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BIOGAS PRODUCTION FROM THE CO-DIGESTION OF COW DUNG AND POULTRY DROPPINGS USING A PLASTIC CYLINDRICAL DIGESTER

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ABSTRACT
This study was carried out to compare the rate and amount of gas produced from the co-digestion of two different substrates of cow dung and poultry droppings under anaerobic conditions. Biogas production from three(3) cylindrical bio-digesters containing cow dung, poultry dropping, and a mixture of cow dung and poultry droppings under an average temperature of 28 ^{o}c and a pH of 6.2 was examined. In each case, the feedstock was diluted with equal volume of water to form slurry. The digestion took place for a period of 35days. The biogas produced during this period was collected by balloon method and subsequently measured and recorded. The results obtained from this study shows that the co-digestion of cow dung and poultry droppings yielded a maximum volume of 2.62 cm^3, while poultry dropping yielded 2.50 cm^3 and cow dung yielded 1.78 cm^3. Thus, the co-digestion of the feedstocks gave a better gas production and the mean biogas yield was found to be significant ($P<0.05$) compared to each of the single substrate. This study has demonstrated that the co-digestion of cow dung and poultry droppings in a plastic cylindrical could be a cheap method for locally producing biogas for domestic purposes. It is however, recommended that gas production can be enhanced during hot seasons where higher temperature is easily attained.

Keywords: Biogas production, co-digestion, cow dung, poultry droppings, cylindrical digester

1. INTRODUCTION
There is considerable amount of renewable feed stocks in the form of animal manure, crop residues, food and food processing wastes in developing countries which can be utilized economically for biogas production while at the same time reducing the cost and environmental problems associated with land-filling (Sebola *et al*., 2014). Nigeria is richly blessed with these feed stocks alongside various sorts of energy resources. According to World Energy Council (1993) the average solar radiation in Nigeria is 5.548kwh/m2/day. This amount of solar radiation encourages mesophilc temperature suitable for anaerobic digestion in biogas production. With recent increase in conventional fuel prices, the option of biogas is a worthy asset in Nigeria as it can substitute conventional fuel obtained from crude oil. Besides, the advanced methods of

refining conventional fuels from crude oils pose a serious threat not only to the environment but also on the health of the people (Speece, 1996; Sebola *et al*., 2014). Again, over 80 percent of the Nigerian population live in the rural areas, and firewood is their main source of energy. The extensive use of this fuel has led to wood fuel crisis and environmental degradation, as the rate of felled trees is not matched with forest reclamation by reforestation and afforestation.

Biogas is produced from anaerobic digestion by anaerobic organisms; they do this by digesting the material inside an air tight system (Webber *et al*, 2008). Biogas has a wide spectrum of application including the combustion engines, burners as well as gas turbines for electricity generation and cogeneration of heat and power (Olowoyeye, 2013). Anaerobic digestion is an innovation broadly utilized for treatment of natural waste for biogas generation due to its dual advantage of biomass waste utilization for energy production while simultaneously resolving ecological and agrochemical issues. The manure for biogas production does not reduce the value of fertilizer supplement as the necessary nitrogen and other substances remain in the treated sludge (Alvarez and Liden, 2008).

Several studies have been undertaken in anaerobic co-digestion of poultry droppings and cow dung. However, among other factors, the technicality of the processes involved in gas production coupled with the complexity of the most often reported bio-digesters, in terms of configuration and architecture, pose serious difficulties in the applicability of these systems, especially in rural settings (Chukwuma, 2013). Hence, this study was carried out to investigate the production of biogas from the co-digestion of poultry dropping and cow dung using plastic cylindrical digesters which can easily be adapted for use by rural farmers and other small scale users.

2. MATERIALS AND METHOD

2.1 Materials

Fresh cow dung and poultry droppings were collected from Sam's farm, Maikunkele, Minna, Niger state. Other materials which include mercury in glass thermometer for temperature reading, pH meter, gas pipe or hose for the transfer of gas produced, stirrer for agitation of the slurry in the bio-digester, and other materials for the purpose of this research were purchased from Minna, Niger State. Cow dung and poultry droppings were mixed in a container to smooth particles, before they were turned into the bio-digester container. The woody stirrer was constructed, incorporated into the bio-digester by using rubber tube to properly tighten it firm, and gum were used to seal the edges.

