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## Optimizing Biogas Production: Comparative Analysis Of Organic Substrates For Enhanced Gas Yield

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### Abstract

*This research aimed to investigate the utilization of various locally sourced substrates in the biogas optimization process and compare the gas yield to determine the most efficient domestic substrate. The samples tested included cow dung, poultry dung, human, and pig manure. A comparative analysis of gas production over a 15-day period was carried out at 3-day intervals using four custom-made biodigesters with batch culture fermentation. The findings revealed that digester 4, utilizing poultry dung, exhibited the highest gas output. The gas production ratios for human, cow, pig, and poultry dung on day 15 were 0.10:0.11:0.12:0.20, equating to percentages of 18.86%, 20.78%, 22.64%, and 37.73% respectively. The notably higher percentage for poultry dung suggests its superior effectiveness as a substrate for biogas production. Alternatively, the co-digestion of cow and/or poultry dung could be considered as a strategy to enhance biogas production.*

**Keywords:** Substrate, Co-Digestion, Anaerobic, Biogas, Methanogen, Fermentation

### INTRODUCTION

The globe is faced with the twin crises of safe energy generation and climate change. Global warming, resulting from an increase in CO<sub>2</sub> in the atmosphere due to the use of fossil fuels, causes the greenhouse effect. Therefore, it is imperative to explore and exploit new energy sources that are renewable and ecologically sustainable. Additionally, it has been shown that energy supply and utilization can be optimized by incorporating various factors that enhance best management practices in the industry. Biogas production has emerged as a promising alternative to fossil fuel sources, and the development of this technology will help humanity overcome the current energy crisis and provide a clean source of energy to address global warming. Biogas is competitive, viable, and generally a sustainable energy resource due to the abundant supply of cheap feedstocks and the availability of a wide range of biogas applications in heating, power generation, fuel, and raw materials for further processing and the production of sustainable chemicals, including hydrogen, carbon dioxide, and biofuels (Moses & Oludolapo 2022)

Anaerobic digestion (AD) process is a biochemical process that converts most biodegradable organic matter into biogas. The AD process is controlled by several process parameters, and determining the optimal values of these parameters is crucial for bioprocess development and scale-up. The first stage in AD process is hydrolysis. This stage is often referred as *the rate-limiting step* as materials considered rich in fibre are employed as feedstock. Some of the bacteria involved during hydrolysis include the *Clostridium*, *Bacillus*, *Proteus vulgaris*, *Vibrio*, *Bacteroides* and *Staphylococci*. Biogas can also be used in fuel cells for direct conversion to electricity and raw material for hydrogen and transport fuel production which is a significant pathway to sustainable energy development. Biogas can be used in processes like combined heat and power generation from biogas (CHP), trigeneration, and compression to Bio-CNG and bio-LPG for cleaned biogas/ biomethane. Fuels are manufactured from biogas by cleaning, and purification before reforming to syngas, and partial oxidation to produce methanol which can be used to make gasoline. Syngas is used in production of alcohols, jet fuels, diesel, and gasoline through the Fischer-Tropsch process (Moses & Oludolapo 2022)

The aim of this research was to utilize various domestically sourced substrates in the

optimization of the biogas production process and to compare the quantity of gas produced in order to determine the most suitable domestic substrate for biogas production.

## MATERIALS AND METHODS

### Sample collection

The samples used in this research/investigation included cow dung, poultry dung, human feces, and pig manure. Cow and poultry dung were collected from the Obinze livestock market along Owerri-Portharcourt Road, while pig manure and human feces were obtained from private homes. These four substrates were then transported to the project laboratory for anaerobic digestion, with two kilograms of each collected from the sample site.

