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Anaerobic Digestion and Co-digestion of Poultry Droppings (PD) and Cassava Peels (CP): Comparative Study of Optimal Biogas Production

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Abstract

An investigation of the effects of poultry droppings (PD) on the anaerobic co-digestion of cassava peels (CP) has been conducted in order to determine the kinetics for optimal biogas production. The laboratory batch anaerobic digestion were carried out in five (5) different ten-litre anaerobic digesters which were used for the fermentation of the substrates with cumulative biogas production of 13.1, 24.6, 16.7, 8.6 and 7.1L/g volatile solid(VS). The digesters A, B, C, D and E with process conditions of (100% PD and 0% CP), (75% PD and 25% CP), (50% PD and 50% CP), (25% PD and 75% CP) and (0% PD and 100% CP) respectively, were incubated for forty four (44) days at ambient mesophilic temperature of 37±1 ^{o}C at a pH of 6.7. The gas production did not begin until the second day for the first four digesters while that of digester E started on the fourth day, (this is as a result of high cellulose content) and then increased steadily until it reached a maximum biogas yield between the 18th and 22nd day of anaerobic digestion. The highest biogas production of 24.6L/g volatile solid(VS) recorded in digester B could be attributed to better synergy of microorganisms in the digester as a result of the presence of some limited quantity of cassava peels and a C/N ratio of 23.4. This result shows that biogas production could be enhanced effectively through co-digestion process of substrates..

Keywords: Anaerobic, Biogas, Co-digestion, Feedstock, Mesophilic

1. Introduction

The problem of inadequate energy supply and environmental pollution in Nigeria cannot be over-emphasized. It is only an imperative given the tremendous increase in our population, access to adequate energy and healthy environment demand for diversification of sources of energy supply, if Nigeria is to achieve any meaningful growth and development. In Nigeria, the level of dependence on fossil fuels has created a great disparity in the sourcing, harnessing, exploration and exploitation of this natural endowment vis-à-vis other energy sources (Achebe, et al., 2007). Biogas generation from anaerobic digestion of readily available wastes seems to be an attractive rescue option. From the global perspective, the over-dependence on fossil fuels as primary source of energy has resulted in climate change, many environmental destruction and related human health problems (Budiyono et al., 2010). The joint challenge of global pollution and depletion of fossil fuels is driving intense search into alternative renewable energy sources, among which is the biogas (Gueguim et al., 2012).

Biogas is produced by the Anaerobic Digestion (AD) of organic wastes through the synergistic metabolic activities of consortia of hydrolytic, acidinogenic, acetogenic and methanogenic bacteria on organic materials (Li et al., 2011). Currently, AD is used to treat more than 10% of organic wastes for the generation of energy in several European countries. Anaerobic co-digestion of a simulated organic fraction of municipal solid wastes and fats of animal and vegetable origin has been reported. A substrate of kitchen waste with cow manure has been used to achieve a yield increase of 44 % (Rongpin et al., 2009). Kaparaju and Rintala (2005) have examined the co-digestion of pig manure, potato tuber and its industrial by-products.

The best combination of various substrates for optimal biogas yield remains a big problem despite the enormous number of potential substrates. The technical and economic feasibility of an industrial anaerobic digestion plant depends on how much methane is produced, the purity, the composition and process variables (temperature, retention time, pH, etc) which can only be possible by co-digesting of substrates. These performances are not often available in literature; thus this could entail an increase of the risk of investments due to excessive uncertainties in the design phase. Co-digestion of different materials may enhance the anaerobic digestion process due to better carbon and nitrogen balance. Digestion of more than one substrate in the same digester can establish positive synergism. Okonkwo, et al. (2016) carried out a comparative analysis of the rates of production of biogas from various organic wastes and weeds which enabled the determination of optimal ratio of poultry droppings to domestic wastes.

1.1.1 Co-digestion of Different Types of Feedstock

Different feedstock materials can vary widely in physical and chemical features that affect digestibility in AD reactors. The co-digestion of two different feedstocks that complement each other with respect to texture, carbohydrate content, moisture, nutrient balance or pH, can substantially increase methane yield and process stability due to synergisms (Chen *et al.,* 2007). This is especially evident when carbohydrate-rich feedstocks are co-digested. For instance, when carbohydrate-rich food or food-processing wastes are digested alone, SCFA can form very rapidly and often accumulate, causing AD failure due to a lowered pH (Kim *et al.,* 2006).

