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Analysis of Various Feedstocks for Biogas Production Using Portable Digester for Sustainable Energy in Jigawa State

Salisu I. Kunya[1], Ibrahim Isah[1] and Sulaiman Zakari[2]

[1]Department of science laboratory Technology, Jigawa State Polytechnics, Dutse, Nigeria
salisukunya2016@gmail.com
[2]Department of Health Information Management, Jigawa State Polytechnics, Dutse, Nigeria

ABSTRACT

A number of experiments were conducted as part of the study to examine the output of biogas from the digestion of horse dung, poultry droppings, and cattle manure with the intent to generate energy for heating needs. As the anaerobic digestion (AD) process of producing biogas from manure has several benefits, such as the creation of jobs, reduces the need for firewood or fossil fuels, and produces less indoor smoke and greenhouse gas emissions than other fuel types used in developing nations. Initially, the slurry were prepared and put into $5.34ml$ digesters, and the biogas produced were analyzed. The results demonstrated that anaerobic digestion of these feedstock successfully operate with maximum biogas yield of $224, 124\ and\ 189\ ml$ respectively for cow, poultry dropping and horse dung respectively. The finding shows that by comparing the samples production yield, we have seen that the daily and cumulative biogas yield from cow dung is higher with peak values of $224\ and\ 2633\ ml$ respectively. A pH results illustrated that a value close or equal to 7 is a favorable condition for methanogeneis. As such, small-scale biogas digesters can be a very useful manure management tool and may help reduce global warming impacts if used appropriately.

Key words: Biogas, Energy, Cow dung, Horse dung, Poultry dropping.

1. INTRODUCTION

The growth of energy resources and technologies is a key driver of the 21st century's sustainable socio-economic development, as the depletion of petroleum fuel is worrisome (Prasad, *et al.*, 2021). Global energy specialists are looking for ways to augment the energy resources from fossil fuels with energy resources from produced bio-fuels (Adewuyi, 2020). The ability of anaerobic digestion to transform biodegradable organics into biogas, which is mostly composed of carbon dioxide and methane, makes it proven method of producing sustainable energy (Pilarska, *et al.*, 2024). Animal manure from pigs, cattle, poultry, or horses is one of the many plentiful sources of biodegradable organic waste. Thus utilization of these waste would add energy to the current demand. In wealthy nations like the US, Canada, and Italy, the anaerobic digestion technology is widely employed (Grando, *et al.*, 2017). Nigeria generally suffers from a significant amount of rubbish being dumped in dumping sites and basic landfills, in contrast to wealthy nations. This resulted in significant releases of methane. Now there is world's population growth, millions of tons of organic garbage are produced globally and are building up over time (Nanda and Berruti, 2021). Therefore, improper waste resource disposal results in environmental issues.
Significant amount of waste manure was released into the environment as a result of the large number of livestock farming in Nigeria. These animals' dung generally contains significant concentrations of a variety of minerals, carbon,

nitrogen, heavy metals, and various microbial populations (Liang, *et al.*, 2023). Also high levels of organic matter, primarily made up of proteins and lipids, with varying proportions of carbohydrates and inorganic substances, are characteristics of animal byproducts. Furthermore, it is the most efficient bio fertilizer for raising crop yields, and it is used in the great majority of nations. However, putting waste manure to agricultural soil incorrectly can seriously contaminate the ecosystem (Koul, *et al.*, 2022). Therefore, for a clean environment and sustainable and reasonably priced energy options, it is crucial to deploy technology that capture and use methane from sources including animal waste, landfills, and manure management systems.

