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AN EXPERIMENTATION ON BIOGAS GENERATION FROM DIFFERENT DOMESTIC ANIMAL DUNGS FOR NIGERIAN HOUSEHOLD ENERGY NEEDS

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ABSTRACT
The issue of energy sources and supply is a major concern in both Nigeria and globally, encompassing challenges such as scarcity, limited availability, and environmental impacts. Progress has been achieved in developing a more eco-friendly fuel source, offering potential benefits for domestic, industrial, and commercial applications.This research was aimed at the experimentation of Biogas Generation from Different Domestic Animal Dungs for Nigerian Household Energy Needs. This was done by preparing an anaerobic digester for batch reactor studies and to develop an appropriate technology for the production of biogas from the solid waste in which Four reactors were prepared using same proportions of animal waste (dung) and other materials. Reactor RI was setup using poultry litter. R2 was prepared using cow dung, R3 was pig dung and R4 was Goat/Sheep dung.The ratio for each combination was 1:1, in which 4 kg of each animal dung was mixed with 4 kg of water before being introduced into the anaerobic digesters. From the experiment conducted, Poultry droppings showed a shorter lag phase and hydraulic retention time (HRT) compared to cow dungs, goat/sheep dungs, and pig dungs with pig dungs showing a more extended lag phase and HRT. This indicates that the co-digestion of poultry droppings is more rapid than that of cow dungs, goat/sheep dungs, and pig dungs. Also, the cumulative daily gas production rates for the digestion of poultry droppings, cow dungs, goat/sheep dungs, and pig dungs resulted in a total biogas yield of 3046 g, 2298 g, 2792 g, and 2226 g, respectively. This shows that Co-digesting domestic animal wastes such as poultry droppings, cow dungs, goat/sheep dungs, and pig dungs is a viable method for producing biogas.

INTRODUCTION
The use of fossil fuels, such as coal, oil, and gas, was the driving force behind the industrial revolution. This revolution was responsible for the simultaneous advancement of technology, the economy, and society, but it had a negative impact and influence on the environment, such as climate change (Kasinath et al., 2021). Therefore, in the present day, the development and utilization of renewable energy resources have become a major component of sustainable global energy strategies. This is done with the goal of decreasing the use of fossil fuels (Chen et al., 2020). There is a growing realization, on a global scale, that one of the most effective ways to realize sustainable growth in the energy sector is to put into practice technology that converts waste into energy(Kabeyi & Olanrewaju, 2022b). The conversion of organic-rich compounds into clean and renewable products through anaerobic digestion (AD) is the approach that has gained the most popularity in recent years. It is possible to produce biogas from agricultural waste, biowaste from municipalities and industries, and other forms of sustainable biomass, particularly materials that are readily available in the area(Kasinath et al., 2021).

Renewable technologies generate power, heat, or mechanical energy through the use of renewable resources such as biomass (energy crops, agricultural or forestry residues, biogenic municipal waste, and so on), wind, solar (thermal and photovoltaic), hydro (river flow, tides, and waves), and geothermal energy(Iwata, 2015). Among the many different sources of alternative energy, biogas is one of the most environmentally friendly, as well as one of the most efficient and effective, sources of renewable energy (Riagbayire & Nayem, 2023). The methanation process results in the production of biogas, and the effluent produced by the process is

exceptionally rich in useful nutrients and has the potential to serve as an excellent fertilizer. In the absence of oxygen, the process of biodegradation of organic materials by microorganisms is known as bio methanation(Kabeyi & Olanrewaju, 2022a).
According to Okoro et al. (2020), the majority of states in Nigeria are struggling to meet the challenge of ensuring a sustainable energy supply and safe waste management. The process of anaerobic digestion satisfies the criteria for environmentally responsible alternative fuels and also serves as a method of waste disposal(Okoro et al., 2020). Producing clean alternative energy such as biogas from waste is also one of the best ways to meet the challenges that are presented here. Because it has such a significant impact, the environmental impact of the process needs to be taken into consideration.The breakdown of different kinds of organic waste is what gives rise to the production of biogas. It is a fuel that is both renewable and environmentally friendly, and it is produced from local feedstocks one hundred percent of the time. It is suitable for a variety of uses, including those in the automotive and industrial sectors. The organic nutrients that are recovered during the production process add another layer of importance to the biogas industry's contribution to the circular economy. Producing biogas from a wide range of different raw materials is possible (feedstocks)(Saidmamatov et al., 2021).. Microbes that consume biomass are the primary actors in the chain of events that leads to the production of biogas. The process of digestion that is carried out by these microorganisms results in the production of methane, which can either be utilized in its natural state locally or upgraded to a quality of biogas that is comparable to that of natural gas, thereby enabling the transport of biogas over greater distances. In the course of the process, material containing organic nutrients is also produced, and this material has potential applications in fields such as agriculture and domestic use(Manikandan et al., 2023).