Likewise, when animal manures (which are rich in amino nitrogen) are digested alone, an operational disturbance often results due to the toxicity of high concentration of ammonia to methanogens (Angelidaki*et al.,* 2008). The co-digestion of animal manures and food wastes not only alleviates the problems associated with anaerobic digestion of either of these feedstocks alone, but also improves biogas yield (Capela*et al.,* 2008). Digestate from co-digestion of food waste and human excreta can be used as biofertilizer (Owamah et al., 2014). This research work is based on Co-digestion of different percentage combination of poultry droppings and cassava peels in order to obtain optimal biogas production. This is achieved by a detailed characterization of the different selected substrates percentage composition in order to get the independent variables such as volatile solids, total solids and carbon-nitrogen ratio.

2.0 Material and methods

2.1The materials used for this study are:

- Poultry droppings
  Poultry droppings used for this study were collected from Landmark University Poultry house on daily basis, within five working days from 23rd May to 27th May, 2016. After the 5 days collections, all treated and homogenized poultry droppings were mixed together and kept in a cold dark plastic container before the commencement of anaerobic digestion experiment.
- Cassava peels
  The cassava peels were obtained from a cassava mill in Omu-Aran. The peels were washed to remove sand particles and then allowed to sun-dry for 7 days. The sun-dried cassava peels were then ground and stored in a plastic container prior to anaerobic digestion experiment.
- Hydrochloric Acid (HCl)
  It is used to acidify the water in the volumetric tank and also to reduce the pH value of leachate solution
- Sodium Chloride (NaCl)

It is also used to prevent the dissolution of carbon dioxide in the volumetric tank in the process of the experiment.

- De-ionized Water
  This is used for the dilution of the leachate solution before injecting into the gas chromatography.

2.2 Procedure for Anaerobic Digestion

The feedstock is pumped from a tank into the digester by means of a peristaltic pump and a flow meter. Supernatant liquid in the digester leaves the side mouth and goes to the buffer vessel, from which the second pump that pumps to the second digester sucks. From the top of the digester, a pipe transfers the produced gas to the volumetric tank where it is measured. The digesters are heated up by means of hot water coming from a thermostatic bath passing through the jacket of the digester. Each digester has a heating water circuit with valves to be able to regulate the temperature of both digesters.

Plate.1: EDIBON Computer Controlled Anaerobic Digester, 2015 model

2.3 Batch digestion

The Batch anaerobic digestion test was carried out on varying mixtures of poultry droppings (PD) and cassava peels (CP). The digesters were labelled A, B, C, D, and E. The mixture compositions for the digesters are; digester A (100% PD and 0% CP), digester B (75% PD and 25% CP), digester C (50% PD and 50% CP), digester D (25% PD and 75% CP), digester E (0% PD and 100% CP). The percentages of the biomass (PD and CP) were based on total solid concentration. The experiments were carried out in five identical 10L reactors with 5L working volume. The reactors were run steadily at mesophilic temperature of 37 ± 1^0 C. The substrates were fed into the reactor through inbuilt peristaltic pumps and flow meters. The flow was set to the maximum of 7liters per day in order to fill the reactor of 5L working volume within the period of 18 to 20 hours. The inflow of substrate was terminated after the working volumes of the reactors were completely filled. Anaerobic digestion for each reactor was terminated after 44 days, when either no measurable or significant biogas production was obtained. The first batch digestion was carried out to determine the effect of cassava peels addition to poultry dropping on biogas production and the evaluation of the optimum combination of poultry dropping and cassava peels for optimum biogas yield.

3.0 Results and Discussions

Table 1 shows the wide diversity in characteristics of the substrates for TS, VS and C/N ratio contents that influence the efficiency of anaerobic digestion process. A good substrate characterization is important on modelling and especially on prediction of biogas potential from different substrates. The solid content of sludge comprises both total solids TS and volatile solids VS, whereas VS represents the organic and biodegradable fraction of the sludge.