### Fabrication of Anaerobic Digester and Slurry Preparation

Four plastic containers of 20-liter capacity were utilized, all of the same size, quality, and transparency. Each container was equipped with a perfectly airtight cork cover. Holes were carefully drilled into the corks to accommodate the size of the bronze nozzles, which were securely attached using a combination of glue and screws to ensure air and water tightness. Rubber transparent hoses were then connected to the nozzles using clips, and four T-valves were employed to link the hoses to small vehicle tubes (Ikeokwu et al., 2023).

According to Ikeokwu et al., (2023), separate paint buckets were used to prepare the slurry by mixing 1kg of each substrate with 9 liters of water. Once thorough and homogeneous mixtures were achieved, they were poured into the designated fabricated digester and labeled accordingly.

### Anaerobic Fermentation and Gas Collection

The fabricated digesters were placed on a high elevated flat surface with the tubes positioned approximately three feet below to facilitate downward gas delivery.

The type of fermentation process utilized in this biogas production is batch culture fermentation.

This decision was made as the prepared slurry was poured into the fabricated digester and sealed, remaining closed until the end of the hydraulic retention time. Gas production was monitored, and readings were taken at three-day intervals (0, 3, 6, 9, 12, and 15 days).

### Physiochemical Analysis of the Substrates

The analysis of Total solid, Volatile Solid, moisture content, organic carbon, and pH was conducted before the anaerobic digestion processes, following the procedure outlined by Ignatowicz et al. (2023), on the four substrates. The recorded readings are presented in Table 2 below.

## RESULTS

After 15 days (RT= retention time) of anaerobic fermentation, results were obtained. These results were indicated by the emergence of gas. The initial process setup did not significantly affect the gas output. From day 0 to 3, the hydrolysis process took place, which is a crucial factor in the biogas production process. The bacteria responsible for biogas production initially experience a lag phase, transitioning to the log or exponential phase over time. This transition is reflected in the increasing volume observed in the collection tube. The gas production volume from day 1-15 (Retention time) of the anaerobic fermentation is detailed in Table 1 below.

### Calculation of the percentage by volume of gas at day 15

$$0.10 + 0.11 + 0.12 + 0.20 = 0.53$$

$$\% \text{ Human waste at day 15} = \frac{0.1}{0.53} \times 100 = 18.86\%$$

$$\% \text{ Cow waste at day 15} = \frac{0.11}{0.53} \times 100 = 20.75\%$$

$$\% \text{ Piggery waste at day 15} = \frac{0.12}{0.53} \times 100 = 22.64\%$$

$$\% \text{ Poultry waste at day 15} = \frac{0.2}{0.53} \times 100 = 37.73\%$$

**Table 1: Volume of gas in Kg produced from day 1-15 ( RT= Retention time)**

Digester	RT0 (kg)	RT3(kg)	RT6(kg)	RT9(kg)	RT12(kg)	RT15(kg)
DIGESTER 1 (Human faeces)	0.000	0.010	0.070	0.080	0.097	0.100
DIGESTER 2 (Cow dungs)	0.000	0.070	0.080	0.090	0.109	0.110
DIGESTER 3 (Pig dungs)	0.000	0.090	0.095	0.098	0.099	0.120
DIGESTER 4(Poultry dungs)	0.000	0.070	0.081	0.120	0.189	0.200

**Table 2: Physicochemical Analysis Results**

Sample Code	N <sub>2</sub> (mg/L)	P (mmol/l)	K (mEq/L)	NO <sub>3</sub> (mg/L)/ppm	OC (%)	NH <sub>3</sub> (mg/L)	COD s/m	pH	Temp (°C)
Poultry	4.12	2.81	2.11	11.21	31.17	20.83	11.12	8.30	45
Pig	4.29	2.99	2.19	10.98	32.28	19.50	10.87	8.48	38
Cow	4.55	2.56	2.32	11.10	32.25	19.45	11.34	8.20	28
Human	1.22	1.30	1.12	6.12	23.34	18.34	10.23	6.70	26