Hence, the primary goal of this research is to investigatethe biogas generation from different domestic animal dungs for household energy needs in Nigeriaand to compare the biogas generation potential of some animals' waste product.This approach to the investigation of the biogas generation from different domestic animal dungs involves the utilization of biogas digesters for four sets of codigestion whichinclude poultry droppings, cow dungs, goat/sheep dungs and pig dungs and performance comparison of biogas yields from the four sets of reactor processes. These ultimately can create a new business potential for investors and domestic gas production revolution.

MATERIALS AND METHODS

Materials

Sample Collection:

Poultry litter and poultry droppings, cow dungs, goat/Sheep dungs and pig dungs were collected from the vicinity of the polytechnic community.

Equipment

- Digester seed material
- Digester feed stock Animal dung, vegetables)
- 20-litre water can
- 1 /4" plastic tubing - possible use in the gas collection system
- Medium size Tyre tube for gas storage
- Tub for mixing water feedstock
- PVC Pipe 3/4" 2.5 ft
- T-valve
- Valve
- Super Glue
- Fine Sand
- Soldering Iron
- Black Colour Paint

Methods

Preparation of reactors

The anaerobic digestion process was studied in batch reactors to develop an appropriate technology for the production of biogas from the solid waste from poultry farms, cow dungs, goat/sheep dungs and pig dungs. A known amount of substrate containing a mixture of waste was transferred into a 20-litre container. All of the containers (reactors) were sealed with air tight rubber stoppers, and another bottle was filled with water to collect gas and was equipped with glass tubes for gas removal. Biogas produced by anaerobic digestion was collected by the water displacement method. Four reactors were prepared using same proportions of animal waste (dung) and other materials. Reactor RI was setup using poultry litter alone. R2 was prepared using cow dung, R3 was pig dung and R4 was Goat/Sheep dung.

Sample analysis

The sample pH was measured with a digital pH meter. The carbon and nitrogen content of the dungs determine (the C-H-N elemental analyzer). Each experiment was conducted at a temperature of 32 ± 30C for 50 days.

Experimental procedure

The experimental process involved four distinct organic feedstocks: Poultry droppings (4kg) combined with distilled water (4kg), cow dung (4kg) paired with distilled water (4kg), pig dung (4kg) mixed with distilled water (4kg), and Goat/Sheep dung (4kg) along with distilled water (4kg). The ratio for each combination was 1:1, respectively.

The experimental procedures were conducted in the following sequence:

- Utilizing a weighing balance, the total mass of each set of the four substrates used in the experiment was measured to be 8kg.
- 4kg of distilled water was mixed thoroughly with each set of substrates until a slurry was formed.
- The mixture of distilled water and substrates was then poured into the bio-digester through the inlet, following which the digester inlet valve was closed.
- The initial gauge pressure was calibrated and recorded at 0.0 bar.
- The pH of the substrate was tested both before and after the digestion process using a digital handheld pH meter.
- The temperature of the anaerobic digestion process was measured with a thermometer.
- The biogas produced was collected in a bicycle tube and measured using a weighing balance to determine the actual quantity produced at each gas evacuation time.
- The same procedure was repeated for the other set of substrates introduced into the digester.
- The biogas yield for the four sets of feedstocks was then compared.

RESULTS

The results obtained from the experiment conducted during the specified period are displayed in the Tables1,2,3 and 4 and Figures 1,2,3 and 4.

