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MESOPHILIC CO-DIGESTION OF CATTLE PAUNCH WITH POULTRY DROPPINGS: MIXTURE EFFECT ASSESSMENT ON BIOGAS PRODUCTION POTENTIALS

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Abstract
Cattle paunch and poultry droppings are wastes that have posed environmental hazards due to poor management and disposal strategies in most municipal abattoirs and livestock farms in Nigeria. Utilization of these wastes for energy production at small and/or large scale requires assessment to ascertain the optimal mix. This study is therefore designed to determine the optimal mixing ratio and its effect on biogas production potentials of cattle paunch and poultry droppings under tropical condition. The fermentation was carried out in 30 litres batch type digesters with 60 days retention period. The single and mixing ratios of cattle paunch and Poultry droppings assessed were: 100: 0, 75: 25, 65: 35, 50: 50, 35:65, 25:75 and 0:100 labeled D1, D2, D3, D4, D5, D6, and D7 respectively. From the study, the mixture effect assessment of cattle paunch co-digested with poultry droppings shows that three digesters had highest cumulative biogas production potential in the range of 35% to 65% of cattle paunch co-digested with 35% to 65% of poultry droppings which are D3 (65% CP + 35% PD) , D4 (50% CP + 50% PD), and D5 (35% CP + 65% PD). On further assessment using anaerobic biomass indicator and technical digestion time assessment criteria, digester D4 (50% CP + 50% PD) was recommended as the optimal mix.

Keywords: paunch manure, poultry droppings, biogas, mixture ratio, Nigeria.

1. Introduction
Anaerobic digestion consists of several interdependent, complex sequential and parallel biological actions in the absence of oxygen, during which the products from one group of microorganisms serve as the substrates for the next, resulting in transformation of organic matter (biomass) mainly into a mixture of methane and carbon dioxide [1]. Wastes generated during the slaughtering of farm animals (such as cow) are blood, horns, bones, reject meat, spent-water, paunch, etc. Cattle paunch (the contents of the rumen in ruminants) has been reported to be one of the abattoir wastes that require proper management/treatment and a major abattoir waste volume-wise in municipal abattoirs in Nigeria [2, 3]. Poultry waste consists of droppings, wasted feed, broken eggs, and feathers. It also include the dead birds and hatchery waste, all which is high in protein and contain substantial amount of calcium and phosphorus due to high level of mineral supplement in their diet. Available statistics showed that there is a steady increase in the population of chicken in Nigeria from 124,620,000 Million in 2001 to 192,313,000 Million in 2010 [4].The availability and need to explore and establish the utility of both animal manure has being reported by various researchers [2, 3, 5].Farm animal wastes contain mostly biodegradable matter and are malodorous, this makes it suitable for anaerobic digestion. Currently there is no organized system of treatment of slaughter wastes in most of the municipal abattoirs in the country [2, 3]. Ezeoha and Idike [3] Investigated on the biogas production potential of cattle paunch, they reported that biogas production from the wastes were rather low when compared to values found in literature for other animal manure. The low values were attributable to the composition of the substrate – fibrous vegetable materials usually with low biodegradability. They recommended more research to investigate and optimise the optimum specific gas productivity value for cattle paunch. To improve the biogas production potential of cattle paunch and poultry droppings, there is need to blend these two major animal wastes, to determine and possibly obtain the synergistic benefits of co-

digestion which has been reported by various researchers [3, 6]. The objective of this study is to investigate the biogas production potential of co-digestion of cattle paunch with poultry droppings, and to assess its mixture effect on biogas production potential at various digestion ratios.

2. Materials and Methods

2.1 Substrates Sources and Characteristics

This study was carried out at Biotechnology Research Centre, Nnamdi Azikiwe University Awka, Anambra state Nigeria, located at latitude 6°20′N and longitude 7°00′E. Cattle paunch utilized in this research was collected from Awka municipal abattoir randomly, while the poultry droppings were randomly collected from a nearby poultry farm. The fresh substrates were taken immediately to the laboratory for compositional analysis. The parameters determined include moisture content, total solid (TS), volatile solid (VS), total Kjeldahl nitrogen (TKN), carbon content and pH. The result of the analysis is shown in Table 1:

Table 1: The composition of the substrates

Composition	Paunch Manure	Poultry Droppings
Moisture Content (%)	86	79
Total Solid (%)	40	19
Volatile Solid (%)	26	15
TKN (mg/g)	3.45	2.98
Carbon Content (%)	12.6	9.8
pH	7.0	7.2

The pH measurements were taken with a pH meter (Fisher Scientific Accumet Basic, Model AB 15 pH meter). Total Solids (TS) of the samples, Volatile Solids (VS), and Total Kjeldahl Nitrogen were measured using Standard Methods [7] while Carbon content was carried out using Walkley and Blackley method [8].