Table 1: Characteristics of the substrates for each reactor for batch digestion

Feeding Substrate	Digester A	Digester B	Digester C	Digester D	Digester E
PD: CP (%) (w/w, based on TS)	100:0	75:25	50:50	25:75	0:100
TS_{total} (g)	40	40	40	40	40
TS_{PD} (g)	40	30	20	10	0
TS_{CP} (g)	0	10	20	30	40
VS (g)	18	15	12	9	8
VS (VS g/L)	3.6	3.0	2.4	1.8	1.6
C/N ratio	10.8	23.4	15.5	14.6	37.9

*All values are on wet basis (i.e. as total weight of sample)

Figure 1 represents the daily biogas productions from the different mixtures of poultry droppings (PD) and cassava peels (CP) in digesters A-E for Forty-four (44) days of anaerobic digestion. 44 days was used as the appropriate solid retention time for the substrates as no measurable biogas production was obtained from any of the five digesters beyond this period.

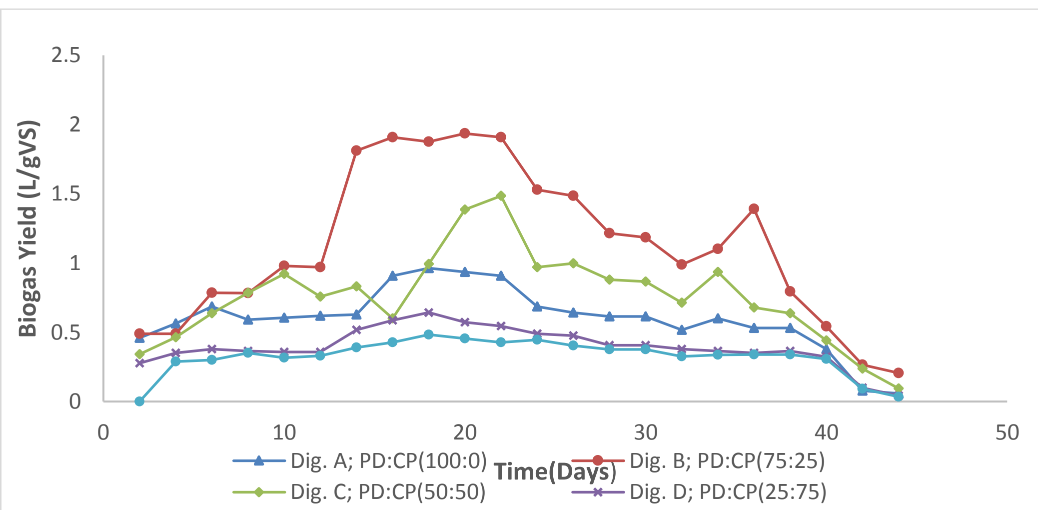

Figure 1: Daily biogas production at the different mix ratios of PD and CP

It can be clearly seen that digester B, with a combination of 75% PD and 25% CP was found to have higher biogas yield than the other digesters. The performance of digester B was followed by digester C having 50% PD and 50% CP.

Digester E with 100% CP had the least biogas production. As shown in table 1, this could have been as a result of the high C/N ratio, above the recommended limit of 20-35 (Ghasimi, 2009, Ozturk, 2013), and higher lignin content (Momoh and Nwaogazie, 2011). According to Ozturk (2013), a high C/N ratio results in acidification which consequently inhibits methanogenic activities while high lignin content inhibits initial hydrolysis of substrates. After 44 days of anaerobic digestion, total biogas production from digesters A, B, C, D and E was found to be 13.1, 24.6, 16.7, 8.6, and 7.1 L/gVS respectively (Figure 2).

