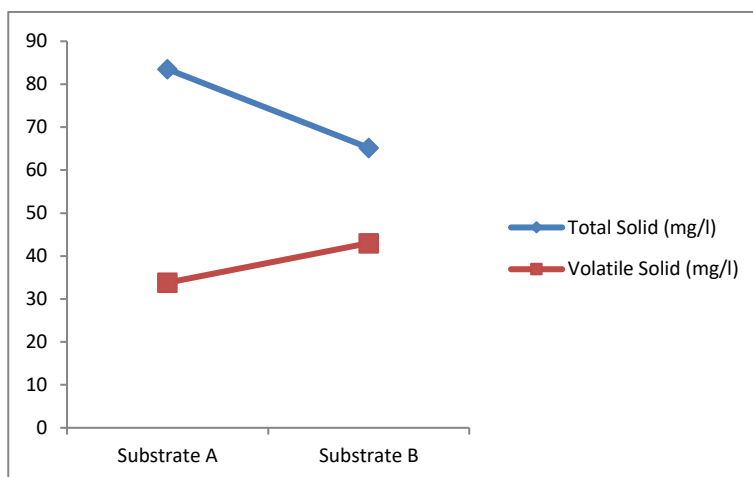


Fig. 2: Graph of Total Solid and Volatile Solid of the Substrates before Digestion (Taken by the authors).

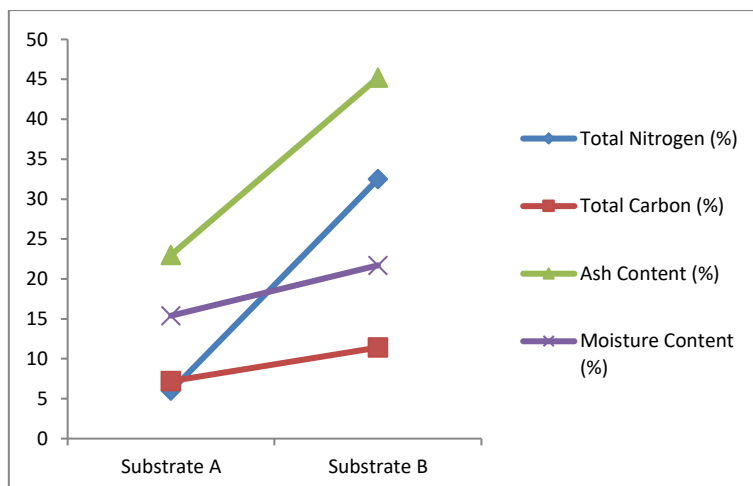


Fig. 3: Graph of Total Nitrogen, Total Carbon, Ash Content and Moisture Content before Digestion (Taken by the authors).

Table 3: Result of Proximate Analysis of the Digestate after Anaerobic Digestion

Parameters	Digester A	Digester B	Digester C	Digester D
Total solids (mg/l)	65.00	52.50	62.10	56.00
Volatile solids (mg/l)	26.00	34.50	27.50	29.00
Total carbon (%)	6.00	7.00	1.93	2.23
Total nitrogen (%)	4.50	11.40	1.21	1.79
Ash content (%)	14.50	18.50	3.50	8.50
Moisture content (%)	2.00	6.00	5.00	4.50

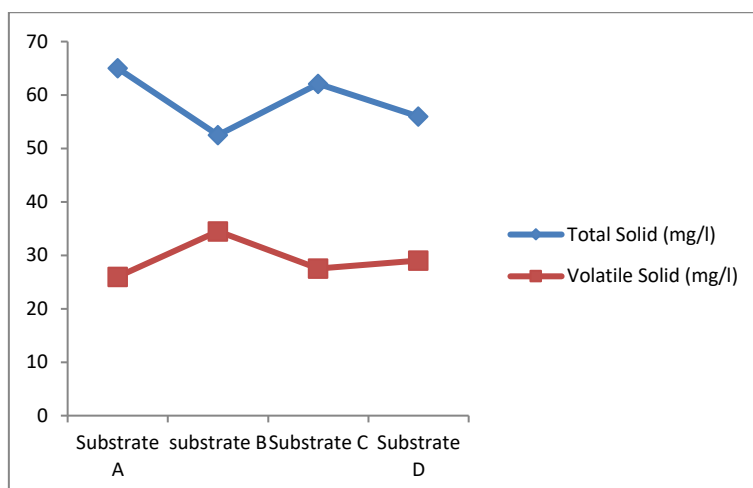


Fig. 4: Graph of Total Solid and Volatile Solid of the Substrates after Digestion (Taken by the authors).

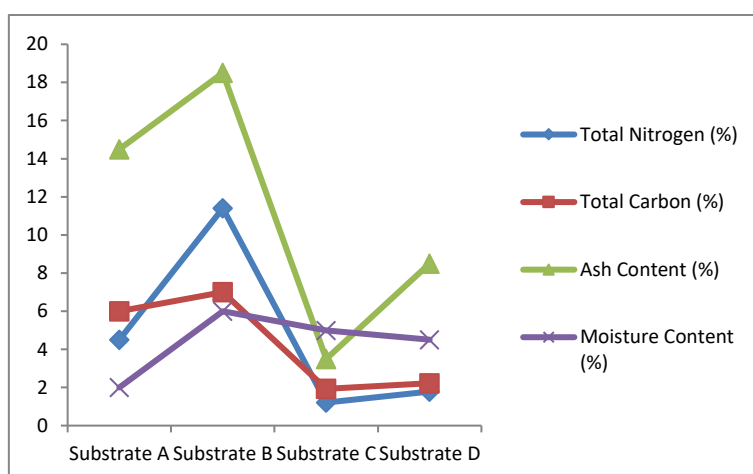


Fig. 5: Graph of Total Nitrogen, Total Carbon, Ash Content and Moisture Content after Digestion (Taken by the authors).