2.2 Experimental Design and Setup

The anaerobic inoculum used, was more than 60 days old mesophilic anaerobically digested cow dung, this is to ensure complete removal of any remaining biodegradable fraction from the seed sludge. Four kilogram of cattle paunch and poultry droppings were weighed respectively for mono-digestion, also both wastes were weighed and blended according to the experimental design. The experimental design for this study for the anaerobic digestion of cattle paunch and poultry droppings carried out using anaerobic batch-type digesters labeled D1-D7 is as follows:

Digester D1: 4Kg of cattle paunch + 0Kg of poultry droppings (100% CP + 0% PD)

Digester D2: 3Kg of cattle paunch + 1Kg of poultry droppings (75% CP + 25% PD)

Digester D3: 2.6Kg of cattle paunch + 1.4Kg of poultry droppings (65% CP + 35% PD)

Digester D4: 2Kg of cattle paunch + 2Kg of poultry droppings (50% CP + 50% PD)

Digester D5: 1.4Kg of cattle paunch + 2.6Kg of poultry droppings (35% CP + 65% PD)

Digester D6: 1Kg of cattle paunch + 3Kg of poultry droppings (25% CP + 75% PD)

Digester D7: 4Kg of cattle paunch + 0Kg of poultry droppings (0% CP + 100% PD)

Fifteen litres of water was added to the waste, before they were fed in 30 liter batch-type digesters for a period of sixty days. The experiment was done in replicate. Digester D1 (100 % CP + 0% PD) and D7 (0% CP + 100% PD) are single substrate digestions and were used as data baseline. Gas production was measured by downward water displacement. The prevailing temperature range was $24^{O}C$ – $30^{O}C$ during the period of study.

The result of biomass anaerobic digestion can be evaluated using the following indicators: intensity of biogas production (b_{dt}); biogas yield from biomass (BP_m); biogas yield from biomass total solids (BP_{ts}); and biogas yield from biomass volatile solid BP_{vs}. The biogas intensity (b_{dt}) indicates the duration of biomass biological degradation. The biogas yield from biomass (BP_m); from biomass total solids (BP_{ts}) and from biomass volatile solids (BP_{vs}) is calculated using equation 1 [9].

$$BP_m = \frac{b_{dt}}{m};\ BP_{ts} = \frac{b_{dt}}{m_{ts}};\ BP_{vs} = \frac{b_{dt}}{m_{vs}} \quad (1)$$

where b_{dt} is the volume of produced biogas during the time interval dt in litres, m is the mass of sample, kg; m_{ts} is the mass of total solids in the sample, kg and m_{vs}-mass of volatile solids in the sample, kg.

For batch type digester, equation (1) above is slightly modified by replacing b_{dt} with b_{av}, therefore:

$$BP_m = \frac{b_{av}}{m};\ BP_{ts} = \frac{b_{av}}{m_{ts}};\ BP_{vs} = \frac{b_{av}}{m_{vs}} \quad (2)$$

In (2), b_{av} is the average biogas production which is obtained by:

$$b_{av} = \frac{C_{bp}}{T_r} \quad (3)$$

where C_{bp} is the cumulative biogas production, (litres) and T_r is the retention time at which the cumulative biogas production is produced (days).

3. Results and Discussion

3.1 Biogas production of the various mixtures

The plot of the biogas cumulative yield is shown in Figure 1. Within the first two days of digestion, biogas productions started and continued until the end of the 60 days detention period (for some of the digesters).