Units of Measurements: K, milliequivalent per litre; N, milligram per litre; P, millimole per litre; NO<sub>3</sub>, milligram per litre; OC (organic carbon), %; COD (conductivity); S/m (Siemens per meter)

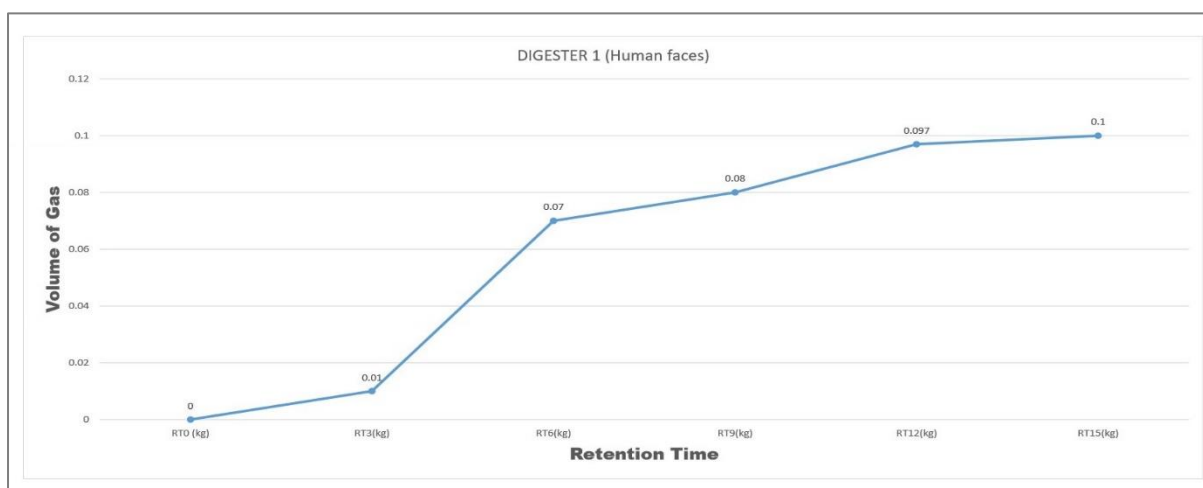


Figure 1: Graph of digester 1 for human faeces in biogas production

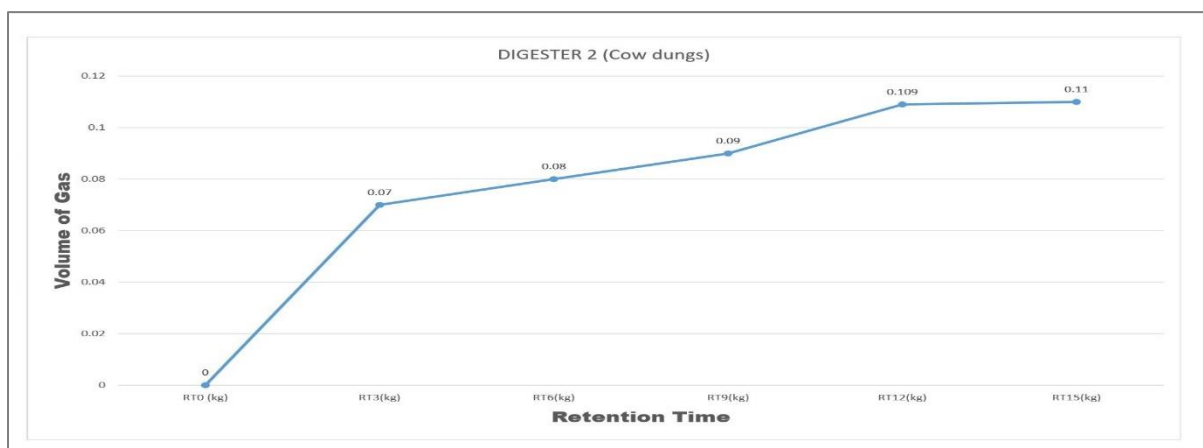


Figure 2: Graph of digester 2 for Cow dungs in biogas production

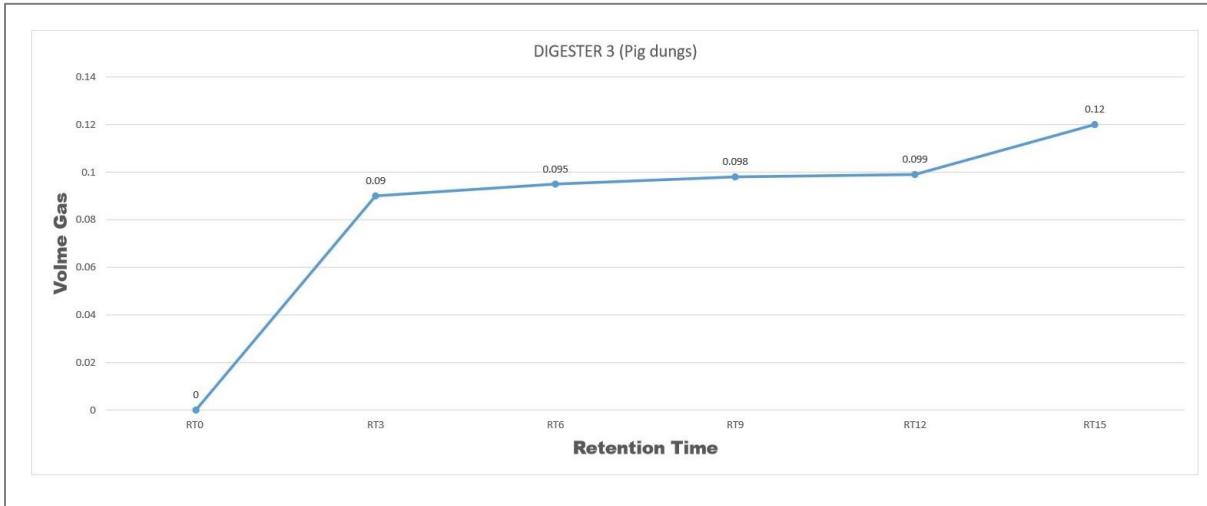


Figure 3: Graph of digester 3 for piggery dungs in biogas production

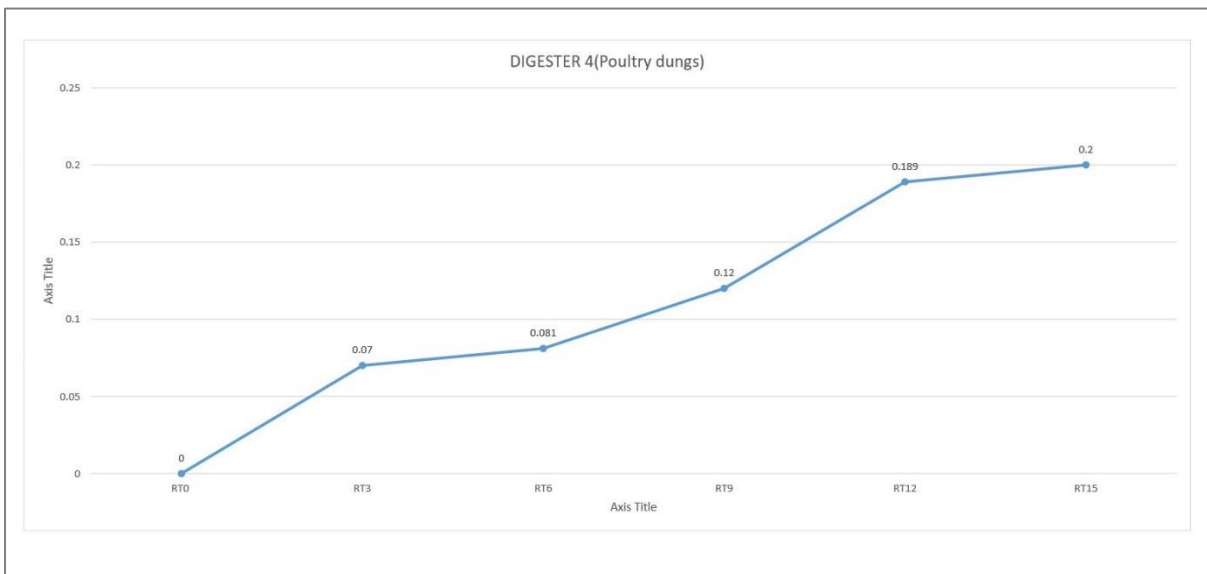


Figure 4: Graph of digester 4 for poultry dungs in biogas production



Figure 5: Locally fabricated digesters and slurry preparation process



## DISCUSSION

The results of this research were obtained by using the electronic weighing balance and recording accordingly. The weight of the tubes were taken first and subsequently, were subtracted from weights at intervals. The Table 1 above showed the result of weights of tubes at interval minus the weight of tube before. It was also observed that the quantity of gas produced started changing between days 3 to 15. It is scientifically difficult to say exactly at which interval that corresponds to hydrolysis, acidogenesis, acetogenesis and methanogenesis. But the knowledge of bacterial growth curve explained why the gas production did not start instantly. This could be attributed to bacteria passing through Lag to Log (exponential) phase. Also similar research done by Ikeokwu *et al.