Table 1: Values for the Co-digestion of poultry droppings

HRT (Days)	**Temperature (ºC)**	**Pressure (Bar)**	**Biogas yield (g)**	**Cumulative biogas yield (g)**
12	37.5	0.02	14	14
13	38.2	0.03	9	23
14	37.8	0.04	23	46
15	37.4	0.04	34	80
16	38.5	0.05	52	132
17	38	0.06	60	192
18	39.2	0.07	84	276
19	39	0.07	112	388
20	38.7	0.07	127	515
21	39.7	0.08	145	660
22	39.8	0.09	179	839
23	40.1	0.09	191	1030
24	40	0.09	210	1240
25	40.2	0.09	210	1450
26	40.1	0.09	210	1660
27	40	0.09	209	1869
28	39.6	0.08	197	2066
29	39.2	0.08	189	2255
30	39	0.08	165	2420
31	37.8	0.06	152	2572
32	38.6	0.08	141	2713
33	38.2	0.05	105	2818
34	38.3	0.05	93	2911
35	37.9	0.04	67	2978
36	38	0.03	34	3012
37	37.7	0.02	24	3036
38	37.4	0.01	10	3046

Table 2: Values for the Co-digestion of cow dungs

HRT (Days)	**Temperature (°C)**	**Pressure (Bar)**	**Biogas yield (g)**	**Cumulative biogas yield (g)**
18	33.5	0.01	5	5
19	34.2	0.01	11	16
20	34.8	0.02	6	22
21	35.4	0.03	12	34
22	35.5	0.04	17	51
23	36	0.03	20	71
24	36.2	0.04	33	104
25	37	0.05	61	165
26	37.7	0.05	94	259
27	37.8	0.06	105	364
28	38.2	0.06	113	477
29	38.1	0.07	149	626
30	38	0.07	188	814
31	38.3	0.07	188	1002
32	38.1	0.07	189	1191
33	38	0.07	189	1380
34	37.5	0.06	178	1558
35	37.2	0.05	157	1715
36	36.8	0.05	135	1850
37	36.8	0.04	121	1971
38	36.6	0.05	95	2066
39	36.2	0.05	82	2148
40	35.8	0.04	65	2213
41	35.7	0.03	45	2258
42	35	0.02	23	2281
43	34.7	0.01	12	2293
44	34.4	0.01	5	2298

Table 3: Values for the Co-digestion of Goat/sheep dung

HRT (Days)	Temperature (°C)	Pressure (Bar)	Biogas yield (g)	Cumulative biogas yield (g)
21	34.5	0.02	9	9
22	35.2	0.03	8	17
23	35.8	0.04	13	30
24	36.4	0.04	25	55
25	36.5	0.05	45	100
26	36.8	0.06	52	152
27	37.2	0.07	75	227
28	37	0.07	103	330
29	37.7	0.07	121	451
30	37.9	0.08	142	593
31	38.4	0.09	195	788
32	38.5	0.09	185	973
33	38.4	0.09	186	1159
34	38.3	0.09	185	1344
35	38.2	0.09	185	1529
36	38	0.09	185	1714
37	37.8	0.08	180	1894
38	37.9	0.08	171	2065
39	37.7	0.08	155	2220
40	37.5	0.06	160	2380
41	37.6	0.08	132	2512
42	37.2	0.05	95	2607
43	36.3	0.05	83	2690
44	35.9	0.04	55	2745
45	35.2	0.03	25	2770
46	34.7	0.02	13	2783
47	34.4	0.01	9	2792

Table 4:Values for the Co-digestion of pig dungs

HRT (Days)	**Temperature (ºC)**	**Pressure (Bar)**	**Biogas yield (g)**	**Cumulative biogas yield (g)**
23	37.5	0.01	5	5
24	38.2	0.02	4	9
25	37.8	0.03	10	19
26	37.4	0.03	13	32
27	38.5	0.04	23	55
28	38	0.05	33	88
29	39.2	0.06	44	132
30	39	0.06	67	199
31	38.7	0.06	98	297
32	39.7	0.07	113	410
33	40.2	0.08	143	553
34	40.1	0.08	169	722
35	40	0.08	170	892
36	40	0.08	168	1060
37	38	0.08	167	1227
38	39	0.08	167	1394
39	39.6	0.07	156	1550
40	39.2	0.07	141	1691
41	39	0.07	122	1813
42	37.8	0.05	109	1922
43	38.6	0.06	101	2023
44	38.2	0.05	73	2096
45	38.3	0.04	62	2158
46	37.9	0.03	34	2192
47	38	0.02	21	2213
48	37.7	0.01	9	2222
49	37.4	0.02	4	2226