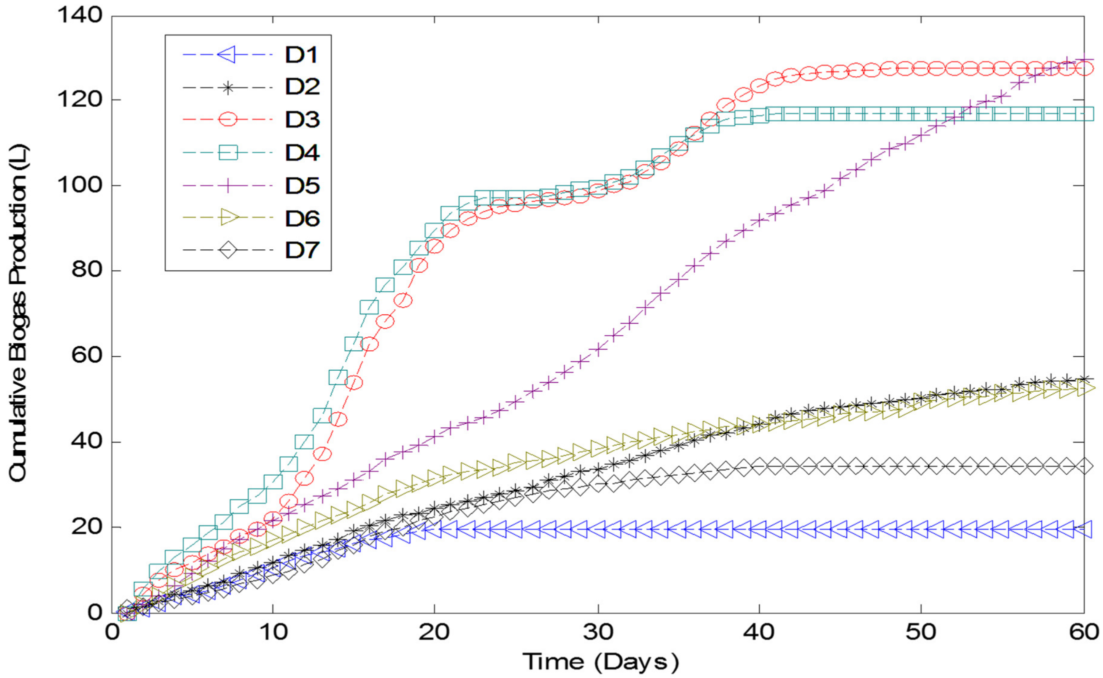


Figure 1: Cumulative biogas production of mono-digestion and co-digestion of cow paunch and poultry droppings.

It was observed that biogas production started in digester D3 and D4 within 24hours of digestion while all other digesters started gas production on the third day of digestion. From Figure 1, it is notable that digester D1 and D7 which are baseline digesters had the least cumulative biogas production; it therefore follows that mono-digestion of substrates lacks synergistic effects which could be responsible for their least performances.

However, single digestion of cattle paunch is noted to have comparative higher biogas production potential to single digestion of poultry droppings. Digester D2 (75% CP + 25% PD) and D6 (25% CP + 75% PD) having similar but opposite composition had cumulative biogas production of 54.5litres and 52.8litres respectively, though within a close range in cumulative biogas production, the digester with higher content of paunch waste had slightly higher biogas production. Clearly, digester D3, D4 and D5 had highest cumulative biogas productions potentials which were twice of D2 and D6, and above thrice of mono-digested substrates; this indicates that blending of both bio-wastes has major effect on the gas production, it also can be deduced that for maximum cumulative biogas production, the range of 35% to 65% of cattle paunch co-digested with 35% to 65% of poultry droppings is needed. Digester D3 (65% CP + 35% PD) and D4 (50% CP + 50% PD)with the highest composition of cattle paunch were closer to the y-axis (see figure 1) which indicates that they had the highest biodegradability. Clearly, biogas production in D3 and D4 has unique characteristic, their biogas production curve tend to more accurately follow sigmoid function (S curve) as generally occur in batch growth curve as observed by [10] in digestion of cattle dung, this indicates that cattle paunch and cattle dung follows similar sigmoid curve pattern. Digester D3, D4 and D5 appears to be ideal optimal mix of both wastes for maximum biogas production in energy generation.

3.2 Mixture Effect Assessment Using Anaerobic Biomass Indicator

From this study of co-digestion of cattle paunch with poultry droppings, there was improved waste treatment efficiencies and higher cumulative biogas production due to synergistic effect. The synergistic effect is mainly attributed to more balanced nutrients, increased buffering capacity, decreased effect of toxic compounds and the structural changes of the fibers in the co-digestion of the substrates. The mixture effect of anaerobic biomass digestion was evaluated using biogas yield from biomass $BP_{m,}$ biogas yield from biomass total solids BP_{ts}, and biogas yield from biomass volatile solids BP_{vs} as shown in the Figure 2 below: Among the ideal optimal mixtures, Digester D4 (50% CP + 50% PD) has the highest BP_m, BP_{ts}, and BP_{vs} values as shown in the Figure 2, followed by digester D3 (65% CP + 35% PD) and lastly digester D5 (35% CP + 65% PD). Obviously, Digester D4 is the optimal mix using anaerobic biomass assessment criterion.