2.2 Methods

2.2.1 Slurry preparation

The feedstock of cow dung and poultry dropping were collected fresh and mixed with a woody stirrer then turned into the bio-digester (Plate 1). The slurry for fermentation were adequately prepared and mixed together with an equivalent amount of water at ratio 1:2 for maximum biogas production as described by Adeniran *et al*. (2014).

Plate 1: Prepared slurry for feeding into digester

2.2.2 Bio-digester Set up and Loading

Three 15 liters dark cylindrical containers (Plate 2) were adopted as digesters to contain 100% cow dung, 100% poultry dropping and a mixture of poultry droppings and cow dung in the ratio of 1:1 respectively. Each digester was of diameter 20 cm and height 30 cm. The lid of each digester was bored in two places with hot iron to accommodate a 2 cm hose for gas outlet and a stirrer to enhance gas production. All Perforations were adequately sealed to prevent gas leakage.

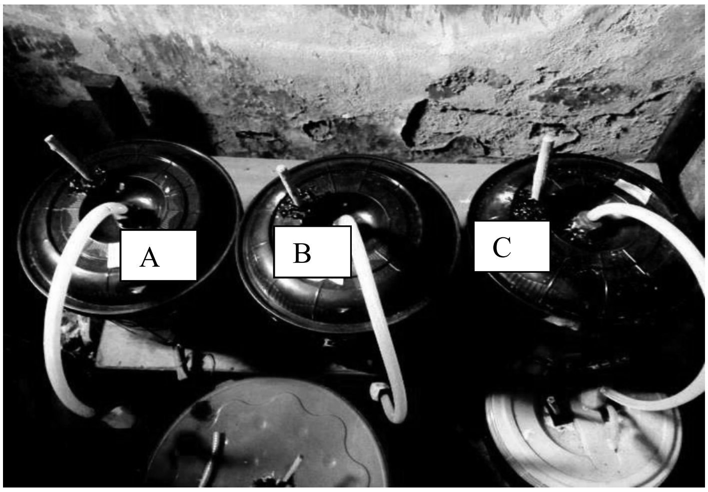

Plate 2: Experimental Set-up for Biogas Production

A= Cow dung, B= poultry, C= Cow dung + Poultry

Adequate space was provided at the upper part of the fermentation chamber for the storage of the biogas produced before delivery through the hose. Each bio-digester was loaded with 2 kg of substrate in batch and a woody stirrer was used to frequently agitate the slurry to ensure proper mixture for enhanced gas production. The experiment was conducted at ambient conditions as there was no any form of control over temperature and pressure and no adjustment was made on pH.

2.2.3 Biogas Collection

The gas produced was allowed to flow through the rubber hose, and into the balloon which was connected to the end of the hose that is attached to the top of the bio-digester. The pressure of the gas generated exacted pressure to the balloon which made it to rise. The diameter of the balloon was measured daily after it was compressed to a spherical shape and the volume of gas was calculated from equation of a sphere as presented in equation 1

$$V = \frac{4}{3}\pi r^3 \qquad \text{eq. 1}$$

2.2.4 Data collection and Analysis

The temperature was measured each day, by inserting a mercury-in-glass thermometer into the bio-digester and recorded. The pH reading were taken at an interval of two days, by releasing the clip on the hose to allow small portion of the slurry into a beaker, and measured with an electronic pH meter (Hanna instruments, HI196107, Italy). Volume of gas produced was calculated as described. The data collected were analyzed using SPSS 23.0 and Excel 7.0

3. RESULTS AND DISCUSSION

3.1 pH and Temperature of Digesters

Several studies on anaerobic digestion of waste have shown that, among other factors, temperature of digestion and pH of substrates have strong influence on the rate of biogas production (Bitton, 1994; Chaiprasert *et al*. 2006; Chukwuma *et al*., 2013; Tengku *et al*., 2014). The pH and temperature from the digester containing a mixture of cow-dung and poultry wastes measured at a 2-day interval are presented in Figure 1.