*, (2023), showed that keeping the digesters outside would have great impact and effect on biogas production. This could be attributed to effect of temperature which is one of the factors that could be varied to optimize biogas production. In his other research, he revealed that addition of CaSO<sub>4</sub> to the slurry will have tremendous effect on the volume of biogas produced. This was as a result of effect of hard water on biogas production. According to (Adebayo *et al.*., 2018) they also revealed further that cow as well pig dung as animal waste has great potential for generation of biogas and its use should be encourage due to its early retention time and high volume of biogas yields He concluded that addition of 200g/dm<sup>3</sup> of CaSO<sub>4</sub> in 1Kg of biomass affected the quantity of gas produced.

## CONCLUSION

Biogas formation can be achieved using locally sourced substrates or biomass. In this research, we compared different substrates (Human waste, Cow, pig, and poultry dungs). Digester 4, designated for poultry dungs, yielded the highest gas and is thus recommended. The quantity and quality of biogas and digestates obtained will vary depending on the feedstock used. According to Ikeokwu *et al.* (2023), the initial process setup did not significantly impact the output. The hydrolysis process occurred from day 0 to 3, as mentioned by Osuji *et al.* (2022). this step is considered a limiting factor. The bacteria involved in biogas production go through a lag phase initially, transitioning to the log or exponential phase over time. The volume of biogas produced is influenced by the residence time of digestion and the concentration of organic matter. The experiment suggested that

utilizing biodegradable wastes like kitchen and animal wastes can produce biogas, a potent greenhouse gas. Anaerobic digestion (AD) is a treatment process that decomposes these wastes in the absence of oxygen, generating biogas for Heat and Power production. Harnessing renewable energy from biodegradable wastes helps address the energy crisis (Sewsynker-Sukai *et al.*, 2017) Poultry dung is identified as a favorable substrate for biogas production, and co-digestion of poultry, cow, and pig manure can enhance yield (Ikeokwu *et al.*, 2023).

## RECOMMEDATION

From the results obtained and the calculations, we recommend the separate use of poultry and pig dungs for optimum biogas production. Additionally, co-digestion of these substrates can be beneficial. It is also recommended to place the digesters outdoors to maintain the optimum temperature required for anaerobic fermentation.

## CONFLICT OF INTEREST

There is no conflict of interest in this research work.

## ACKNOWLEDGEMENT

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