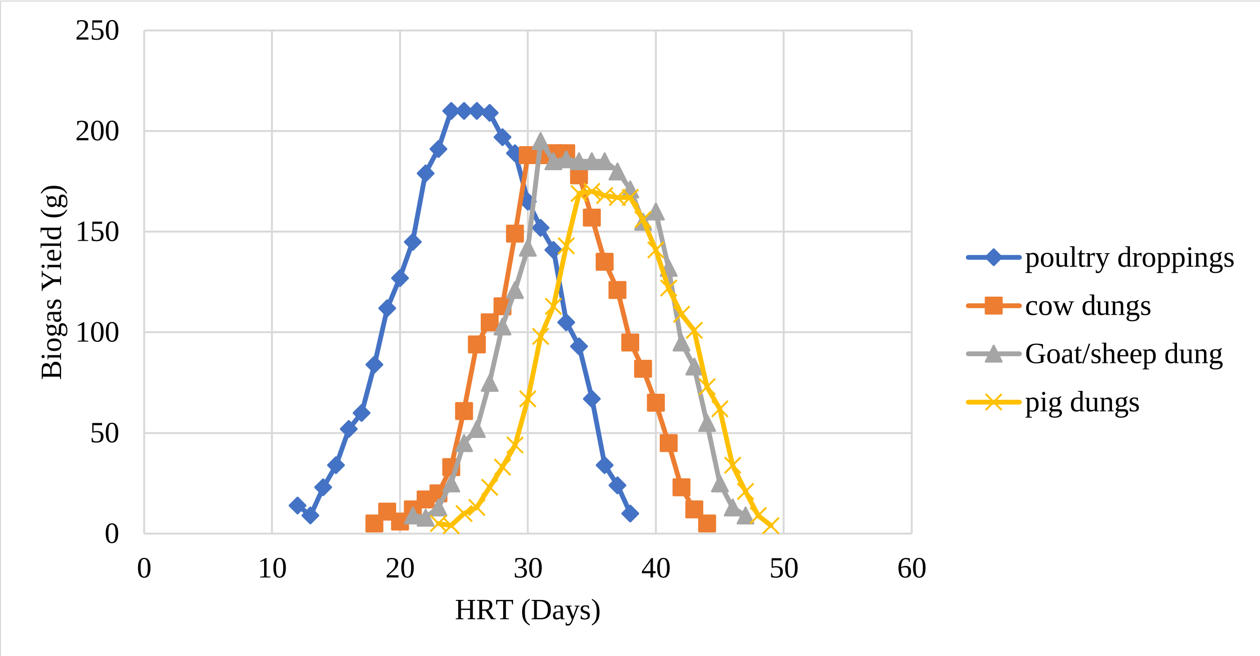

Figure 1: Plot of the Daily generation of biogas for the four groups of materials