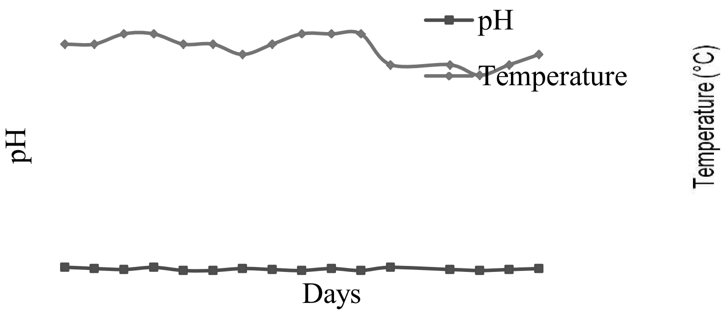

Figure 1: Temperature and pH variations with Retention Time

The values of the pH of the substrates determined in this study are in the range of 6.1 to 6.4. Previous studies have reported that methanogens activity is optimum within a narrow pH range of 6.3-7.8 (Pan *et al*., 2008; Tengku *et al*, 2014). The range of temperature attained in this study is 25-29 °C (Figure 1). This range is below the temperature range of 35-37°C which has been reported for optimum biogas production in anaerobic digestion (Sebola *et al*., 2014; Tengku *et al*, 2014). This short fall in temperature is attributed to the rainfall season (July-August) in which the study was carried out. Thus, it was difficult to attain higher temperature as no measures were taken to control it. This fluctuation in temperature might have been responsible for the low pH range and consequently, inhibition of methanogenesis process (Tengku *et al*, 2014).

3.2 Biogas Production of Substrates and Mixture

The digesters performances in term of volume of biogas are presented in Table 1. Biogas production began for cow dung digestion on day 4; for poultry droppings digestion on day 3 while for the mixture gas production started within 24 hours. This observation agrees with previous studies by other researchers as it has been reported that poultry droppings degrade faster than cow dung (Marchaim, 1992). Thus, the relatively faster production of biogas from the mixture of cow dung and poultry (1:1) compared to any of the single substrate could be attributed to the optimum C/N ratio in this digester obtained by a balanced mixture of nitrogen rich substrate (poultry dropping) and cow dung that contains bacteria needed to kick start the anaerobic digestion (Chukwuma *et al*., 2013). As clearly seen from Table 1, gas production was lower at the beginning of the process and at the end for all digesters. This follows a general trend of gas production in batch mode due to the microbial activities of methanogens responsible for biogas production (Gupta *et al*., 2009; Rabah *et al*., 2010).

Table 1: Volume of Biogas (cm^3) produced with the Feedstock in 35 Days

Day	Cow dung	Poultry	Cow dung+ poultry	Day	Cow dung	Poultry	Cow dung + poultry
1	0.00	0.00	0.00	18	1.30	2.22	2.49
2	0.00	0.00	0.10	19	1.38	2.45	2.62
3	0.00	0.12	0.16	20	1.61	2.50	2.60
4	0.10	0.15	0.20	21	1.78	2.00	2.46
5	0.12	0.16	0.62	22	1.70	1.97	2.40
6	0.16	0.20	0.75	23	1.67	1.97	2.38
7	0.20	0.29	0.85	24	1.64	1.94	2.36
8	0.26	0.38	0.97	25	1.60	1.90	2.34
9	1.10	1.10	1.39	26	1.57	1.88	2.33
10	1.15	1.17	1.96	27	1.54	1.74	2.03
11	1.17	1.26	2.21	28	1.44	1.65	1.97
12	1.14	1.23	2.27	29	1.02	1.22	1.59
13	1.14	1.23	2.36	30	0.52	0.95	1.04
14	1.18	1.25	2.29	31	0.33	0.73	0.95

Day	Cow dung	Poultry	Cow dung+ poultry	Day	Cow dung	Poultry	Cow dung + poultry
15	1.18	1.58	2.36	32	0.21	0.44	0.67
16	1.22	1.82	2.38	33	0.00	0.12	0.52
17	1.25	1.98	2.42	34	0.00	0.00	0.09
18	1.25	2.03	2.46	35			