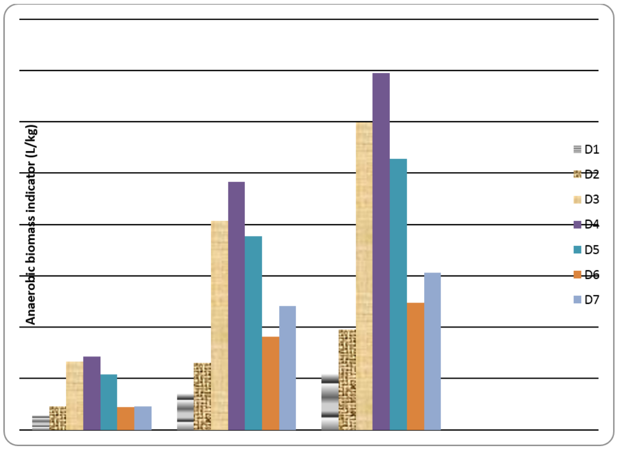
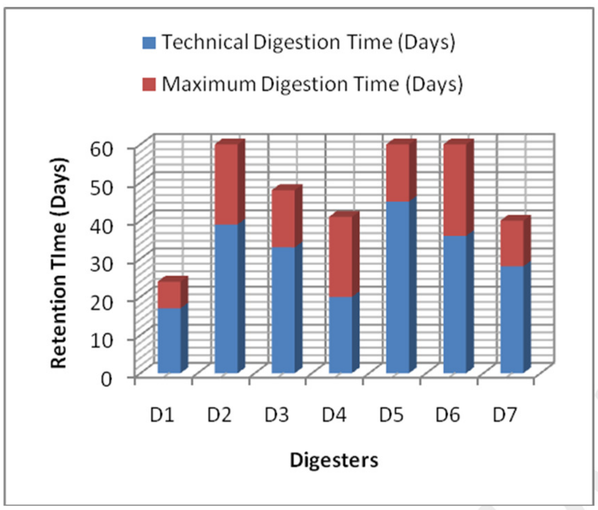
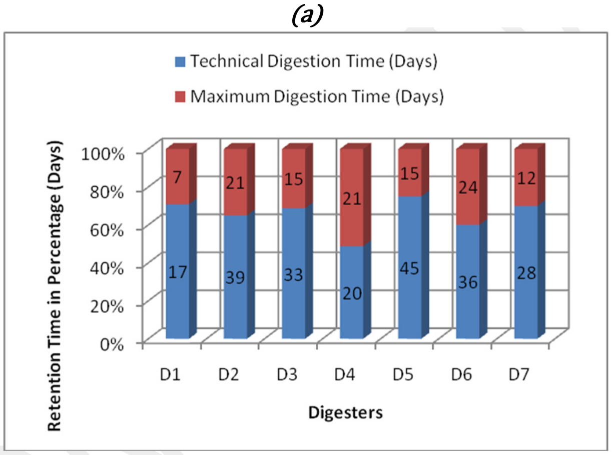


Figure 2: biogas production potentials using anaerobic biomass indicators



(a)



(b)

Figure 3: *Comparison of Technical Digestion Time of the Digesters with Maximum Digestion Time*

It therefore follows that cumulative biogas production potentials should not be the only basis for determining optimal mix. Anaerobic biomass indicator obviously is a good tool in further investigation in the determination of optimal mix in co-digestion of substrates as shown in this study

3.3 Mixture Effect Assessment Using Technical Digestion Time

The digestion time is a key indicator to substrate biodegradability and the utilisation rate, and was thus used in this study to assess mixture effect on biogas production potentials.The technical digestion time, (TDT80) is defined as the time needed to produce 80% of the maximum gas production [11] and can be used as a guideline in design of the hydraulic retention time (HRT) and solid retention time (SRT) for anaerobic digesters. Technical digestion time of all the treatments is shown in figure 3 :In Treatments D1, D2, D3, D4, D5, D6 and D7, TDT80 calculated were 17, 39, 33, 20, 45, 36 and 28 days respectively while the maximum time for cumulative biogas production are 24, 60, 48, 41, 60, 60 and 40 respectively. Figure 3(a) shows that among all the treatments, mono-digestion of poultry droppings had the lowest technical digestion time as expected because of its composition, followed by D4 with TDT80 of 20 days. Figure 3(b) presented in percentage shows that D4 has the lowest TDT80 in percentage among all the treatments. Based on anaerobic biomass indicator assessment and on technical digestion time assessment; digester, D4 (50% CP + 50% PD) is recommended as optimal mix against D3 and D5 (supposed ideal optimal mixes based on cumulative biogas production potentials). However, Digester D3 and D5 could serve as an alternative in the face of unavailability of equal amount of both wastes for biogas energy generation.

4. Conclusion

From this study the mixture effect assessment of cattle paunch manure co-digested with poultry droppings shows that three digesters had the highest cumulative biogas production in the range of 35% to 65% of cattle paunch co-digested with 35% to 65% of poultry droppings which are D3 (65% CP + 35% PD), D4 (50% CP + 50% PD), and D5 (35% CP + 65% PD). On further assessment using anaerobic biomass indicator and technical digestion time assessment, D4 (50% CP + 50% PD) is recommended as the optimal mix. Successful digestion of these two major abattoir wastes will go a long way to proffer solution to waste nuisance currently experienced in various livestock farms and municipal abattoirs in various parts of the country by providing environmentally friendly waste treatment and management system; clean energy for meat processing and storage; and provision of bio-fertilizers; reduction in flies, odor and pathogen transfer in livestock farms and municipal abattoirs across the country.

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