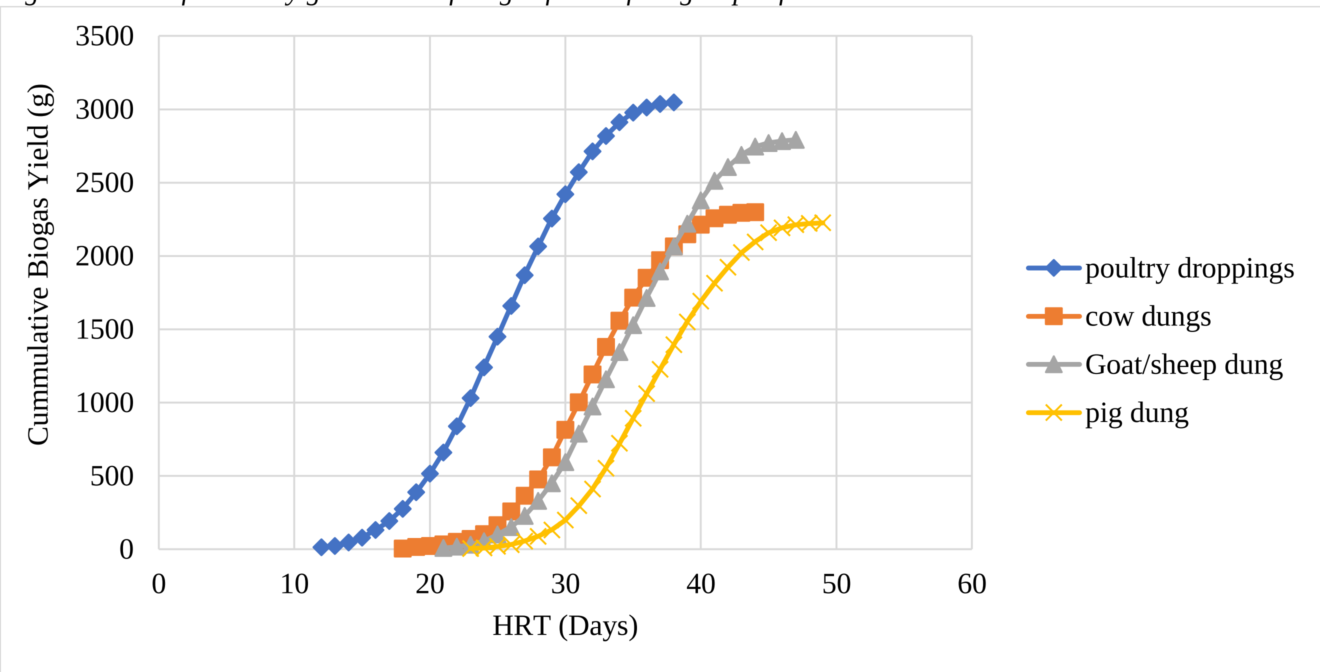

Figure 2: Plot of the Cumulative biogas generation for the four sets of substrates