Any biomass with cellulose, proteins, carbohydrates, lipids, and hemicelluloses as its main constituents has the potential to be used as a substrate in the biogas production system (Kasinath, *et al.*, 2021). Because different feedstock has varied compositions, the amount of biogas produced by one feedstock may range greatly from that produced by another, making a thorough analysis of feedstock essential. So the, study focused on manure generated from cow, poultry, and horse. Cows are a common animal species worldwide and are regarded as a cheap source of feed. The proliferation of microorganisms that break down organic waste to produce biogas is aided by the high carbon to nitrogen (C/N) ratio of cow manure (Hamzah, *et al.*, 2024). The cellulose, hemicellulose, and lignin found in cow dung are essential for the synthesis of biogas. Anaerobic bacteria can efficiently break down these components during the biogas production process.

Horses are a significant animal in the agricultural and recreational sectors. Depending on feed, bedding, and cleaning systems, horses produce 18 to 25 kg of feces and 9 L of urine per day in addition to 8 to 10 kg of bedding (Westendorf, *et al.*, 2020). Horse manure is a type of organic waste that is enriched with a mixture of feces, urine, and bedding; typically, the bedding material makes up the majority of the manure's composition. The disposal of horse manure presents challenges related to hygiene and manure handling, which has raised interest in renewable energy and nutrient recycling. Domesticated birds raised for their meat, eggs, and feathers are called poultry. Chickens, ducks, and other birds are included in the category known as poultry. Thus, because of its large unexploited benefits for biogas production, these manures from these livestock certainly deserve research attention for use as a feedstock for anaerobic digestion.

1.1 STUDY AREA

Jigawa State Polytechnics, which is leading in science, technology, management, and health education courses among other institutions, was the site of the study. The state capital is its permanent side, and its coordinates are $12^{o}\,00'\,N$ *and* $9^{o}\,45'\,E$. It is located in the north-western region of Nigeria. The national electricity utility grid is linked to the establishment. But, like the majority of other consumers in the state, it experiences disruptions in the energy supply as a result of growing expenses, which makes it impractical to run the generator for extended periods of time since running costs become expensive. But the polytechnics is characterized by strong rock stability, thus it is beneficial to create a biogas digester since rock stability stops digesters from cracking, which stops gas from leaking through the walls of the digester. Figure 1 show the map of the polytechnics.

Figure 1. Map of Jigawa State Polytechnics

2. MATERIAL AND METHOD

The following materials were used in this work: Robber tube, measuring cylinder (250 ml), bucket, wood stick, plastic container, hand glove, sack, polythene bag, desiccator, oven, pH metre, weighing balance, crucible, and Digesters.

2.1 FABRICATION OF DIGESTER

The digesters are of the batch type and were constructed from clear plastic containers with a working volume of 1.09 liters and a capacity of 5.34 liters. In triplicate, three reactors (D1, D2, and D3) were constructed. A soldering iron was used to make two holes in each digester. The smaller hole at top of the digester is for a collecting gas from the digester to the measuring device. The other hole at the side, is for inserting a metre to monitor pH of the slurry. To block off light, they were wrapped in black polythene bags. This was done to prevent light from affecting microorganisms that are susceptible to it. Light greatly inhibits methanation but does not kill methanogens. Through the delivery tube, the gas generated exits the digester and is connected to the measuring cylinder, which served as the gas measurement apparatus.

2.2 SAMPLE COLLECTION AND PREPARATION

The current study used three substrates: horse dung, chicken droppings, and cow dung. Horse manure was gathered at Kano Emir Palace, while cow manure and fowl dropping were gathered from Almawash Farm, Daura Road Farm, and Bayero University Kano, respectively. Airtight bags were used to store the samples. After removing any undesired debris, the feedstock and water were combined in a 1:1 ratio in the mixing tank to create a final slurry, which was then fed into the digester through the inlet chamber. The addition of slurry was halted when the digester reached 80% of its capacity. The digester had been closed down. The batch fermentation experiment was permitted to run for 21 days. It should be noted that in order to accelerate the production of gas, the slurry was shaken daily. The materials were not chemically treated before to use, and the delivery tube lacks a tap to control gas flow