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	8.20	9.50	8.70	9.10
After	4.4	6.9	5.10	5.60

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	32	372	152	1871	412
2	32	2770	2620	4534	4724
3	32	4972	5222	5564	5978
4	34	3564	3675	4698	4998
5	32	4100	3573	3290	5458

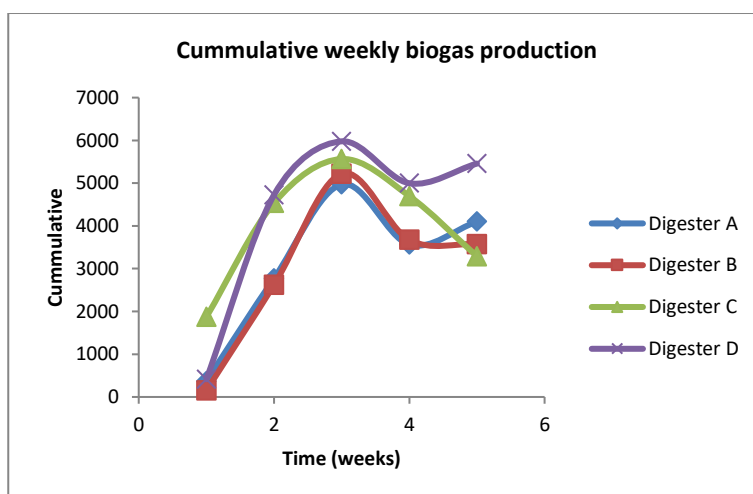


Fig. 6: Graph Cummulative Weekly Biogas Production.

4. Discussion

The results of total solid (TS) for the sample A and B before digestion were 85.50% and 65.20% respectively as shown in Table 1. After the anaerobic digestion, there was a decrease in the values of total solid for the two substrates as shown in Figure 2 and 4. The values are 65.0% and 52.5% respectively for digester A and B and compare well with the result of 8.00 mg/l and 4.32 mg/l for rice husk before and after reported by Ezekoye et al., (2014). Digester C and D have the following values 62.1% and 56.0% respectively.

After the anaerobic digestion, there was a decrease in the result of the volatile solid for the two digesters. The values are 26.00 % and 34.50 % for digester A and B respectively. The values for digester C and D are 27.50 % and 29.00% respectively as shown in Figure 2 and 4. The increase in the values is as a result of the high volatile solid that has been converted to biogas. The results obtained are greater than 16.95 % and lower than 81.20 % of cow manure and garden waste respectively as reported by Spyridon and Gerrit, (2019).

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 as shown in Figure 2 and 4. After the anaerobic digestion, the values of Ash content were 14.5% and 18.5% for digester A and B respectively and it is compare well with the results obtained for cow dung and fowl dung 10.10 % and 16.40 % respectively as reported by Ukpabi et al., (2017). Digester C and D have the following values 3.5% and 8.5% respectively.

Substrate A has the higher moisture content before digestion. After the anaerobic digestion, the values of moisture content were 2.0 and 6.0 for digester A and B respectively Digester C and D have the following values 5.0 and 4.5 respectively.

pH is an important factor that affects anaerobic digestion as reported by Spyridon and Gerrit, (2019), the values of the pH before the anaerobic digestion of the four(4) slurries are 8.20, 9.250, 8.70 and 9.10 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 (Spyridon and Gerrit, 2019). There was a decrease in the pH of the digestate after the anaerobic digestion.

After the anaerobic digestion, the values of total carbon were 6.0 and 7.0 for substrate A and B respectively. Digester C and D have the following values 1.93 and 2.23 respectively. There was a decrease in the values; this might be as a result of biogas formation (Aremu and Agarry, 2012).

It has been noted that temperature and retention time are among the parameters that influence anaerobic fermentation of organic matter. From figure 6, it can be observed that from retention time (RT) interval between 0 week and 1 week, the rate of production of biogas was almost constant. Between about 1 wee and 3 weeks, the rate of generation of the gas was increased.

The temperature range throughout the retention periods is within 32-34°C which is optimum for biogas production under mesophilic condition. This also validate the temperature range cited by oyeleke (2007), at low temperature, microorganism become inactive and rate of gas production drops but resumes when the temperature is favorable.

Digester D (fonio husk and donkey dung 300g and 200g); the production began on the 3rd day of the retention period by producing 40mls of biogas. The highest production was recorded on the 3rd with the value of 5978 ml. Digester D produces higher volume of biogas compared to digester B. This was as the result of improved nutrient provided by donkey dung based on the result of the proximate analysis obtained before digestion.

5. Conclusion

The proximate analysis had been conducted to show the characteristics of fonio husk and donkey dung to become biogas via data of total solid, volatile matter, moisture, ash content etc.

Digester D recorded the highest experimental daily biogas volume on the third week of the digestion process. 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. Biogas production from anaerobic co-digestion of fonio husk and donkey dungs was established in this research work to be feasible of mesophilic temperature range (32- 40 °C) and this gives positive attribute towards a search for sustainable renewable energy source (SRES).

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