The gas production from the three digesters of this study cannot be said to follow a linear tread as several peaks were observed for both single digestions and co-digestions. The daily gas production varied as temperature and pH also varied (Table 1 and Figure 1). Thus the non-linear tread of the biogas production can be attributed to the effect of temperature fluctuations. The gas production for all substrates started from 0.00 cm^3 on day 1. For cow dung, a maximum of 1.78 cm^3 was attained on day 22 at a temperature of 29 °C while for poultry droppings; a maximum volume of 2.50 cm^3 was obtained on day 21. The highest volume of 2.62 cm^3 was achieved on day 20, at a temperature of 29 ^oC and pH of 6.3 (Figure 1) with the co-digestion of the two substrates at the ratio of 1:1. The highest volumes for all the substrates were achieved with the highest temperature during this study. This is an indication that higher volumes of biogas would be achieved with higher temperatures, thus the major limitation to this study was low temperatures due to weather condition of the season.

Tables 2 and 3 present the analysis of variance (ANOVA) and post-hoc test respectively, for biogas yield for the different substrate while Figure 2 compares the mean biogas yield for the three digesters. Table 2 shows that there is significant difference in the mean gas yield for the three substrates at the 95% probability. Table 3, on the other hand, showed that the mean difference (0.27714) between biogas yield from cow dung and poultry in separate digesters is not significant ($P > 0.05$). However, there is significant difference between gas yields from the mixture of the two feed stocks compare to each of the single substrates. Thus biogas yield was significantly influenced by the co-digestion of the two substrates in a plastic cylindrical digester. This effect has been explained to be due to improvement of nutrient balance with mixture of waste for co-digestion which enhances sludge Solubilization, digestion, and biomethane production by ameliorating the antagonistic and synergistic effects of different sludges (Sebola *et al*., 2014). This result also concord with the findings of Chukwuma *et al*. (2013) that the effect of co-digestion is synergistic and not antagonistic. It can be added here that the synergistic effect of co-digestion exist even at temperature and pH below the optimum values.

Table 2: One Way Anova for Biogas Yield

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Cow dung	35	31.93	0.912286	0.399542
Poultry	35	41.63	1.189429	0.651547
Cow dung + poultry	35	56.59	1.616857	0.822657

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.819116	2	4.409558	7.060015	0.001344	4.81949
Within Groups	63.70736	102	0.624582			
Total	72.52648	104				

Table 3: Post Hoc Tests for Multiple Comparisons of Mean Differences

	(I) Feedstocks	**(J) Feedstocks**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
						Lower Bound	**Upper Bound**
LSD	**cow dung**	**poultry droppings**	**-.27714**	**.18892**	**.145**	**-.6519**	**.0976**
		Poultry + cow dung	**-.70457***	**.18892**	**.000**	**-1.0793**	**-.3299**
	poultry droppings	**cow dung**	**.27714**	**.18892**	**.145**	**-.0976**	**.6519**
		Poultry + cow dung	**-.42743***	**.18892**	**.026**	**-.8021**	**-.0527**
	Poultry + cow dung	**cow dung**	**.70457***	**.18892**	**.000**	**.3299**	**1.0793**
		poultry droppings	**.42743***	**.18892**	**.026**	**.0527**	**.8021**

***. The mean difference is significant at the 0.05 level.**

Dependent Variable: Volume of Gas (Cm^3)