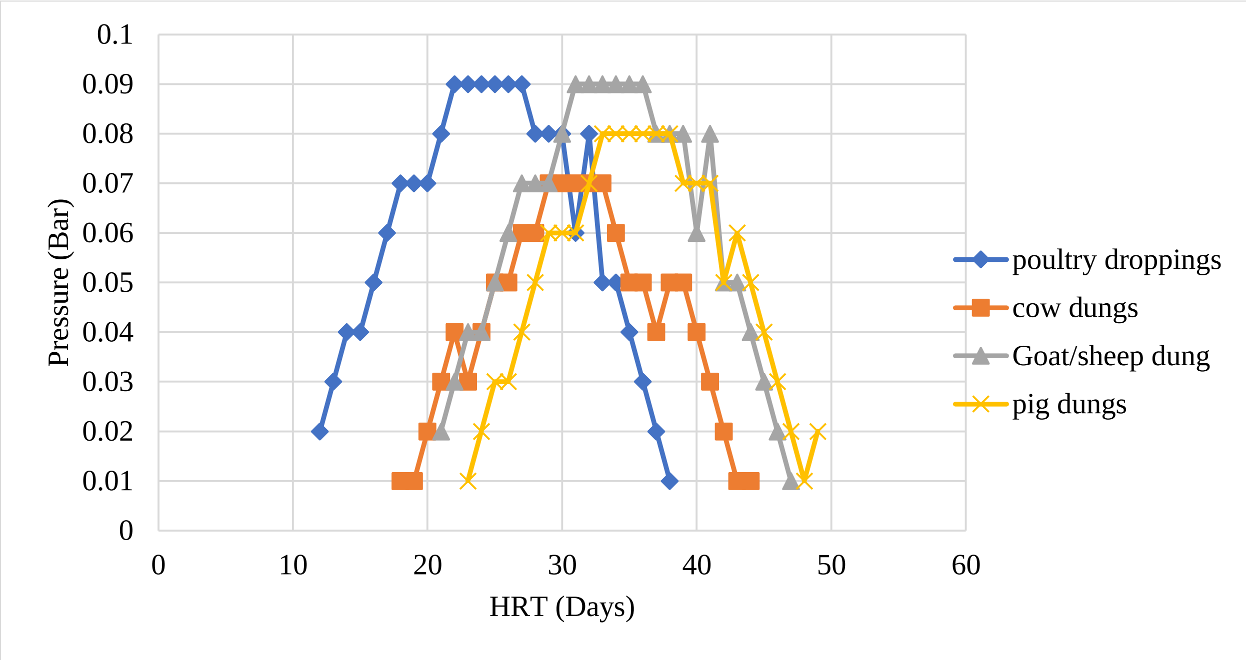

Figure 3:Plot of Daily digester pressure readings

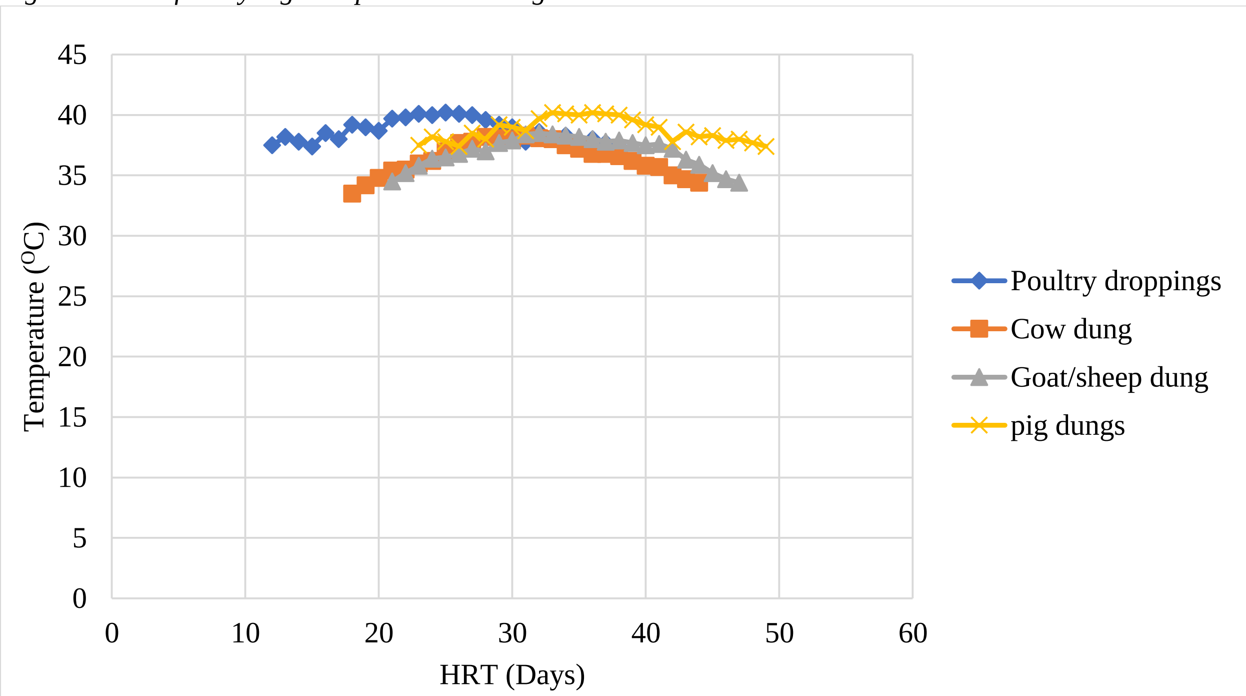

Figure 4: Plot of the Daily digester temperature of the substrates

DISCUSSION

Measurement of the Gas Production Rate

Figure 1 illustrates the daily gas production rate for the four sets of substrates investigated in this study. It is observed that the initiation of biogas production occurred on day 12, 18, 21, and 23 for poultry droppings, cow dungs, goat/sheep dungs, and pig dungs, respectively. The termination of biogas production was noted on day 38, 44, 47, and 49 for the corresponding substrates after introducing them into the digester. This