2.3 METHODS OF MEASUREMENT

Several techniques were used to characterize the fresh manures. Water displacement method was used to calculate the biogas's daily production. Total solids (TS) and volatile solids (VS) were determined using the conventional proximate analysis method (Kizito, *et al.*, 2022). A known weight of mixed materials was prepared in an oven at 105 °C until a consistent weight was reached in order to estimate the total solid. The samples were reweighed after being allowed to cool to ambient temperature in a desiccator to stop moisture from absorbing from the air. The Total Solids calculation was performed using (Djimtoingar, 2023).

$$\%TS = \frac{W_2 - W_0}{W_1 - W_0} \qquad (1)$$

The crucible's empty weight is denoted by W_0, the crucible with the fresh sample by W_1, and the crucible and sample after drying at $105^o C$ by W_2.

Parts of the dried sample were burned at a steady temperature of $550^o C$ after the total solids were determined. After being taken out of the oven, the crucibles were left to cool in the open until most of the heat had been released, and then they were put in a desiccator. The samples were then weighed and warmed up till their weights didn't change. Next, the percentage of volatile solids was calculated using (Djimtoingar, 2023):

$$\%VS = \frac{W_2 - W_3}{W_2 - W_0} X100 \qquad (2)$$

W_0 represent the weight of the empty crucible, W_2 represents the weight of the crucible and sample following $105^o C$ drying, and W_3 represents the weight of the crucible and sample following $550^o C$ heating.

3.0 RESULT AND DISCUSSION

The results obtained from digestion of cow, horse dung and poultry dropping are presented in this section and interpreted using figures.

3.1 SUBSTRATE PARAMETERS

The goal of the substrate characteristics was to investigate the variables affecting the digester's methane productivity. Based on the experimental findings shown in Table 1, it was demonstrated that all of the substrates had different parameters. Its distinctive compositions were the primary cause of this. In reference to the moisture content experiment, the moisture content is extremely low.

Table 1. The properties of various feedstock

Parameter	Substrate		
	Cow dung	Poultry dropping	Horse dung
Moisture content	14.90	13.83	14.91
Total solid	85.10	86.17	85.09
Volatile organic solid	83.10	79.85	83.65

The amount of substrate that has the capacity to create methane is indicated by the volatile solid. The analysis's findings indicated that all of the samples had high total solids. Systems with high levels of total solids might produce a lot of biogases. The percentage of organic compounds that can be transformed during anaerobic digestion increases with the volatile solid content. Mothe, *et al*, (2024) show that substrates with quite good amount of volatile solid content, demonstrating the potential for biological degradation and ensuing biogas production.

3.2 DAILY BIOGAS YIELD

The most wanted outcome of anaerobic digestion is biogas. A key factor in the production of biogas is selecting a high-quality substrate. Figure 1 illustrate that, the amount of biogas produced in a digester with a varied substrate under the same experimental conditions varies. The results showed that, although there was no change in gas for any of the samples on the first day, biogas production tended to grow on the second day. It was clear that biogas production had increased. At the final stage of experiment the higher percentage of biogas was found to be decreased. But from 17th days it was found to be decreased. This is because the longer the fermentation time, the less organic material is used by microorganisms to produce biogas. Additionally, findings indicate that cow dung produces more biogas, with peak values of 224 ml; this could be because it contains a lot of carbohydrates. Poultry dropping dung produced less biogas because simple sugars break down in a matter of hours. This could be likely the manure contains feeding components that are less biodegradable due to their high cellulose and lignin concentration.