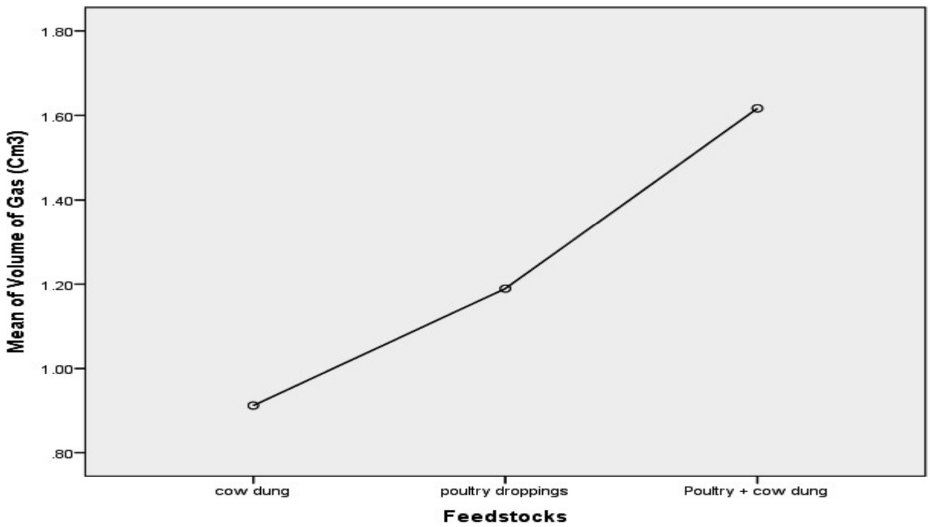

Figure 2: Mean Biogas Yield for the Substrates

The plot of the biogas cumulative yield for the three substrates is shown in Figure 3. From the graph, it can be deduced that the co-digestion yielded the highest biogas cumulative volume of 56.5cm^3, followed by poultry dropping of 41.63 cm^3 and cow dung of 31.93 cm^3. It can be seen from Figure 3 that biogas production was generally low within the first few days of observation. This is generally the lag phase of microbial growth where microbial community (in this case methanogens) becomes established and accustomed to the environmental conditions within the digester. This phase is followed by exponential growth of the microbial population and then the stationary phase where little growth is seen, but living cells are maintained (Nopharatana *et al*, 2007; Jenna, 2010). The observation presented in Figure 3 clearly depict the activities of methanogens in the digesters.

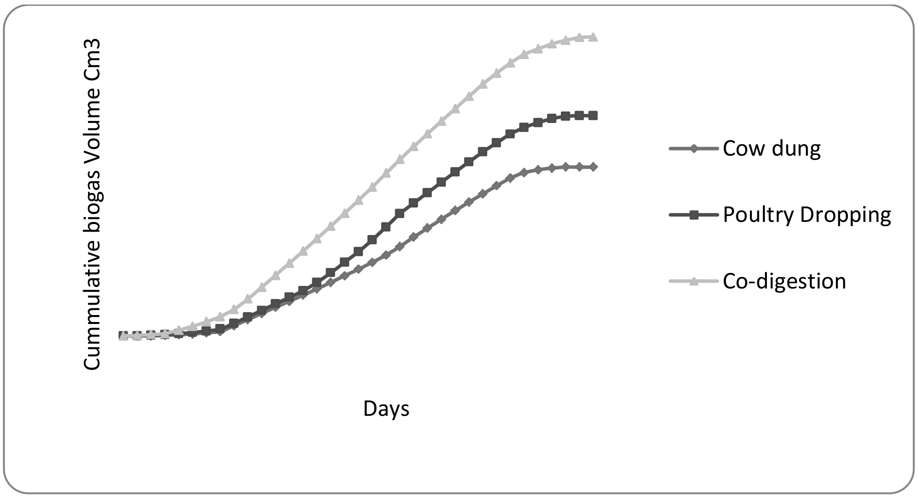

Figure 3: Biogas Cumulative Yield

4. CONCLUSION

The results obtained from the study shows that cow dung yielded a maximum biogas volume of 1.78 cm^3, while poultry dropping yielded 2.50 cm^3. The co-digestion of cow dung and poultry dropping yielded a maximum biogas volume of 2.62 cm^3, at a temperature of 29 ^oC and pH of 6.3. Thus, it can be concluded that the production of biogas from the co-digestion of cow dung and poultry dropping is feasible using a cylindrical digester which is affordable, locally available and requires little skill for setup and operation. It is, however, recommended that further studies should be carried out to determine the best mix ratio for these feed stocks; and the best temperature and pH ranges for optimum biogas yield using the plastic cylindrical digester.

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