suggests a shorter lag phase and hydraulic retention time (HRT) for the digestion of poultry droppings compared to cow dungs, goat/sheep dungs, and pig dungs. Notably, pig dungs exhibited a more extended lag phase and HRT. The data also indicates that the co-digestion of poultry droppings is more rapid than that of cow dungs, goat/sheep dungs, and pig dungs. Also, figure 1 highlights the peak daily biogas production, reaching 210 g, 189 g, 185 g, and 170 g during day 24 to 27 for poultry droppings; day 31 to 33 for cow dungs; day 34 to 36 for goat/sheep dungs; and day 34 to 35 forpig dungs, respectively. This corresponds to the stationary phase, where daily biogas production remains constant. This phase signifies steady microbial activity and a consistent biogas yield. The superior biogas yield from the co-digestion of poultry droppings suggests faster substrate utilization by microorganisms compared to cow dungs, goat/sheep dungs, and pig dungs.
Figure 2 presents a visual representation of the cumulative daily gas production rates for the four substrate sets employed in this investigation. The illustration highlights that the combined digestion of poultry droppings, cow dungs, goat/sheep dungs, and pig dungs resulted in a total biogas yield of 3046 g, 2298 g, 2792 g, and 2226 g, respectively. This discrepancy in biogas yield is likely influenced by the inherent characteristics and chemical composition of the respective feedstocks.

Biogas Pressure
The pressure at which anaerobic digestion occurs is a crucial factor in biogas production. The operational pressure within a digester is contingent upon the gas generation within the system, following the principles of the general gas law (PV=nRT, where P represents gas pressure, and n is the quantity of gas produced). As gas accumulates in the bio-digester, the pressure rises, evident on the pressure gauge. Regular gas evacuation is essential to prevent unwanted incidents such as gas explosions. Optimal pressure for biogas production varies depending on the process type (batch or continuous).
Figure 3 depicts a graphical representation of the biogas pressure profile correlated with the hydraulic retention time for the four feedstock sets. Initially, the gas pressure for all substrates increased at the onset of production, maintaining a steady level before declining. Rising pressure signifies heightened microbial activities and biogas production rates, while declining pressure indicates reduced microbial activities and biogas quantity. The pressure readings on the graph (ranging from 0.1 to 0.9 bar) illustrate the trend of biogas production throughout the anaerobic digestion process in the bio-digester.

Biogas Temperature
Figure 4 displays the temperature variations observed in the two sets of feedstocks utilized in this study. The co-digestion of poultry droppings, cow dungs, goat/sheep dungs, and pig dungs resulted in biogas production within temperature ranges of 37°-40°C, 33-38°C, 34-39°C, and 37-40°C, respectively. Illustrated in Figure 4 is the increase and subsequent gradual decline in bio-digester temperature. The continuous increase denotes a phase with ample nutrients in the co-digested substrates, facilitating microbial engagement in the decomposition process. Conversely, the gradual decline in bio-digester temperature signifies nutrient depletion, leading to reduced microbial activities, decomposition rates, and biogas yield.
Fermentation temperature significantly influences biogas production, with methanogens exhibiting optimal performance in mesophilic (20-45°C) temperature ranges. Biogas production rates correlate positively with temperature, emphasizing the importance of maintaining a constant optimum temperature in the digester(Velmurugan et al., 2014). While the temperature in a digester is influenced by feedstock and digester type, the optimal temperature range of 25°C to 40°C favours biogas production. Temperatures exceeding this range (25°-40°C), known as thermophilic, accelerate substrate decomposition, microbial activities, and, ultimately, biogas yield. This implies that regions with moderate temperatures, like Nigeria (monthly temperature between 28-35°C), are conducive to biogas production, while areas with higher temperature ranges significantly favour biogas yield.

CONCLUSION

The study's findings lead to the following conclusions:

- Co-digesting domestic animal wastes such as poultry droppings, cow dungs, goat/sheep dungs, and pig dungs is a viable method for producing biogas.
- The anaerobic digestion process serves as an effective alternative for treating organic wastes, including poultry droppings, cow dungs, goat/sheep dungs, and pig dungs, prior to disposal. This process not only recovers the energy content in the waste but also mitigates odours, rendering the by-product suitable as organic manure.
- The utilization of plastic vessels as bio-digesters underscores the feasibility of employing cost-effective and readily available materials in the design of biogas plants.
- The anaerobic digestion occurred under mesophilic temperature conditions (35°C-45°C) and low pressures (0.1-0.9 bar), aligning with the specified conditions in existing literature.
- Poultry droppings showed a shorter lag phase and hydraulic retention time (HRT) compared to cow dungs, goat/sheep dungs, and pig dungs.

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