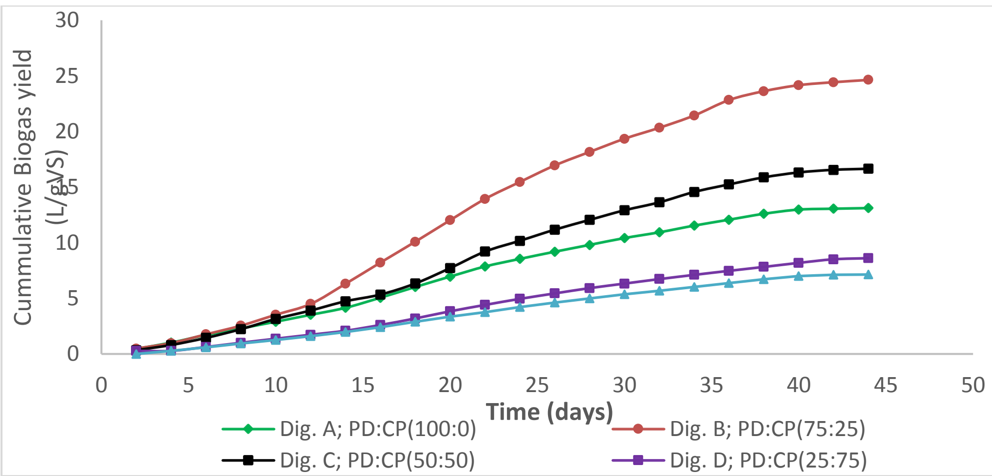

Figure 2: Cumulative Biogas Production for the different mix ratios of PD and CP

Figure 2 also shows clearly that digester B with the highest cumulative biogas production has a more efficient performance in terms of biogas production than the other digesters. This result shows that the co-digestion of PD with agro-wastes such as cassava peels can enhance its biogas production when mixed optimally. This has an added advantage of diluting the high acid content of the cassava peels with the poultry droppings for optimum biogas production. According to Azbar et al. (2008), the anaerobic co-digestion of diverse organic wastes can improve nutrient balance; dilute potentially toxic compounds such as sulphur-containing substances, and subsequently increase the processing capacity and biogas production. Co-digestion of poultry dropping and cassava peels could also therefore serve as a means of treating both wastes, with the added benefit of contributing to solving the nation's energy problems through biogas generation and utilization.

There was significant difference in the biogas yield from the different digesters A, B, C, D and E. Statistical analysis using two-way ANOVA without replication ($p < 0.05$) was done with the experimental data.

Table 2 shows the descriptive statistics of the average biogas produced at different mixtures of poultry droppings (PD) and cassava peels (CP). This was used to determine the best combination of PD and CP for optimal biogas yields. The two most important parameters used for this prediction is the mean value and the confidence level. From the results obtained it could be said that the best combination is that of digester B which indicates a higher average biogas yield with a confidence level that tends closer to one when compared to the other digesters.

	DIGESTER A PD:CP (100:0)	*DIGESTER B PD:CP (75:25)*	*DIGESTER C PD:CP (50:50)*	*DIGESTER D PD:CP (25:75)*	*DIGESTER E PD:CP (0:100)*
Mean	0.5961	1.1198	0.7568	0.3933	0.3245
Standard Error	0.0489	0.1180	0.0706	0.0303	0.0272
Median	0.6098	1.0453	0.7707	0.3714	0.3395
Mode	0.6846	0.4890	#N/A	0.3645	0.4274
Standard Deviation	0.2293	0.5531	0.3313	0.1423	0.1275
Sample Variance	0.0526	0.3061	0.1098	0.0202	0.0163
Kurtosis	1.3166	-1.1041	0.5239	1.1983	1.9583
Skewness	-0.6920	0.0673	0.1669	-0.6464	-1.5283
Range	0.9050	1.7296	1.3906	0.6011	0.4830
Minimum	0.058	0.2056	0.094	0.0418	0
Maximum	0.9630	1.9352	1.4846	0.6429	0.4830
Sum	13.1147	24.63	16.65	8.6521	7.1388
Count	22	22	22	22	22
Largest (1)	0.9630	1.9352	1.4846	0.6429	0.4830
Smallest (1)	0.058	0.2056	0.094	0.0418	0
Confidence Level (95.0%)	0.1017	0.2453	0.1469	0.0631	0.0565

4.0 Conclusion

It is evident that the anaerobic co-digestion of poultry dropping and cassava peels was found feasible, indicating that the treatment of these wastes which are both nuisance to the environment and pose a public health risk could be attained through anaerobic digestion. Furthermore, the energy gas generated in the course of the treatment could be used for electricity generation, thereby contributing to solving the present day energy crisis in Nigeria. The optimum combination of poultry dropping (PD) and cassava peels (CP) for optimum biogas yield and higher methane content was found to be (75%PD and 25% CP). Thus, it is concluded that for optimum biogas production in co-digestion of poultry dropping and cassava peel, a combination of the materials in the ratio of 3:1 respectively is recommended.

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