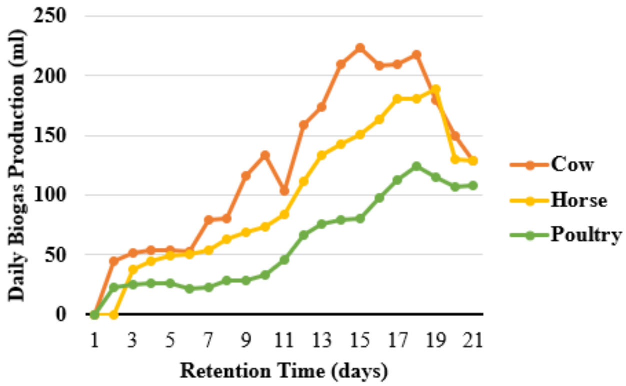

Figure 2. Daily Biogas Production Graph from Individual Digestion

3.3 CUMULATIVE BIOGAS YIELD

The total gas in each digester were calculated. Figure 3 displays the total amount of biogas produced. It is evident that the cumulative rate was small during the first five days but increased over time. After 20 days, the total amount of biogas produced by horse dung quickly drops. It is evident that cow dung produces more accumulative biogas than other types. By the end of the digestion period, the total biogas yield for cow, horse, and poultry waste is predicted to be $2633, 2039\ and\ 1248\ ml$, respectively

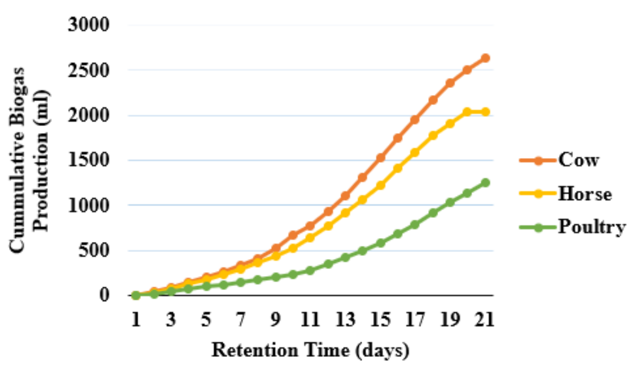

Figure 3. Cumulative Biogas Production Graph from Individual Digestion

3.4 EFFECT OF PH ON THE YIELD OF BIOGAS

Measuring pH is important because different microorganisms require different optimal pH values, even though most of them prefer neutral pH conditions. The pH of the slurry was monitored and the result is presented in figure 4. From the graph it was revealed that the pH is below neutral in the first 7 days of retention time. The low pH of substrate during hydrolysis process is an indicator of production of organic acids. However, horse and poultry waste shows a lower level of pH than cow waste. Bahira et al. (2018) suggested that low pH values inactivate methanogenic bacteria. As the number of days increase the pH begins to rise when acetic acid was converted into biogas. This is due to increase in alkalinity of substrates, the condition which activate methanogenic bacteria. However, Studies show that the pH of about 6.8 to 7.2 is suitable for biogas production (Jameel, 2024). According to the report of Ceron-Vivas, *et al., (*2019) shows that best biogas production would occurs when the digester's input mixture has a pH between 6 and 7. This might me the reason for higher methane yield in cow dung

Figure 4. Graph of pH against Retention Time

4. CONCLUSION

The ecology is in danger due to the increase in organic waste from plant and animal wastes as well as unlawful large-scale dumping. Since renewable energy sources have the ability to mitigate the negative impacts that fossil fuel pollution has on both the environment and people, it is imperative that every nation use them. Nigeria has a wide range of potential feedstock for biogas generation, which shows that our institution needs to thoroughly characterize and assess each type of feedstock in order to use compatible biogas technology. In the present study, comparative investigation of the gas produced from cow, poultry, and horse waste was carried out. These wastes were used because they are relatively abundance in the region, good quality and easily transported from farm. The assessment of these feedstock shows that the daily and cumulative biogas yield from cow dung is higher with peak values of 224 and $263\ ml$ respectively. The proximate analysis results shows that volatile solid of cow, poultry and horse dung are 83.10 , 79.85 and 83.65 respectively. Cow manure is superior for producing biogas, according to the test results. The outcome demonstrated the feedstock's capacity to reduce carbon dioxide emissions and contribute to increased energy security in polytechnics.

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